International Relations
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THESIS SUMMARY

Krisztina Hegedüs

NATURAL GAS DEPENDENCY, AIR POLLUTION AND ENERGY POVERTY

Through the example of Hungary

Ph.D. dissertation

Supervisor:

Viktória Endrődi-Kovács, PhD
assistant professor

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World Economy Institute

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1. Introduction and hypotheses

1.1. Research background and relevance of the topic

The European Union import 69,1% of its natural gas consumption, while this portion in Hungary is 69,7% (Eurostat; 2018a), which raises the issue of the security of supply. Because of this almost every strategy that concerns energy has the aim to create energy security in it both in Hungary and in the European Union (e.g.: Energy Union and the Hungarian Energy Strategy 2030). There are goals to diversify the routes or the sources of the natural gas supply. However one of the most desirable alternative of natural gas to reduce the European energy dependence would be to enhance the production of renewable energy.

However, natural gas has many preferential features for example it produces the lowest level of harmful emmissions during utilization, furthermore it can play a major role on the electricity reserves capacities market. (IEA; 2011)

Meanwhile, there are many studies regarding the realization of the security of supply and the substitution of natural gas consumption (e.g.: Baran; 2010, European Commission; 2014b; Weiner; 2016), another phenomenon can be observed in Hungary as well. In spite of the continuous decrease of domestic primer energy consumption, the end use of energy and the consumption of natural gas until 2015 (Eurostat; 2018), the air pollution has been increased in Hungary. Especially the amount of airborne dust particles which are harmful to health (KSH, 2017a és 2017b).

A decrease in energy consumption usually has a positive effect on air pollution therefore this phenomenon is contradictory. According to statistics especially the private consumption of natural gas is decreasing meanwhile the use of biomass in heating has increased (Eurostat; 2018d). In theory this latter would be preferable as it is a renewable energy source and the increase in its utilization is an important energy policy goal for the European Union. The National Energy Strategy 2030 (2011) also counts on the growth in the share of renewables because the use of domestic renewables plays the most important role in reducing Hungary's energy import dependency. At the same time a "smart heating" campaign has been started with the support of the Ministry for Agriculture since 2016. The campaign tries to raise awareness of the growth in the share of air polluting fuels in residential use and informs the people which fuels are worth using when trying to be more conscious of the quality of air.

As the topic is so novel that the Hungarian Energy and Public Utility Regulatory Authority (HEA) – the official energy statistics provider of the country – published the correction of the data

on the private use of biomass 5 years retrospectively only in the beginning of 2017. Changing the statistics was necessary because of an EU regulation (European Commission; 431/2014/EU regulation) but the phenomenon described above was given – irrespective of weather conditions or any kind of energy efficiency investment (HEA; 2017). The data on residential natural gas consumption and district heating was reliable, thus it was likely that a correction was needed in the data on residential incineration of waste and biomass. Previously the data was based on the amount of officially sold firewood but it is very likely that in mixed combustion boilers not only officially bought firewood is being incinerated. With that correction the biomass data has increased.

Empirically the phenomenon, that the increasing comsumption of the resindential biomass is the cause of the increasing concentration of the airborne dust particles, is easy to find. When walking in an area with family houses during the heating season and mainly firewood is being burnt it is not hard to notice the fume coming from the chimneys and the deterioration in the quality of the air. In my dissertation I aimed to quantitatively prove this empirical assumption and to reveal connection between biomass and air pollution.

My dissertation tries to provide possible answers to what causes the phenomenon of the increasingly growing share of the use of biomass in household heating? How sensitive is the population to changes in the retail selling price of natural gas? Which part of the society is the most price sensitive and how substitutable are the different energy resources when it comes to household heating?

The issue of energy poverty connects to these question in my dissertation. Thomson-Snell (2016) examined which European countries defined energy poverty already, but Hungary is not among them. Despite of the lack of definition in Hungary more and more emphasis is being put on the elimination of energy poverty both politically and academically. The recent politics were unequivocally aimed at decreasing the energy costs of Hungarian households, including the costs of heating by cutting down the retail price of natural gas. Besides these steps, more and more households are burning biomass or waste not qualified as biomass in mixed combustion boilers, in spite of the fact that controlling and reaching a steady temperature without continuous work is much easier when using natural gas.

There is the question however that is it safe to assume that the increased price of the natural gas was the trigger that has made households to change their natural gas based heating systems into

biomass based heating systems? If the answer to that question is positive than which part of the society undertook the inconvenience to heat with biomass? Was it the energy poor?

The presumption in my dissertation was that the price of the natural gas does not change the energy consumption habit of the energy poor, therefore when the price is decreasing it is not the energy poor who can benefit from that. In Hungary the typical energy source of the residential heating is natural gas due to historical reasons (Herrero-Ürge-Vorsatz; 2012), yet the energy costs of the households are more affected by the other factors than the price of natural gas. Those other factors could be the consumpted quantity, the characteristics of the buildings, or the income of the households as well.

The increasing air pollution, and biomass consumption with the decreasing natural gas consumption it seems that there is a possibility to replace one energy source to another within a household. The question is which consumer base is the most price sensitive and able to replace the energy source used for heating. Or is it possible to flexibly change between energy sources when it comes to heating?

To research the questions above I have formulated my hypothesis.

1.2.Hypotheses

In my dissertation I research three hypothesis:

H1: Biomass, increasingly used by the households as an energy source for heating, is the major cause of the deterioration of air pollution indicators.

H2: The retail sales price of natural gas is not the main determinant of the household's energy expenditures, therefore it is not the main determinant of the energy poverty either.

H3: The household's consumption of natural gas is mainly determined by the type of real estate.

The link between my three hypotheses are the increasing household consumption of biomass, the decreasing consumption of natural gas and the increasing level of air pollution, more specifically, the emission of particular matters, which is very harmful to human health. My presumption is that some of the households have replaced the natural gas to biomass as a heating energy source during the last 10 years. However the household biomass consumption, even though

it is a renewable energy source, worsen the air quality, because with the biomass or mixed combustion, particular matter emission increased. I would like to prove that presumption with my first hypothesis (H1). Particular matters in the air is harmful to health, it would be essential to stop the increasing emission, therefore it is important to turn around the tendency to replace natural gas to biomass in household heatings.

To understand the tendency of why the houselhold natural gas consumption decreasing, while biomass consumption increasing, first we should understand what factors have the most influence on the household energy costs.

With my second hypothesis (H2) I analyse the price effects of the different energy sources to the energy costs of the different social groups. If my presumption were true that the price of the natural gas is not the main factors to determine the household's energy costs, than with my third hypothesis I analyse the consumption data. What are the main factors that determine the consumtion of the natural gas by households? Whether is it the price, the weather or the building they live in? In my third hypothesis (H3) I presume that it is not easy to replace the energy sources with each other when it comes to heating, moreover it is not always up to the consumer's will to change the heating of the given household. Therefore I analyse how the price, the weather and the buildings effects the consumption of natural gas by households, to realize which the key factor of the consumption is, and how consumers could replace one energy source to another.

2. Methodology

The hypotheses are based on causality. I analyse them by quantifying those causality. I would like to prove my hypotheses by statistical and econometric methods. I made presumptions based on statistical data, to prove those presumptions I use correlation and regression analysis. Correlation examines the existence, direction, and strenght of the relationship between the criteria. While regression calculation can be applied to the case when there is a connection between the variables and the characteristics of the connection need to be determined (Hunyadi-Vita; 2003).

According to the regression calculations I use linear regression, as I believe it suits my hypothesis the best. For the linear regression I use the classic Ordinary Least Squares (OLS) modell. It has the advantage to minimize the sum of squared residuals. The OLS method result in the Best Linear Unbiased Estimate (BLUE). (Ramanathan; 2003)

For all my hypothesis a correlation matrix was created with each of the variables to find out how they correlate with each other, and for a purpose to exemine if there is any deterministic connection or should any variable be eliminated.

I calculated the variance inflation factor (VIF) of the variables to quantify multicollinearity. (Hunyadi-Vita; 2003) Based on the VIF calculations I could decline variables. If the VIF value was above 3 than I only put one of the variables in the model at a time, and than examine which model resulted better.

To test autocorrelation, I use the Durbin-Watson test, as I have time series in my models.

To have better results I used heteroskedasticity corrected models as well and those models showed better results as the residuals distribution approximated to normal.

3. Results

3.1. Findings of the hypotesis' analysis

- **H1: Biomass, increasingly used by the households as an energy source for heating, is the major cause of the deterioration of air pollution indicators.**

It was difficult to describe the air pollution with a single indicator, however for the regression model a single indicator was the key. I started my research with concentration of PM 10 and PM 2,5 in the air as indicators. I have found a deterministic correlation between the two indicator which was not surprising as only the particle size is the difference between the two indicator. As the PM 10 fraction comes more from the road wear, soil erosion and industrial activity, while PM 2,5 fraction from the combustion products, aerosol and households (OKI; n.a.), therefore I used PM 2,5 for my model in my first hypothesis (H1).

During my research I found, that the national PM 2,5 concentration was only 20-30% due to national emission and the other 70-80% was due to effects coming from abroad (Ferenczi; 2016). Therefore in my model I use the PM 2,5 emission of the households as the dependent variable and not PM 2,5 concentration. The independent variables in the first hypothesis are heating degree days,

and the households energy consumption by the type of energy source (such as biomass, natural gas and coal).

The correlation matrix suggested a realtivelly strong positive connection between PM 2,5 emission and household biomass consumption. There was a strong negative connection between household biomass and natural gas consumption, as the biomass consumption increase the natural gas consumption decrease, which suggests that households replaced natural gas as a heating energy source to biomass.

I run the regression for the 17 years, which I have had the full data (from 2000-2016). I run 3 models, to M1 I put all the independent variables, to M2 I excluded household coal consumption - because the VIF calculation was a bit high (3,882967) between coal and natural gas – and M3 I excluded natural gas from the independent variables.

Excuding multicollinearity and heteroskedasticity M2 model had the best result. In M2 all the independent variable were significant (heating degree days, household biomass and household natural gas consumption as well), and the model had a strong explenatory value (adjusted R^2=0,9776).

According to the Durbin-Watson test I could nor rule out, nor confirm the existence of autocorrelation in M2. Therefore the results of the regression should be treated with caution.

Nevertheless based on the correlation matrix and the regression model, it is highly probable that the increasing consumption of household biomass is the cause of the increasing household PM 2,5 emission.

- **H2: The retail sales price of natural gas is not the main determinant of the household's energy expenditures, therefore it is not the main determinant of the energy poverty either.**

To research my second hypothesis I started with the identification of energy poor. I had the data of the income groups devided to deciles, and their energy use habits and their energy expenditures. Therefore with the help of the EU Energy Poverty Observatory (n.a.) indicators I identified which income deciles could be the energy poor. With this method I could examine only those deciles habits on energy use who could be considered energy poor as well. And this way It could be shown whether the energy poor changes their habits in energy consumption or it was another socail group. The indicators for this research were: arrears on utility bills; hidden energy poverty; high share of

energy expenditure in income; and inability to keep home adequately warm. A find that the energy poor is most probably in the 1to 4 deciles.

Examining the heating systems of the first 4 deciles, I have come to the conclusion that this group has a high degree of specific room heating with wood. During the last 6-7 years the first decile has not increased the biomass consumrption for heating, however the 2-4 deciles habits shows a significant increase in the proportion of individual heating systems with wood. Besides comparing the years 2010 and 2016 the 1-4 deciles the cost of natural gas decreased in proportion to total energy costs. At this point in my research I realized I might have to decline my second hypothesis as the energy poor has seemingly changed its heating habits. The price of the natural gas may have a significant impact on the energy cost and energy poor. All the more so that as a result of the data analysis the number of the energy poor has decreased with the lower natural price level.

As a result of the energy poor research, I found it valuable to conduct an analysis for household energy expenditure and the retail prices of the energy sources.

In the regression model I define the factors that could determine the hopuseholds energy expenditures. The regression was based on panel data from the 10 income group deciles for the time period of 2011-2016. The dependent variable of the model was the households energy expenditure. The independent variables were the income deciles, the average income per capity, the heating degree days, the average area of the real estate, and the retail price of the energy sources such as natural gas, biomass (I had data for wood only), and electricity.

First I calculated a correlation matrix, which has shown a high correlation between the dependent and the independent variables. The households energy expenditure and the average income per capity have high correlation. Within the independent variables the retail price of the energy sources have high correlations, which is not surprising as during this period was a regulatory price reduction for natural gas and electricity for household consumption. However the retail price of the wood is not regulated and during this period the demand has increased. According to the correlation matrix the heating degree days and the households energy expenditure has no correlation, which was a surprising result for me.

I have tested 4 models in this regression. As a result for testing multicollinearity I had high VIF value (above 4) between the price of the natural gas and electricity and wood and electricity. Also I excluded the income deciles from the independent variables. Clearing the models from

heteroskedasticity I found that M6 model has had the best results, in that model the independent variables were: the average income per capity, the heating degree days, the average area of the real estate, and the retail price of natural gas and wood. According to the M6 model the significant variables were: the average income per capity, the average area of the real estate, and the retail price of natural gas, with a high explenatory value (adjusted R^2= 0,8701)

However according to results of the Durbin-Watson test I can not decline nor accept the existence of autocorrelation.

The results of the regressions should be treated with caution, even though I have had enough data for a regression the time series of the panel was short. However, it is still a prominent result of the regression analysis of household energy expenditure that the most influential independent variable was the average income per capita. The more income residentials have the more they spent on energy. It is important to highlight that if a model had the retail price for natural gas as an indenpendent variable it was always significant. Therefore I could not prove H2 hypothesis.

For reasons mentioned above, I decided to further research H2 hypothesis, thus the impact of the price of natural gas is an important factor, and it could have more significant impact on the households heating expenditures.

In this regression model I define the factors that could determine the households heating expenditures. The regression was also based on panel data from the 10 income group deciles for the time period of 2011-2016. The dependent variable for this regression was the households heating expenditures, while the independent variables were: the income deciles, the average income per household, the heating degree days, the average area of the real estate, and the retail price of the natural gas, and wood.

I have run 2 models, and after I corrected the model by excluding autocorrelation and heteroskedasticity, the best resulted model (M9) where the independent variables were: the average income per household, the heating degree days, the average area of the real estate, and the retail price of the natural gas, and wood. Significant variables according to M9 were the average income per household and the retail price of natural gas. The explenatory value of the model is high (adjusted R^2=0,8143).

All of the regression models I have run to prove H2 hypothesis showed that for househols energy or heating expenditure tho most influantial variable is the income of the households or

individual. However the price of the natural gas also a significant variable in every regression model. Even if I only research the energy poor or 1-4 deciles the retail price of the natural gas has shown that it is a significant determinant factor for the households energy expenditure.

- **H3: The household's consumption of natural gas is mainly determined by the type of real estate.**

Following the examination of energy costs and natural gas prices, I have analyzed the impact of natural gas on the amount of natural gas consumed, and what determines the amount of consumption. I considered it important because I assumed that the replacement of natural gas based heating to biomass was to reduce energy costs.

I started the research of my third hypothesis H3 with a calculation of the correlation between the natural gas consumption of the households and the retail price of natural gas. The correlation index was 'r' = -0,51167 for the last 20 years, which shows a negative correlation and suggests that it is worth to research further with regression.

The dependent variable of my model (M10) was the natural gas consumption of the households, with two independent variable, the heating degree days and the retail price of natural gas. I put only those two independent variable as I was curious of the explanatory value (R^2) of the model. The heteroskedasticity corrected M10 model showed moderate explanatory value (adjusted R^2=0,4297) and only the retail price was significant variable. Therefore I have come to the conclusion that the natural gas consumption of the households is not only dependent on these two variables, and it is worth considering the buildings as well.

For the research of the buildings the appropriate guidance was provided by the assessment of residential buildings in the National Building Energy Performance Strategy (NFM; 2015). It separates 15 residential buildings, and 7 types of heating systems.

I created a matrix for the building and the heating system, and even if I assume that family houses could replace their energy source used for heating within a year, 65% of the households heating with natural gas could have replaced natural gas to biomass. In 2011 47% of all residential households used natural gas as energy source for heating, while this portion in 2017 has decreased to 39,1% (KSH 2017d). This means that (with a quantity correction) approximately 8% of the family houses replaced their heating system to biomass during 6 years.

It is important to emphasize that in Hungary 74% of the all residential households have access to natural gas though pipelines in their home (KSH 2017d). Even those households that replaced natural gas to biomass has the natural gas pipelines are still in their house. It is important because these households can return to natural gas heating at any time, but this is likely to be dependent on the prices of natural gas and wood (for biomass).

3.2. Summary and recommendations

Based on my dissertation it is safe to assume that biomass based household heating is an undesirable phenomenon among current conditions. Thus the emission values of combustion units less than 140 kWth capacity are not controlled, which combustion unit are mainly household units. (AJB; 2016). In such circumstances it increases the concentration of particular matter in the air and that is principally harmful to human health.

However increasing the share of renewable energy of the gross final energy consumption is one of the main intention in the European Union, partly because of the dependence of the natural gas import, we have to be careful about which type of renewable energy we use, and how we utilize them. I believe that it is an important message for the establishment of further strategies in the European Union, such as the Integrated National Energy and Climate Plans, as it will be an obligation for each Member State to set up targets for the renewable energy share. I would suggest that in the light of the above, that besides the renewable energy targets, preferred types of renewable energy should be aimed and supported.

The particular matter emission from the biomass based heating systems could be decreased by regulation as well. The regulation could include an obligation to install emission filters for biomass or combined combustion units, or to install emission sensors for households and penalize above a certain emission.

It has been presented in my dissertation that the price of the natural gas and income of the household have an impact on the energy cost, therefore those factors eventually have an impact to the amount of natural gas consumption and also on the preferred energy source. Consequently if the retail price of the natural gas remains at a lower level, than the consumption could increase according to the assessment of residential buildings.

I would like to emphasize that it was not the intent of my dissertation to promote the increasing consumption of natural gas, the aim was to show that the household consumption of biomass results an increasing emission of particular matter and it should be discouraged to use biomass in household combustion units, and that natural gas is a better alternative in a national level, even though the import dependence.

The best solution should be to reduce the consumption of energy in household by improving the energy efficiency of buildings, and promote modern and energy-efficient heating systems.

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