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ECONOMETRIC ANALYSIS OF HOUSEHOLD FIREWOOD CONSUMPTION AND TRASH INCINERATION TO IMPROVE AIR QUALITY

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1. Research Background and Objectives

The widespread use of solid fuels by the general population significantly impairs air quality, which in turn contributes to the development of diseases. In this dissertation, I analyze the consumption of the most popular solid energy source in Hungary, firewood, and the illegal household trash incineration, so that I can come up with proposals that point in the direction of a better environmental condition. It is important to reduce wood consumption for the health of the forests and for the better air quality as well. In order to reduce the particulate matters and the toxic substances in the air, we also need to reduce trash incineration. I approach these issues primarily from an economic perspective, and I see meeting heat needs with cleaner, more modern energy sources as a key to achieving the goals. As Leach (1992) writes in his study The Energy Transition, which can be considered a very important piece of work for my topic, the shift to more modern energy sources may be desirable in part because it reduces indoor air pollution and the health effects it causes. On the other hand, the pressure on forests can be reduced while making it easier for households too poor to obtain biomass for the transition.

Many researchers begin to study such a shift, i.e., the energy transition, based on the “energy ladder” hypothesis (e.g. Hoiser - Dowd, 1987; Arnold et al., 2006; Zhao et al., 2017; Paunio, 2018). The hypothesis is also suitable for studying the shift towards cleaner/more polluting energy sources. One of the keys to remedying the domestic problems described is to move quickly up the “ladder”.

The model assumes that, as a result of rising incomes, the population automatically moves to the ever-higher rung of the “ladder,” leaving behind primitive, inferior[1] energy sources. That is, for example, a household at the level of waste, manure, and crop residues will give up these awkward, inferior goods and switch to the level of firewood as a result of rising income. As a result of further welfare increases, wood is replaced by charcoal, then petroleum derivatives, later the household reaches the level of natural gas, then finally electricity. The theory thus implicitly states that the prosperous economy, without any external intervention, pushes users to an ever-higher degree of "hierarchy of purity and convenience," which ultimately paints the picture of an environmentally friendly energy mix. Such a process can also be understood as a kind of environmental Kuznets curve (Kerekes, 2007; Bodor - Kerekes, 2017; Benedek - Fertő, 2018).

However, a number of circumstances are possible that could divert the "energy ladder" model from perfect functioning, as factors other than income affect users behaviour. These can reduce and even suppress the impact of income on wood consumption. As we will see in the next chapter, income is not necessarily the most important explanatory factor for consumption, but the most important factor is that one that has the greatest impact on the (not merely material) well-being of households. Based on my preliminary studies (see Section 2.5), I assume that this variable is the price of the most important substitute for firewood, that is the price of piped natural gas (Csuvár, 2019). Leach (1992), Song et al. (2012a), Karimu (2015) also attaches a prominent role to the relative price of the resource, i.e., relative to an alternative. If the differences between energy sources are persistent and significant, consumers can switch to the energy they consider cheaper, even if the change has significant fixed costs (such as the purchase and installation of a gas stove). That is, even with rising incomes, the usage of firewood can expand if it

[1] We can speak of an inferior good if the demand for the good responds to a change in the consumer's income with a change of the opposite sign.

represents the lowest cost compared to the alternatives. In addition, of course, it may also be that firewood in Hungary is not inferior, but a normal good. Thus, with increasing earnings, wood consumption continues to expand.

The logic of these thoughts can also be translated into the area of household trash. Unfortunately, I have not found any research that has examined this, so I will derive my theoretical model from the literature and the model of firewood.

All this gives rise to the research questions of the dissertation:

1. If Hungarian earnings increase, can we really "lean back" and enjoy the ever-cleaner air without state intervention, or is a carefully planned and implemented regulation still necessary?

2. If regulation is needed, what are the areas where intervention can most effectively reduce residential firewood burning/trash incineration?

The complexity of the problem is also illustrated by the many different "solution" proposals available in the press[2]. For example, the package of proposals put forward by Greenpeace calls for consumer information, official action and sanctions against illegal burning, a ban on residential use of lignite and the sale of wet firewood, and the provision of fuel of the right quality to

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[2] For example:

1) https://merce.hu/2017/01/24/hiaba_okozhatja_evente_tobb_mint_10_ezer_ember_korai_halalat_a_szmog_nincs_ez_ugyben_atfogo_kormanyz/
2) https://merce.hu/2019/01/11/szemettel-futenek-a-raszorulok-de-a-kormany-buszke-a-meg-sem-erkezett-tuzifa-tamogatasra/
3) https://www.origo.hu/kornyezet/20161123-lakossagi-futes-szennyezi-legjobban-a-levegot.html
4) https://www.origo.hu/tudomany/20191021-tilos-es-veszelyes-a-hulladekegetes-megis-sokan-teszik.html
5) http://ecolounge.hu/nagyvilag/a-helytelen-futes-avagy-a-lathatatlan-tomeggyilkos

those in need (Greenpeace, 2016). Planning the most effective interventions is not an easy task, and the toolbox of economics can help explore the causal side of the problem.

The aim of the dissertation is to identify the most important factors affecting firewood consumption and trash incineration and to determine which factors may be under the focus of the authority. If we can determine the factors that influence consumers to change their use of firewood and garbage, then we can encourage them to burn less of them with official regulations that reduce/amplify the impact of the most important ones. It is therefore also my task to formulate proposals that work towards a sensible reduction in firewood consumption and household trash incineration and can be used to plan public intervention. It is therefore conceivable that well-designed barriers and incentives need to be put in place to create less environmentally and health-damaging energy use. With this work, I would like to help design these tools. On the one hand, the novelty of my work is given by the fact that, to my knowledge, these issues have not yet been studied in Hungary in this way, with the data I use (this is especially true of the economic-scientific nature of my study).

I intend to fulfill my objectives by examining the following hypotheses:

<u>Hypothesis 1 (H1)</u>: With regard to residential firewood, income is not the strongest driving force in the energy transition in Hungary, so even with its growth state intervention in socio-economic processes is necessary. Nor can the quality of the environment in this area be left to market processes alone.

<u>Hypothesis 2 (H2)</u>: The most effective way to reduce residential firewood consumption can be achieved by state regulation of the price of the wood substitute product, i.e. the price of the pipeline natural gas.

Hypothesis 3 (H3): Increasing the material well-being of households is the most effective factor in reducing illicit trash incineration.

Hypothesis 4 (H4): Regulation of certain factors reduces residential firewood consumption and illegal trash incineration at the same time. Due to their effectiveness, these circumstances should be taken into account when planning state interventions.

In the dissertation I try to clarify the questions empirically, and I will evaluate the hypotheses with the help of econometric modeling.

2. Data and Method

2.1. Application of a multivariate linear regression model to explore relationships in firewood consumption

In the dissertation, I firstly deal with wood burning. Using a multivariate regression model, I examine the relationship between household firewood consumption and the selected explanatory variables between 1990 and 2018. The historical approach makes it possible to take stock of long-term changes, the disadvantage of which stems from the aggregation or averaging of the data, with which I am unable to shed light on regional and technological differences. I chose this type of approach because only annual, sectoral data on firewood use in Hungary are available. The data used for the analysis were downloaded from the Internet interfaces of the Central Statistical Office and Eurostat (Table 1). Stata version 15.1 was used for the analysis.

The dependent variable of my model is the amount of firewood consumed annually by the population (WOOD), which is examined using the following explanatory variables.

I take into account the annual average gross earnings (EAR). As described in the previous chapter, I primarily suggest a negative relationship between this variable and consumption, but I do not consider a positive relationship to be unthinkable either. I expect that as households become richer, they will use less firewood and more modern energy sources such as natural gas and electricity, suggesting that wood is an inferior good in the study area (Israel, 2002; Jiang - O'Neill, 2004; Couture et al., 2012). However, I also maintain the possibility that firewood is a normal good, so increasing consumer welfare increases the amount used from it (Arnold et al., 2006; Baland et al., 2010).

According to some researchers, the own price of energy has a stronger effect on consumption than income, so I also consider the price of firewood

(PWOOD) (Hiemstra-vander Horst - Hovorka, 2008; Kowsari - Zerriffi, 2011; Couture et al., 2012; Lillemo - Halvorsen, 2013). Just as firewood is considered an ordinary good, I assume a negative relationship between its price and the amount consumed from it.

I consider pipelined natural gas and electricity[3], which have a higher position on the "energy ladder", to be important factors. A substitution relationship, such as a positive relationship between these goods' price (PGAS, PPOW) and wood consumption, is likely. I believe that if the difference between the price of wood and its substitutes is significant and lasting, users will, where it is possible, switch to a cheaper energy source over time.

Due to the poor energy efficiency of the Hungarian housing stock (NFM, 2015; Juhász, 2017), consumers may be quite exposed to changes in outdoor temperature. Based on this, I think that the outside temperature plays a significant role in the development of firewood consumption, it has a positive relationship. The average annual heating degree days (HDD) can be used to quantify the temperature effect (Quayle - Diaz, 1980; Sugár, 2011). The heating degree day[4] is the deviation from the threshold temperature, which is

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[3] I would make so many additions that, in fact, electricity appears both as a substitute product (electric radiator, air conditioner, heat pump, etc.) and as an ancillary product on the market. Substitute/complementary nature is difficult to distinguish on the basis of aggregate data, it also strongly depends on the income situation, but since electricity is an important element of the energy mix in almost all households, it has a serious impact on consumers' budgets, so I think it is worth considering.

[4] „The heating degree day is usually calculated for a specific period of time, such as a month or a year. The heating degree day is calculated as follows. We determine the average daily temperature, and then we summarize the 16 - X values calculated daily for the given period if X is below 16 °C, or the corresponding value is zero otherwise. (Sugár, 2011, old.: 385.)"

positively related to the heating demand, so the higher the heating degree day, the higher the heat demand, the higher the energy consumption expected.

All monetarized data, including prices of firewood, piped natural gas and electricity, as well as earnings, were deflated and expressed at 1990 price levels. I work with the natural-based logarithm of the variables to be able to observe the elasticities. Thus, I assume that household firewood consumption can be well estimated as a function of the explanatory variables just presented, thus remaining almost within the theory of demand (demand theory variables and temperature effect):

*ln*WOOD = f (*ln*EAR, *ln*PWOOD, *ln*PGAS, *ln*PPOW, *ln*HDD)

Table 1: Abbreviation, definition and source of variables used to analyze firewood consumption:

Abbr.	Definition	Source
*ln*WOOD	Annual residential firewood consumption, toe	Eurostat, 2020
*ln*EAR	Average net real earnings, HUF	KSH, 2020
*ln*PWOOD	Real price of firewood, HUF/100 kg	KSH, 2020
*ln*PGAS	Real price of piped natural gas, HUF/m3	KSH, 2020
*ln*PPOW	Real price of electricity, HUF / kWh	KSH, 2020
*ln*HDD	Annual heating degree days	Eurostat, 2020

The basic descriptive statistics of the data (number of observations, mean, standard deviation, minimum, maximum) are shown in Table 2.

Table 2: Descriptive statistics of variables used to analyze firewood consumption

Variable	n	Mean	Std. dev.	Min.	Max.
*ln*WOOD	29	7,176522	0,2127749	6,81564	7,618988
*ln*EAR	29	9,730862	0,2148877	9,411797	10,16051
*ln*PWOOD	29	5,339646	0,1624511	5,066181	5,680677
*ln*PGAS	29	1,892647	0,3154847	1,411214	2,43567
*ln*PPOW	29	3,48072	0,2388156	2,791165	3,771568
*ln*HDD	29	7,929802	0,0795504	7,730913	8,078003

The relationships between the factors are examined using a multivariate linear regression model, the general formula of which can be written as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_i X_i + \varepsilon$$

where Y is the dependent variable,

$X_1, X_2, X_3, \ldots, X_i$ are explanatory variables,

β_0 is constant,

ε is the error term.

The model, that is the definition of a straight line to describe relationships is based on the ordinary least squares method (OLS). The method seeks to minimize the sum of squares of the deviation of the original data points from the estimated line (Koop, 2008).

2.2. Application of a multivariate linear regression model to explore the relationships associated with trash incineration

Household trash incineration is approached "from below", also in line with the available database. The analysis is performed on settlement-level cross-sectional data, which were downloaded from the website of the National Spatial Development and Spatial Planning Information System (TEIR, 2020). As much of the required information is only available from the census survey, the data refer to the year of the last census, 2011. Nevertheless, I believe that the processes mediated on the basis of the data (microculture, preferences, consumer behavior) have not changed in the past 9 years, so the results can be interpreted with confidence even today. The observations apply to all settlements in Hungary, i.e. to 3154. Data were processed with version 15.1 of the Stata software.

To visualize some basic data and to support the most important hypotheses, I created maps. For the map representation of the settlements I used the OpenStreetMap settlement boundary map files[5], the thematic maps were created with the QGIS 2.18.20 software.

Based on my preliminary examination (White test), the phenomenon of heteroskedasticity occurs, so I try to explore the factors affecting trash incineration by multivariate linear regression modelling with robust standard errors. Although, in addition to heteroskedasticity, OLS estimates remain unbiased and consistent, they will not be effective, so it is important to consider this condition (Ramanathan, 2003).

The dependent variable of my model is the amount of trash per capita transported from the settlement (TRASH). Behind this is the idea that the more

[5] http://data2.openstreetmap.hu/hatarok/kozighatarok.zip

trash is removed from the settlement, the less it is incinerated. Thus, changes that have a positive impact on waste generation are welcome. Of course, this is a strong simplification of reality, which we need to take into account when evaluating the results, but in the absence of better data, I need to achieve this. To estimate consumption, I use 10 explanatory variables, ones that I think are reasonable based on the literature. I did not find a study on the economic analysis of illicit household trash incineration, so I created my model based on the econometric model of firewood (or solid fuels in a broader sense).

The map on the left of Figure 1 is intended to emphasize the spatial differences of the dependent variable (Horváthné Kovács - Nagy, 2015). The map shows in red the settlements where the amount of municipal waste transported per capita is higher than the national average. In blue, we can see settlements with a lower amount than the national average, i.e. those where I assume that illegal incineration is more significant. The territorial distribution of waste concentration is uneven, at first glance the urban-rural, hilly-lowland, rich-poor differences are strongly mixed. Causal regularity cannot really be detected.

As most research emphasizes the impact of material well-being on fuel switching, I focus on income (Hoiser – Dowd, 1987; Shafik, 1994; An et al., 2002; Arnold et al., 2005). Due to the inconvenience of their use and the increased dust emissions, I consider (traditional) solid fuels as inferior goods. I expect income (INC) to be positively related to shipped (i.e., "not-incinerated") waste and is one of the most important explanatory factors. In the map on the right of Figure 1, the settlements with a per capita income higher than the national average are shown in red, while the settlements below the average are shown in blue. That is, if my first hypothesis were to prevail very strongly in reality, the colouring of the two maps would have to be very similar.

If I compare the maps, I can see some overlap between the red areas, but I cannot notice a clear relationship.

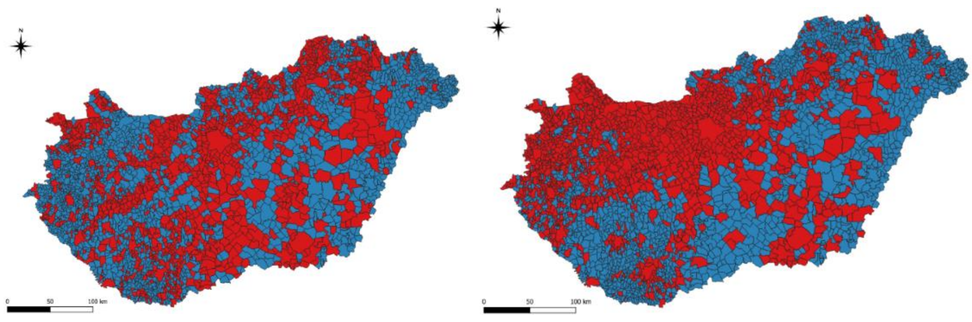

Figure 1: Trash transported per capita per settlement compared to the national average (left); per capita income per settlement compared to the national average (right) (red/blue: quantity above/below the national average), 2011

Source: TEIR, 2020

I also consider the extent of afforestation (FOR) as a particularly important variable (Fu et al., 2014; McLean et al., 2019). This can determine the abundance of firewood supply, which affects the price, can affect the degree of "theftability", transportation costs, and established habits. Thus, more abundant wood can make the use of firewood more popular, which also creates the possibility of trash incineration through co-fired boilers and stoves. Where it is possible to use traditional firewood, there is also a high chance that household rubbish will be incinerated, and in this respect, the two materials are also considered to be “synonymous” with each other. I hypothesize that the more opportunities there are to use more modern fuel, the less solid fuel, thus burning wood and trash. Thus, certain natural, social, economic, and technical factors influence the rate of trash incineration, which I hypothesize have a similar effect on firewood use. The map on the left of Figure 2 illustrates the dependent variable as previously described, but the map on the right now shows the degree of afforestation. There is no clear-readable pattern between the two maps this time either.

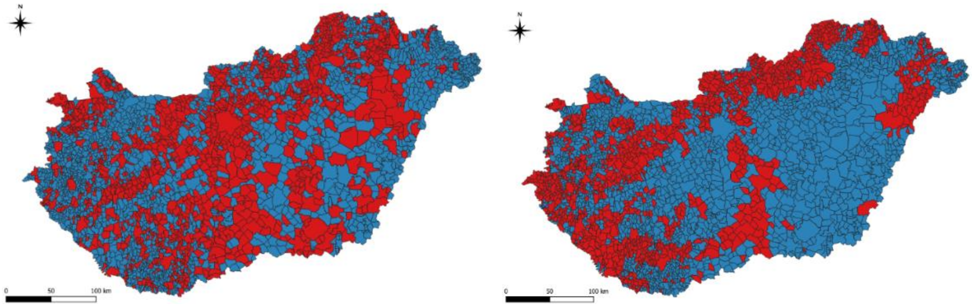

Figure 1: Trash transported per capita per settlement compared to the national average (left); extent of forest cover per settlement compared to the national average (right) (red/blue: quantity above/below the national average), 2011

Source: TEIR, 2020

I assume a positive relationship between the amount of trash transported and the use of products suitable as substitutes for waste incineration, such as natural gas (GAS) and electricity (POW) (Fu et al., 2014; McLean et al., 2019).

As solid fuel, such as illegal waste incineration, is more common in rural areas, more densely populated urban areas (POPDs) can have a positive effect on the amount of municipal waste transported (Abbott et al., 2016; Tao et al., 2016; McLean et al., 2019).

I expect that combustion is also positively related to the number of households (HOU) and the size of the dwelling, as measured by the average floor area of the dwellings (FLOOR) (Song et al., 2012). More and bigger homes also require more energy, so it is more likely to burn waste.

The age of the inhabitants can also affect the amount of energy used, which is expressed in terms of the number of seniors per hundred children (AGE) (Rahut et al., 2016). I hypothesize that older people have higher heat demand due to their poorer health (e.g. circulatory system-related diseases) and more time spent in housing, resulting in less trash being transported from more aging settlements.

I suggest a negative relationship between consumer education and solid firing (Karimu, 2015; Rahut et al., 2016; McLean et al., 2019). Higher education may have a reducing effect on waste incineration through higher average incomes and urban residence. Education is measured by the ratio of people with tertiary education to the total population (EDU). This can also affect an individual's knowledge and environmental awareness, which has a huge impact on heating habits. According to a non-representative survey, lack of knowledge and carelessness can also be important causes of illegal waste incineration (Lenkei, 2016).

I also take into account household congestion (~ family size), which is represented by the number of individuals per hundred households (CROWD) (Van der Kroon et al., 2014; Rahut et al., 2016). I believe that the more modest the financial opportunities, or the better the old habits live, the more residents live under one roof. Like deprivation, a more traditional way of life can encourage residents to burn “everything” that is left over and from which they can get energy.

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The descriptive statistics of the variables used in the analysis (number of observations, mean, standard deviation, minimum, maximum) are summarized in Table 4. Due to the observability of the elasticities, in this case, I also work with the natural logarithmic transformation of the data.

Table 3: Abbreviation, definition and source of variables used for trash incineration analysis

Abbreviation	Definition	Source
*ln*TRASH	Transported municipal waste per capita, t	TEIR, 2020
*ln*INC	Per capita income, HUF	TEIR, 2020
*ln*FOR	Proportion of forests in relation to the total area, %	TEIR, 2020
*ln*GAS	Gas consumption per capita, 1000 m^3	TEIR, 2020
*ln*POW	Electricity consumption per capita, 1000 kWh	TEIR, 2020
*ln*POPD	Population density, people/km^2	TEIR, 2020
*ln*HOU	Number of households	TEIR, 2020
*ln*FLOOR	Floor area per apartment, m^2	TEIR, 2020
*ln*AGE	Senior people per a hundred children	TEIR, 2020
*ln*EDU	Proportion of people with higher education, %	TEIR, 2020
*ln*CROWD	People per a hundred households	TEIR, 2020

Table 4: Descriptive statistics of the variables used to analyze trash incineration

Variable	n	Mean	Std. dev.	Min.	Max.
*ln*TRASH	3154	-1,658	0,420	-4,346	-0,018
*ln*INC	3154	13,182	0,397	10,789	14,401
*ln*FOR	3154	-1,930	1,262	-6,908	1,196
*ln*GAS	3154	-2,120	1,630	-6,908	0,682
*ln*POW	3154	0,013	0,271	-3,327	1,465
*ln*POPD	3154	3,.806	0,881	0,450	8,015
*ln*HOU	3154	5,812	1,332	1,946	13,617
*ln*FLOOR	3154	4,454	0,102	4,060	4,942
*ln*AGE	3154	5,064	0,742	-6,908	7,937
*ln*EDU	3154	-2,976	0,778	-6,908	-0,931
*ln*CROWD	3154	5,527	0,113	4,682	6,094

Residential trash incineration is estimated as a function of the following variables:

*ln*TRASH = f (*ln*INC, *ln*FOR, *ln*GAS, *ln*POW, *ln*POPD, *ln*HOU, *ln*FLOOR, *ln*AGE, *ln*EDU, *ln*CROWD)

The relationships between the factors are examined in a multivariate linear regression model with robust standard errors, the general formula of which can be written as already described:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_i X_i + \varepsilon$$

where Y is the dependent variable,

$X_1, X_2, X_3, \ldots, X_i$ are explanatory variables,

β_0 is constant,

ε is the error term.

The determination of the line suitable for describing the relations is also performed by the method of ordinary least squares (OLS).

Since the dependent variable is based on a strong simplification, I perform another estimation as well, the result of which may strengthen or weaken our first model. The method used is the same as the previous one, but the result variable of this second model is the sulfur dioxide concentration (per capita per settlement) (µg/m^3; *ln*SO2) [6]. This data comes from the database of the Central Statistical Office and is unfortunately only available for 27 settlements for the year under review[7]. The hypothesized correlation is that increased illegal trash incineration causes higher sulfur dioxide concentrations, so it can be used as a proxy indicator of the phenomenon under investigation. Given the low number of observations, I use only three of the explanatory variables described earlier, namely per capita income (*ln*INC), forest cover (*ln*FOR), which is identified as the supply of the substitute product, and per capita gas consumption (*ln*GAS), which characterizes the demand, the "availability" of the substitute product. I also work with the natural-based logarithm of the variables in this way, the assumed correlation can be written as follows:

*ln*SO2 = f (*ln*INC, *ln*FOR, *ln*GAS)

[6] n: 27, mean: 5,637737, std. deviation: 2,461803, min.: 1,254144, max.: 14,114511

[7] From the settlements that had an automatic air pollution measuring station at the time: Ajka, Budapest, Debrecen, Dorog, Dunaújváros, Eger, Esztergom, Győr, Hernádszurdok, Kazincbarcika, Komló, Miskolc, Nyíregyháza, Oszlár, Pécs, Putnok, Sajószentpéter, Salgótarján, Sarród, Sopron, Százhalombatta, Szeged, Tatabánya, Tököl, Vác, Várpalota, Veszprém

3. Results and Discussion

3.1. Results and evaluation of firewood consumption estimates

The results of the regression model are shown in Table 5. All results except heating degree days (*ln*HDD) are significant (at 1 or 2 percent). I expected the relationship to be in the case of wood (*ln*PWOOD) and natural gas (*ln*PGAS), contrary to my expectations in the case of demand (*ln*EAR) and electricity (*ln*PPOW).

Table 5: Results of the OLS estimation of firewood consumption

Variable	Coefficient	Std. error	P > |t|
*ln*EAR	0,64431	0,2561	0,019
*ln*PWOOD	-1,50401	0,3789	0,001
*ln*PGAS	1,24254	0,1620	0,000
*ln*PPOW	-1,25036	0,2093	0,000
*ln*HDD	0,38270	0,3219	0,247
Constant	7,90343	3,2169	0,000

Prob > F = 0,000; R^2 = 0,7724

Household firewood consumption is positively related to earnings (lnEAR). Increasing prosperity increases the demand for firewood too, but income elasticity is less than one, meaning that the demand for firewood increases to a lesser extent as income increases. A 1 percent increase in earnings increases wood consumption by 0.64 percent. This contradicts my initial assumption that firewood is a inferior commodity in Hungary. As a result of rising incomes, consumers are not moving up the “energy ladder” but are using more of this energy source. This confirms the first hypothesis of the dissertation (H1). As the growth of earnings in Hungary does not stimulate this stage of the energy transition (it even further increases wood burning), the quality of the environment cannot be relied purely on market processes in this respect either. It is not enough to expect the blessing effects of economic growth, well-designed and implemented incentives and constraints are needed to encourage consumers to build a more sustainable energy structure.

However, I do not rule out the possibility that there will be (then) an inflection point at a higher income level, beyond which the demand for wood will decline with rising income. To test this hypothesis, I fitted the quadratic term of income (*ln*EAR2) to the model to account for a possible nonlinear relationship, which, however, did not yield significant results (Table 6). Without this, I cannot confirm this hypothesis.

Table 6: Results of the extended OLS estimation of firewood consumption

	Coefficient	Std. error	P > |t|
*ln*EAR	11,26904	11,97234	0,357
*ln*EAR2	-0,54521	0,6142189	0,384
*ln*PWOOD	-1,47092	0,3825129	0,001
*ln*PGAS	1,24075	0,1627577	0,000
*ln*PPOW	-1,29525	0,2162976	0,000
*ln*HDD	0,41978	0,3260418	0,211
Constant	-44,14557	58,72624	0,460

Prob > F = 0,000; R^2 = 0,7802

A higher own price (*ln*PWOOD) is associated with lower consumption, as is usually the case for an ordinary good. The direction of the relationship is the same as the direction of the relationships obtained in the papers studied.

A decrease in the price of gas (*ln*PGAS) reduces wood consumption, which is natural in the case of a substitution relationship. The higher the burden of gas heating, the more attractive the cheaper alternative becomes where technical conditions allow for substitution - and vice versa.

The relationship between wood burning and the power price (*ln*PPOW) is negative, suggesting a complementary relationship between the two resources as opposed to the substitute. However, I treat this finding with extreme caution. The basis of the relationship is perhaps to be found around household budgets: the less is spent on power (inelastic demand in the short run), the more remains for firewood. The phenomenon may be true especially for poorer households, but if we accept this assumption, we also extend it to a large part of firewood consumers, as we can see from the data (too) that wood is primarily a fuel for poorer families.

The absolute value of price elasticities is greater than one, which means that the demand for firewood is elastic both in terms of own and cross-price elasticities. Namely, a 1 percent increase in the own price of wood reduces consumption by 1.5 percent. A 1 percent increase in gas prices will increase consumption by 1.24 percent, while a 1 percent increase in electricity prices will reduce demand by 1.25 percent.

No significant results were found for the heating degree days (*ln*HDD). Under the modeled conditions, temperature does not appear to have a direct effect on consumption, its effect is likely to be suppressed by other factors.

Since the data sets are logarithmically transformed, the regression coefficients can also be interpreted as the coefficients of elasticity of Hungarian household firewood burning. This helps me to evaluate the second research question/hypothesis of the dissertation, which is about the prominent effect of the price of natural gas (in other words: the relative price of firewood). The results show that it is not the price of natural gas that has the greatest elasticity, it is not the variable that has the greatest effect on the demand for wood. In light of this information, I reject the second hypothesis (H2). The biggest marginal effect is the own price of firewood: a 1 percent change in the price of wood causes a 1.5 percent change in consumption with all other factors unchanged.

According to this, the authority is able to influence the behavior and choice of consumers the most by influencing the price of wood. This result is in line with the findings of several foreign authors who draw attention to the prominent role of the own price in their work, such as Hiemstra-vander Horst - Hovorka (2008), Kowsari - Zerriffi (2011), Couture et al. (2012), Lillemo - Halvorsen (2013).

The second strongest effect is on the price of electricity, a 1 percent change in consumption results in a 1.25 percent change. My third largest variable is the price of natural gas, a 1 percent change in which is associated with a 1.24 percent change in firewood consumption. The result is consistent with Leach (1992), Song et al. (2012a) and Karimu (2015), who (also) emphasize the importance of the relative price of the energy source.

After extracting the results, I examine whether autocorrelation occurs, which would impair the efficiency of the estimation (even if left unaddressed and consistent) (Ramanathan, 2003). I first perform the Breusch – Godfrey test, which has a null hypothesis that there is no autocorrelation. The result of the test is shown in Table 7, according to which the null hypothesis can be accepted.

Table 7: Results of the Breusch – Godfrey test

lags (p)	chi2	df	Prob > chi2
1	0,981	1	0,3220

Second, the Durbin - Watson test is used. The result of the test (d-statistic = 1.60218) is above the critical upper value (1.254), so I do not have to reckon with autocorrelation according to this.

I then examine whether the condition of homoskedasticity is met. The test is performed with the White test, which shows that (chi2 (20) = 23.98; Prob> chi2 = 0.2431) there is no need to fear heteroskedasticity.

Finally, I check whether we have to reckon with the phenomenon of multicollinearity. It is conceivable that the explanatory variables involved in the study have an effect not only on the dependent variable but also on each other, thus amplifying each other's effect, making it difficult/meaningless to examine the separate effect of each explanatory variable (Kovács, 2008). (Even then, my estimates remain unbiased, effective, consistent (Ramanathan, 2003).) To test multicollinearity, I examine variance inflation factors (VIFs). Table 8 shows that the multicollinearity that occurs is not a problem.

Table 8: Variance inflation factors for testing multicollinearity

Variable	VIF	1/VIF
*ln*PWOOD	8,46	0,11825
*ln*EAR	6,76	0,14797
*ln*PGAS	5,83	0,17156
*ln*PPOW	5,58	0,17930
*ln*HDD	1,46	0,68351
Mean VIF	5,62	-

3.2. Results of trash incineration estimation and their evaluation

Most of the results of the model are significant (at 1 or 5 percent). Examining the regression coefficients that can be considered significant, I can say that four developed as expected (*ln*POW, *ln*POPD, *ln*EDU, *ln*CROWD), but two did not (*ln*FOR, *ln*AGE). My results for income (*ln*INC), gas (*ln*GAS), number of households (*ln*HOU) and size of dwellings (*ln*FLOOR) are not significant, the variables according to the model do not affect the amount of trash transported (Table 9).

Table 9: Results of the OLS estimation of trash incineration with robust standard errors

Variable	Coefficient	Robust std. error	P > |t|
*ln*INC	0,0250	0,0342	0,4650
*ln*FOR	0,0191	0,0066	0,0040
*ln*GAS	0,0067	0,0061	0,2730
*ln*POW	0,1746	0,0338	0,0000
*ln*POPD	0,0523	0,0137	0,0000
*ln*HOU	0,0110	0,0087	0,2060
*ln*FLOOR	0,0184	0,0859	0,8300
*ln*AGE	0,0294	0,0146	0,0450
*ln*EDU	0,0456	0,0190	0,0160
*ln*CROWD	-0,7111	0,0952	0,0000
Konstans	1,6331	0,6113	0,0080

Prob > F = 0,000; R^2 = 0,125

One of my most important hypotheses for income (*ln*INC) is that an increase in welfare reduces illegal burnings by allowing the use of more modern, cleaner, and at the same time more expensive technologies. Wealthier consumers can afford to give up uncomfortable and dirty sources of energy. In the absence of a significant result, I reject this hypothesis, according to which income does not have a direct effect on trash incineration in Hungary today. These correlations do not confirm the third (H3) hypothesis of the dissertation. It is conceivable that the income effect is overridden many times by other factors, but it is also possible that my dependent variable, as it is based on strong abstractions, is in fact unsuitable for mapping the connections!

The degree of afforestation in the region (*ln*FOR) has a positive effect on the amount of trash transported, which contradicts my hypothesis. This phenomenon may be explained by the fact that larger forests mean a greater supply, which, among other things unchanged, reduces the price of firewood. Locally available raw materials also keep transportation costs low, making residents of these areas more likely to cause garbage to replace residents of more barren areas. Abundant timber also creates greater opportunities for illegal trade and theft[8], which, although arguably, also helps replace trash. It is likely that these reasons may be behind the positive relationship.

As the result is not significant, I reject the hypothesis related to natural gas consumption (*ln*GAS). Incineration can theoretically be replaced by natural gas, but in practice this does not seem to be the case.

In contrast, the more electricity (*ln*POW) households consume, the less trash they incinerate. On the one hand, incineration can be replaced by electricity (radiators, electric heaters, air conditioners, heat pumps, etc.). On the other hand, more electricity-intensive (typically richer) households often lack a device suitable for mixed (solid fuel) combustion, so if they wanted to, they would not be able to burn "anything".

I also found a positive relationship for population density (*ln*POPD). More advanced heating systems in more densely populated urban regions (e.g. district heating, central heating) limit the possibility of mixed combustion.

The result for households (*ln*HOU) and dwelling size (*ln*FLOOR) is not significant, the variables have no effect on garbage incineration. The relationship between the age of the inhabitants (*ln*AGE) and the municipal trash transported also contradicts my initial assumption. The relationship

[8] The structured legal and moral implications of this issue have already been discussed by Karl Marx in his 1842 Debates on the Law on Thefts of Wood.

between the two variables is positive, for which I cannot find a well-founded explanation. One possible explanation is that older people wear more clothes, dress more thickly than fire more (Csutora et al., 2018). It is conceivable that the older generations did not have the characteristic of a great warm home as a child, and have not demanded it ever since. This can also lead to older people heating less, so they also burn less trash than younger ones. To understand the exact reasons, a deeper and more detailed examination is needed.

According to my results, higher education (*ln*EDU) has a reducing effect on trash incineration. This is not surprising, as higher education is usually accompanied by an urban environment and greater environmental awareness (Brávácz, 2014).

My hypothesis that the more people living in a household (*ln*CROWD), the higher the rate of illegal firing seems to be justified. It is conceivable that although the specific energy demand of a more congested household is lower, household waste appears to a greater extent in consumption. This can be caused by a more modest income relationship that forces more and more people under one roof, but the result can also carry a regional message. For larger families, the traditional way of life is mostly characteristic of rural areas. The incineration of household waste (which not so long ago meant only natural materials) could also be part of the traditional heating culture developed here.

Again, I check to see if I need to account for multicollinearity, testing it with variance inflation factors (VIFs). Based on the results in Table 10, we can see that only a weak, non-problematic degree of multicollinearity occurs.

Table 10: Variance inflation factores for testing multicollinearity

Variable	VIF	1/VIF
*ln*POPD	3,05	0,33
*ln*HOU	2,73	0,37
*ln*EDU	2,66	0,38
*ln*INC	2,56	0,39
*ln*CROWD	1,73	0,58
*ln*GAS	1,57	0,64
*ln*FLOOR	1,52	0,66
*ln*POW	1,43	0,70
*ln*AGE	1,23	0,81
*ln*FOR	1,11	0,90
Mean VIF	1,96	-

The results of the second model used to investigate illegal trash incineration are shown in Table 11. The dependent variable of this estimate is the logarithm of the per capita sulfur dioxide emissions. We can see that of the results, only income can be considered significant (at 1 percent), which, however, shows a negative relationship between the two variables. This contradicts the result of the first estimate and confirms the third hypothesis, but due to the nature and size of the sample, we have to handle this calculation in place, no more serious conclusions can be drawn from it. However, it can be assumed that the data do not form a consistent, non-contradictory whole, so we have to treat the results with reservations.

Table 11: Results of OLS estimation of trash incineration with robust standard errors (2)

Variable	Coefficient	Robust std. error	P > |t|
*ln*INC	-6,0985	1,9934	0,006
*ln*FOR	-0,2407	0,2937	0,421
*ln*GAS	0,0593	0,7925	0,941
Konstans	88,3005	27,8066	0,004

Prob > F = 0,0128; R^2 = 0,4909

4. Conclusions and Recommendations

4.1. Conclusions and recommendations for reducing firewood consumption

Based on the results of the regression modeling, I now formulate conclusions and suggestions that may be worth keeping in mind when designing regulatory policies.

Rising wages will lead to higher consumption, but limiting wealth growth cannot, of course, be an official goal. Although my modeling does not predict the existence of the mentioned inflection point, researching the question can be an exciting task (in the future). If we can substantiate with arguments that a higher income level reduces wood burning as a result of enrichment (as shown in a significant part of the literature: decoupling), then a carefully designed income and tax policy can be a successful tool to accelerate the energy transition, which may also be supported by favorable macroeconomic developments. An increase in the minimum wage and a progressive personal income tax in favor of the lower social classes can in this case help the spread of cleaner technologies, including air purification. The idea is based on the need to help households with public intervention to use fuels more efficiently and (for whom this is a realistic, sensible decision) to replace wood-based technology with a cleaner alternative. Both measures reduce airborne dust content. A multi-rate personal income tax allows the state to deduct only a relatively small portion of the income of poorer consumers compared to the one-rate alternative. That is, if you like, it’s a kind of inverse form of state aid: the state leaves more money at the people. As a result of the progressive income tax policy[9], more money remains in people's pockets, which can be

[9] In connection with the progressive or multi-rate personal income tax policy, the proponents of free markets and minimal state intervention are fighting hard against the camp of those who

used, for example, to insulate the apartment (replacement of doors and windows, covering walls with insulating material) or to modernize or replace the heating equipment. The latter option involves the dissemination of cleaner technologies: the purchase of new, more efficient ones instead of old stoves, the replacement of wood-based technology with gas-based ones, the purchase of solar collectors and/or heat pumps, etc.

Though the results show that raising the own price of wood will reduce demand as its primary consumer is poorer people, it is not advisable to raise any form of price increase. It would be unacceptable not only for reasons of fairness and justice, but the increased cost burden could also increase illegal incineration and theft of wood, all of which run counter to the environmental objectives set.

Reducing the price of natural gas (keeping it low) is a rational solution, as it becomes more attractive in this way, and in terms of its local environmental impact, it is certainly more sustainable than any solid fuel, as it does not involve dust emissions. In the case of Hungary, the regulator can operate not only with the tax content of the product, but also with its official price. The popularity of natural gas can indeed be increased indirectly, for example by distributing the pipeline network that provides its supply and by reducing connection costs. In this respect, relatively little "empty space" is available, as the coverage ratio with the gas pipeline is 91.2 percent (KSH, 2020), and from

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support "tamed capitalism", significant state intervention. While the former argue that a multi-rate tax is unfair because it punishes the rich, thus performance, and is overly inefficient in economic terms, until then, the latter emphasize the injustice, inequality, and gap between individual performance and wealth caused by the structural problems of the economy and society. I do not intend to decide which side is right, it is a very complex question that requires empirical research in the field of economics or sociology just as much as it is about the worldview, religion, morality of the individual. With the possibility of a progressive income tax, I want to draw attention to one thing: the larger amount of money left behind by poorer people, which could theoretically easily lead to cleaner use of thermal energy.

July 1, 2017, public utility connections are free of charge (Miniszterelnökség, 2017). The reduction of fixed costs can also be considered as an indirect stimulus to consumption, for example, we are thinking of supporting the purchase of gas appliances and reducing their sales tax. A more special form of encouraging gas consumption is gas price subsidies. Since the reduction in gas prices affects all gas consumers equally (see the official gas price reduction and its anomalies in footnote 23 of the dissertation on page 55) and as people who consume more gas belong to the richer half of society, it is likely that this form of intervention is not as effective from an environmental point of view as gas price subsidies. As the system of procedures leading to gas price subsidies allows beneficiaries to decide individually on the basis of their socio-economic characteristics, I believe that this form of intervention can be better targeted to those places where it is most needed, i.e. to households too poor for the energy transition. In general, it can be said that the form of intervention is likely to be more environmentally efficient, most of which can be directed to where the negative marginal effect of the subsidy on emissions is greatest. However, it is also worth seeing that the transaction costs of gas subsidies are significant due to individual treatment and can also cause social tensions ("who gets subsidized, who does not…?").

Based on the degree of marginal effects, the price of electricity is an important factor, but as I have already pointed out, it is worth treating its relationship with wood with caution. Based on the regression coefficient, higher electricity prices are coupled with lower wood consumption, but at the resulting tax and/or official price increase, we again run into barriers of fairness and justice.

Of course, firewood consumption is also influenced by a number of other non-market factors that I omitted in the present analysis. I did this because I had a relatively short time series (28 observations), but it would be important to expand the sample with other variables, and I make some suggestions for this below. I could include in the study the size and extent of the infrastructure ensuring the availability of the most important substitute product (Karimu, 2015), thus I would take into account the proportion of settlements supplied with piped gas to all settlements. It is useless to have sufficient purchasing power and intent if the technical conditions (or the lack of gas pipelines) do not allow the use of natural gas. I believe that the demand for wood is also significantly determined by the urbanization of the consumer's place of residence. This effect can occur on at least two sides. On the one hand, the demand for firewood is affected by the proximity of forests. The more readily available it is, the more abundant the supply and the lower the cost of transport, the more attractive the product is to consumers. Since villages tend to have a closer “relationship” with forests, I can assume that the proportion of people living in urban conditions is inversely related to the amount of firewood used. On the other hand, the use of more modern energy sources and heating equipment in urban settlements may reduce the usability/attractiveness of firewood, so the former connection is likely in this respect as well. I forecast a negative relationship between the energy efficiency status of homes and consumption. For example, the energy efficiency of homes can be measured by the total energy consumption per unit of heating degree days (Schueftan et al., 2016). An important factor would be the level of education (Karimu, 2015; Rahut et al., 2016), which can be well mapped by the ratio of students in higher education to the total population. Higher educational attainment is typically associated with higher incomes and urban environments, and is also associated with greater awareness, all of which contribute to declining firewood consumption. There are many more variables to consider, but even these few show that the scope of the study can be easily extended to include natural, social, and technical factors — certainly at the level of theory.

I also consider it worthwhile to carry out an analysis based on settlement-level cross-sectional data in the future. By comparing the results of researches with different approaches, we can get a more thorough picture of the study area. However, this requires data that is not currently available. It is therefore also a request to the authorities to record and publish the data needed for the research.

As a further possibility, I consider a panel regression analysis, as the use of firewood is similarly widespread in several countries of my region (e.g. Slovakia, Serbia, Poland). Examining the problem with such an extension could lead to much more reliable results, but this requires a thorough knowledge of the relevant elements of countries' energy policies, statistical and communication history[10].

4.2. Conclusions and recommendations for reducing illicit trash inceneration

From the results of the OLS estimate, now I draw conclusions that can help plan government interventions. Among the examined factors, the largest marginal effect is caused by the number of people per one hundred households (-0.71). According to this, less crowded homes are less prone to illegal firing. In order to formulate a related official measure, I need to look behind things. Larger family size is an incomprehensible phenomenon in itself, one of its main causes may be poverty and the other may be the retention of traditions. The former is relevant for government policy. Income can also play a major role in reducing congestion and enhancing energy transition. The need for a well-designed, fair and efficient economic policy, social and fiscal policy that

[10] Think of the radical statistical change in the field of domestic renewable energy consumption: Mezősi et al., 2017

promotes wage growth is thus a current, legitimate demand at all times. Successful implementation of these tools can indirectly change consumer behaviour and improve the quality of the environment.

My second largest variable is electricity consumption (0.18). If households could consume more electricity, they could reduce waste incineration. The pipeline network enabling consumability covers all settlements in the country, so there is no further room for maneuver in this area (KSH, 2019). Reducing and keeping electricity prices low, and indirectly helping to increase incomes, can also lead to higher consumption and thus a cleaner environment.

Population density (0.05) and education (0.05) also have a significant effect on consumer choice. The average values of both variables are higher in the cities, so the urbanization processes, which take place dynamically on their own, can bring good changes to our topic. In addition, campaigns and workshops to increase knowledge and awareness can play an important role. As a first step, it would be important to assess what information consumers have about the impact of firing on environmental quality and human health.

I have rejected my hypothesis about income, i.e. it is not enough to entrust the solution of the problem to a fortunate economic situation, increasing prosperity, free markets and social processes, a state role is also needed to stimulate beneficial processes. The second most important hypothesis in the modeling seems false, but it draws my attention to a number of important things: it seems that in areas with abundant timber, trash incineration can be triggered by wood. If I think according to the hierarchical order of the "energy ladder" model, this is a logical assumption. So, if we are able to increase the availability of a higher quality source of energy, consumers will switch themselves to a more environmentally friendly and health-friendly alternative. Reducing the price of firewood can be a good way to reduce illegal firing, which can reduce the release of toxic substances into the atmosphere, but it can easily be a significant increase in the emission of particulate matters. A hypothetical means of reducing the price of pipeline gas to reduce dust pollution from biomass combustion. Using it does not allow particulate matter to enter the air, but increases greenhouse gas emissions.

The complexity of the situation could be illustrated by a number of other examples, but even these few thought experiments suggest that we are facing a cross-disciplinary issue, which cannot be without the involvement of various aspects in the design of state interventions. Both regionally and according to the vertical stratification of society, different strategies may be needed, so several different studies are needed. In addition to quantitative studies, we can really understand the behavior and heating habits of the certain consumer groups through qualitative research that can capture softer information (questionnaires, in-depth interviews). Exploring such characteristics is an important task, so we can only ensure that society is not treated as a homogeneous mass and that the most effective policies are tailored to each group.

Finally, I draw attention once again to the fact that the dependent variable of my model - the “unburned” trash - stands out only with very strong abstractions. My results may be highly skewed, however, I could not have acted otherwise without better data. Knowing the importance of the topic, seeing the results of my research, it would be important to get more reliable data as soon as possible, with which I can make more accurate estimates. This is also supported by the result of my second model, which linked the sulfur dioxide concentration per settlement to a negative relationship with income. This contradicts the result of the first model that income has no direct effect on illegal waste incineration, but due to the nature and size of the sample analyzed, I cannot say more than the reliability of the data is in doubt, so it is appropriate to examine the phenomenon with a better database.

4.3. Regulatory similarities and differences

In Table 12, I summarized the significant explanatory variables of the two analyzes based on the strength of their effect (elasticities). In the light of my results (taking into account the studied variables), I can say that the reduction of firewood consumption can be achieved most effectively by regulating the own price of wood, the price of electricity and the most important substitute product, natural gas. (As indicated earlier, regulating [to be precise: increasing] the wood price and the electricity price is not seen as a real option, as it would further undermine the well-being of already disadvantaged consumers.) In the field of illegal incineration, we can achieve our goals most effectively through regulations on family size, electricity consumption (price), population density (urbanization) and education. (In this case, I am not dealing with a policy that directly affects the family size, as its strict purpose would be to reduce the size of families, which obviously cannot be a government goal.)

Income - given a prominent role in the literature and in my theoretical models - does not have the expected effect for any of the resources. The effect of income on the energy transition could not be demonstrated in the way suggested by the results of others. The positive coefficient for wood and the lack of a significant result for household trash show that the “energy ladder” mechanism is inoperable. Increased welfare increases the use of wood, but has no effect on illegal trash incineration. That increase in incomes, all other things being equal, does not reduce the consumption of the two fuels in one fell swoop, in both cases I need to focus on other areas.

Rising wood own price reduces wood burning, but because it makes it harder to replace trash with wood, it can even increase illegal burnimgs. In this area, it may be worthwhile to classify consumers into separate groups, seeing the continuous rise in firewood prices (KSH, 2020). We could provide free/discounted firewood for the most disadvantaged households, which will enable them to replace their trash (at least part of it), so that the environment will not deteriorate even with rising prices. The group of those living in better material conditions may be encouraged to replace wood with a more modern (and cleaner) energy source by the ever-increasing price.

We can also think about the factors that cause indirect effects, such as the degree of urbanization and education. My results show that illicit incineration is reduced by urban conditions (higher population density) and education. In the case of firewood, I have not been able to examine these variables, but it is likely that an urban environment far(ther) away from forests may increase the price of wood through longer transport routes and a scarce supply, which reduces consumption. Though higher incomes can be earned in cities and due to higher education increase the demand for wood, gas stoves installed in urban dwellings, such as factors that promote gas consumption, may encourage (force) the replacement of firewood.

Reducing the price of gas (and presumably any circumstance that makes natural gas a more attractive alternative) will stimulate gas consumption, thereby reducing the demand for firewood. On the other hand, gas consumption (hence gas price policy) has no effect on waste incineration.

Reducing the price of electricity increases firewood consumption and reduces waste incineration. As I have already pointed out, despite the result, I treat the relationship between wood and electricity with due caution, but even if the relationship is strong, increasing the price of electricity (similar to increasing the price of firewood) is not a real policy option.

Table 12: Variables affecting firewood and trash incineration based on the strength of elasticities and the direction of their effect

Strength of the effect of variables	Firewood	Trash
1.	Firewood price (-)	Family size (+)
2.	Power price (-)	Power consumption (-)
3.	Gas price (+)	Population density (-)
4.	Income (+)	Education (-)
5.	-	Age (-)
6.	-	Forestation (-)

All in all, even if there are differences between the two energy sources, it seems true for both that their use will not decrease as a result of increasing prosperity, but through policies to support urbanization and the consumption of modern (substitutable) energy sources. These results confirm the fourth hypothesis of the dissertation (H4), according to which certain factors have a similar effect on wood consumption and illicit trash incineration, so we can achieve success in both areas by regulating them. Of course, the "perfect" evaluation of the hypothesis requires the safe availability and inclusion of additional variables in the analysis, which sets the direction for further research. With these data, the results of the two models can only be compared with great certainty, and more reliable conclusions can be drawn from them.

5. New Research Results

In the following, I present the elements of the dissertation that make the research and its results novel.

On the one hand, the novelty of the research is that the microeconomic analysis of household firewood use in Hungary has not yet been performed with the method and data I used. I identified the important factors affecting wood burning and determined the direction and strength of the relationships. The economic model of illegal household trash incineration with the model I built and the variables used is also considered novel. To my knowledge, this problem has not been investigated anywhere with the approach I have taken.

Based on my results, it can be stated that the “energy ladder” model does not apply in Hungary. According to my analysis, earnings are not the variable that most explains wood consumption. Moreover, the positive relationship shows that its growth will lead to an increase in demand. In the case of garbage, I did not find a significant relationship in terms of material well-being. So the enrichment of households does not control the energy transition, thus not improving air quality. For my topic, it is not enough to wait for the blessing effects of economic growth, we need well-designed and implemented incentives and constraints that point in the direction of more sustainable energy use. In answer to my first research question, I can say that even with increasing earnings, we cannot just “lean back”, state intervention is needed to improve air quality and thus protect human health.

Indeed, the identification of areas where intervention can effectively reduce residential wood burning/trash incineration can be considered a novel result. In the case of wood, policies to help reduce the price of natural gas may be of the greatest practical significance, (but we must not forget important variables that have a significant impact and practical significance but were not included in the analysis). Trash incineration can be effectively reduced by reducing electricity prices, urbanization, and increasing education, while again drawing attention to the dependent variable used in the model, as it can roughly simplify reality, which can lead to distorted results.

In short, although there are differences between the two energy sources, it is true for both that their usage can be reduced through policies that support urbanization and the consumption of modern, alternative energy sources, but not just by rising incomes.

My work has also highlighted that the data needed to study these areas are very scarce and sometimes even non-existent. As these are very serious problems, it would be important to set up a reliable, comprehensive database as soon as possible, with which researchers from different disciplines could study the connections.

6. Publications on the Topic of the Dissertation

Csuvar, A., Barna, R. (2020). Econometric Analysis of Residential Trash Incineration Based on Cross-Sectional Data. *European Research Studies Journal*, 13(4), 771–784.

Csuvár, Á. (2020). A háztartási tűzifafelhasználás ökonometriai modellezésének indokoltsága és lehetséges megközelítése. *Gazdálkodás*, *64*(1), 13–55. https://m2.mtmt.hu/api/publication/31194466

Nagy, B., Horváthné Kovács, B., Csuvár, Á., Titov, A. (2020). Multivariate model for the usage of renewable energies in a rural area. *Visegrad Journal on Bioeconomy and Sustainable Development*, *9*(1), 19–22. https://doi.org/10.2478/vjbsd-2020-0004

Csuvár, Á. (2019). The Justification and Possible Approaches to Econometric Modelling of Households' Firewood Usage. In D. Koponicsné Györke & R. Barna (Szerk.), *Abstracts of the International Conference on Sustainable Economy and Agriculture* (o. 50). Kaposvár University. https://m2.mtmt.hu/api/publication/31124708

Csuvár, Á. (2019). Háztartások tűzifafogyasztásának változása az „energialétra" hipotézis tükrében. *GAZDÁLKODÁS*, *63*(4), 15–324. https://m2.mtmt.hu/api/publication/30785579

Csuvár, Á., Horváthné Kovács, B., Nagy, B., Titov, A. (2019). Alternative Wood Usage in a Potential Agroforsestry Area. In D. Koponicsné Györke & R. Barna (Szerk.), *Abstracts of the International Conference on Sustainable Economy and Agriculture* (o. 28). Kaposvár University. https://m2.mtmt.hu/api/publication/31124683

Csuvár, Á. (2018). Hungarian households' biomass and natural gas consumption in the context of the "energy ladder" hypothesis. In V. Varjú (Szerk.), *Socio-economic, environmental and regional aspects of a circular economy* (o. 84). MTA KRTK RKI Transdanubian Research Department. https://m2.mtmt.hu/api/publication/3385676

Csuvár, Á. (2017). A földgáz és a tűzifa harca a magyar vidék életében. In M. Bodor, S. Kerekes, & G. Zilahy (Szerk.), *„Jót s Jól!": 26 tanulmány a fenntarthatóságról* (o. 163–168). Felsőbbfokú Tanulmányok Intézete. https://m2.mtmt.hu/api/publication/3341963