Demand adjustment in Hungarian natural gas consumption: effect of punitive block tariffs?

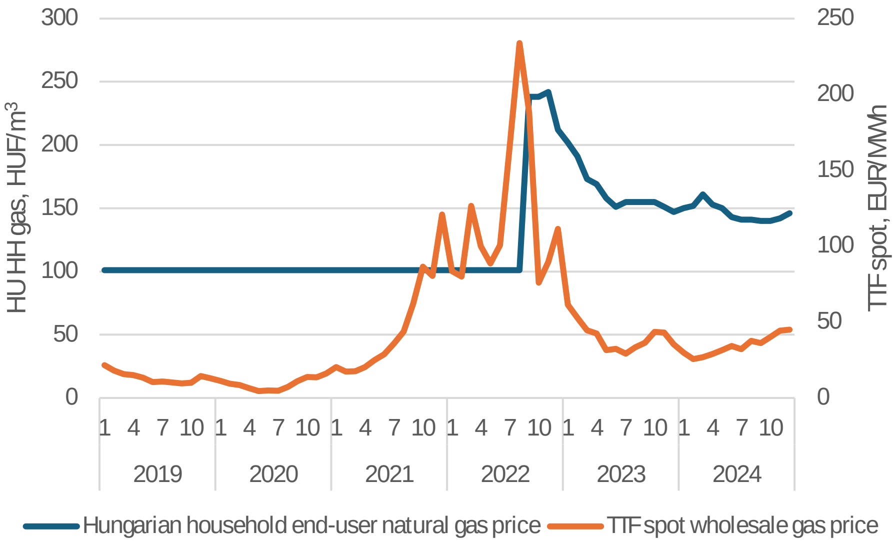
Abstract

We provide a detailed analysis of the block pricing in household natural gas end-user prices in Hungary. Following a decade of fixed end-user prices, the new block tariffs introduced a second-tier rate in 2022 that was seven times higher than the first tier. We quantify the effects of the price regulation by separating the temperature and workday effects. We have estimated the weather and price effects with 268 unique regressions for each distribution exit point of the natural gas transmission system. Our first model quantifies the expected gas demand for each exit point based on the period prior to the introduction of the block tariff. Our results indicate that gas consumption decreased by 16% due to the change in regulation. In another estimation, we introduce end-user price as an independent variable and quantify the own-price elasticity of natural gas demand at -0.3. We argue that the block tariff has considerably decreased the energy consumption of households. Our results can be further utilised in designing policies such as carbon pricing for the household sector to affect fossil fuel use.

1 Introduction

Natural gas end-user prices have been regulated and fixed for the Hungarian households since 2014 as the topic of protecting the consumers via the utility price regime was among the highest priorities of the ruling Government. Household end-user natural gas price has not changed since then up to mid-2022, the peak of the European energy crisis. The low regulated price created losses for the state-owned company MVM supplying the households with gas, which was compensated from the government budget. However, as wholesale natural prices skyrocketed and losses were impossible to finance from the budget, the government introduced a two-tier block tariff for natural gas. From September 2022, households consuming more than the average (1729 m^3/year) had to pay almost seven and a half times the previous price for natural gas consumed above threshold (Figure 1). Price of electricity was similarly regulated, but higher block price increased only two-fold. A widespread alternative for heating in the Hungarian rural areas is fuelwood, which has an unregulated market price. The introduction of the block tariff serves as a natural experiment, as households were presented with a shock-like price increase and adjusted their consumption accordingly.

Figure 1. Hungarian household natural gas prices (HUF/m3) and wholesale natural gas prices (EUR/MWh)



Source: KSH and EEX

As of 2023, 91.2% of Hungarian municipalities were connected to the natural gas network, and 60% of households use gas as a primary fuel for heating.[1] Majority of Hungarian families live in single-family homes, heated by natural gas and 15% do have access to alternative heating solutions, such as solid fuel boilers as a backup.[2] This allows fast and cost-effective adjustment of natural gas consumption.

In this article we provide a detailed analysis of the natural gas consumption in Hungary, quantifying the effects of change in price regulation on consumption. Besides making the obvious temperature and working day related effects on gas consumption, we quantify the own price elasticity of natural gas.

The purpose of our first analysis is to estimate the extent to which the change in regulation reduced national gas consumption in the years 2023-2024. We apply a linear regression estimate in which we explain the consumption of the period before the change in regulation (2019-2022). For each exit point of the transmission system a single linear equation of HDD and gas consumption is fitted between September 2022 and December 2024 to determine what the consumption would have been at each point without the change in regulation. By comparing these results with actual consumption data, we can give an estimation of how much the price increase reduced gas consumption. This can also be interpreted as a weather-adjusted natural gas demand.

In our second analysis, our goal is to determine the own price elasticity of residential gas consumption. To obtain results comparable to the data found in the literature, this time the regression estimation is performed for the entire examined period (October 2018 – December 2024). Compared to the previous estimate, the logarithmic data series of the residential gas price[3] is added as an explanatory variable, and the dependent variable is the natural logarithm of gas consumption.

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[1] Central Statistical Office (KSH): Piped Gas supply https://www.ksh.hu/stadat_files/kor/en/kor0043.html

[2] Census Database 2022 https://nepszamlalas2022.ksh.hu/en/database/

[3] Central Statistical Office (KSH): Average consumer price of selected products and services (raw data), monthly https://www.ksh.hu/stadat_files/ara/en/ara0044.html

This model specification allows the interpretation of the price coefficient as short-term own price elasticity.

The article is organised as the following: Part 2 provides a concise summary of the literature on price elasticity of demand. Part 3 introduces the Hungarian end-user price regulation and the characteristics of Hungarian households. Part 4 gives a detailed description of the data used for analysis and the methods applied. Part 5 lists our results, primarily giving a weather and working day corrected natural gas consumption for the country, then secondly an assessment of own price elasticity of natural gas consumption. Our results are evaluated and compared to the elasticities found in literature. Part 6 concludes and drafts policy recommendations and the applicability of our results.

2 Literature review

A number of meta-analyses have already provided a summary of the rich and diverse literature of elasticity on residential energy consumption (Labandeira, Labeaga, & Xiral, 2017; Miller & Alberini, 2016). Research of this topics differs greatly on the methodology applied (panel regression, ARIMA, decomposition indices, etc.), on the analysed fuels (primarily electricity, but also natural gas and solid fuels), on the short- or long-term elasticity, as well as the income, own or cross-price elasticity. Short-run own price elasticity of natural gas has been estimated by the majority of papers to be lower than unitary, i.e. 1% change in natural gas price incurs a demand adjustment below 1%, while on the long run it is somewhat higher but still below unitary (Alberini, Gans, & Velez-Lopez, 2011; Alberini, Olha, & Ščasný, 2020; Auffhammer & Rubin, 2018; Rozwałka & Tordengren, 2016; Filippini & Kumar, 2021). Many articles emphasise that price elasticity of households may differ by socio-economic background: lower and higher income deciles tend to be more inelastic than households in medium income deciles. (Bakaloglou & Charlier, 2019; Romero-Jordán, Peñasco, & Río, 2014; Romero-Jordán, Río, & Peñasco, 2016; Silva, Soares, & Pinho, 2017; Tilov, Farsi, & Volland, 2020; Trotta, Hansen, & Sommer, 2022). The reason behind the alternate elasticities might be the fact that lower income households can not save fuels in any other way, and have no financial means for fuel switching. On the other hand, higher income households spend relatively insignificant share of their income on energy, and are not willing to sacrifice their quality of living.

Own price elasticity estimated by the academic papers scattered on a wide range: income elasticity between –0,009 and –0,8. It is obvious that country or region-specific elasticities might be quite different. Therefore, it is required to set up a model which is characteristic for weather, socio-economic background, economic and other variables. The model specification may be based on general assumptions, but the country-level estimates are unique for the country and the time period.

Empirical research by Bartek-Lesi et al (2021) based on a household survey conducted in five EU countries in 2018 suggests that about 65% of households in Hungary heat their rooms to above 22°C in winter, and 24% increase their room temperatures to above 24°C, regardless of whether they have the ability to control the temperature in their home. Although temperature measurements were not part of the study, the self-reported winter indoor temperatures were significantly lower in the other four countries. The researchers concluded that over-consumption of heating energy is a common phenomenon in Hungary. They also found in the same survey that only 14% of Hungarian households would like to receive feedback on their heating energy efficiency compared to their peers in similar households. This is a very low rate compared to about 40% of households in other countries. In addition, only 22% of Hungarian households wanted to receive targeted advice on how to save energy, compared to 44-78% in the other four countries.

Besides price, income and socio-economic factors, natural gas consumption is primarily driven by weather and the characteristics of the heated building. Some articles claim that weather and technical variables are more important than price (Brounen, Kok, & Quigley, 2012; Estiri, 2014; Frondel, Kussel, & Sommer, 2019), while others still found the socio-economic factors more important. (Fuerst, Kavarnou, Singh, & Adan, 2020).

A central topic of election campaigns of Hungarian government party since 2012 has been the protection of Hungarian households from the high utility bills (electricity, gas, district heating and water utilities). (Bölcskei, 2016) To this end, prices have been reduced by 30% and maintained at that level. Any change in pricing has high political cost. *Hancevic et al.* (2016) discuss the phenomenon of "energy populism", a political strategy to ensure votes by keeping energy prices below their long-run marginal costs. Financial losses of energy companies are usually financed by the budget or saving costs by postponing required network maintenance. On the long term this creates and unsustainable and expensive energy sector. Abolishing such a scheme hurts the consumers and is highly unpopular, but keeping up is extremely costly and favours more affluent households, which consume more energy.

Pacudan and Hamdan (2019) analysed the impact of the residential electricity tariff change in Brunei. Brunei, an energy exporter, has not increased electricity prices between 1969 and 2012 and a employed a decreasing block tariff - i.e. consumers in the higher consumption band paid less per unit of electricity. This system was fundamentally changed to an increasing block tariff in 2012. The authors quantified the impact of the tariff change per income decile under given price elasticity assumptions. Their results show that the change in regulation affects richer households more favourably than poorer ones, as their consumption is higher. The results show that an increasing block tariff is more socially just than a decreasing block tariff, because for a unit increase in electricity prices, the welfare of poorer households would decrease more with a decreasing block tariff than with an increasing block tariff.

Turdaliev and Janda (2022) studied the impact of Russia's increasing electricity block tariffs. It was shown that the block tariffs increase the energy expenditure of the population, which tends to switch to more polluting fuels instead of heating with electricity. Their results show that the introduction of the block tariff has increased the use of more polluting fuels - such as municipal waste, coal and oil.

Weiner and Szép (2022) analyse the effect of Hungarian price regulation on energy consumption. Applying an index decomposition method, they separate price, income, extensive and intensive structural effects by income deciles. They argue that the end-user price regulation caused additional 13 PJ energy consumption between 2013 and 2018 in Hungary, which is around 2% of total household final consumption of the period. Solid biomass (fuelwood) burning decreased and was replaced with the relatively cheaper and more convenient natural gas use. The regulation favoured the higher income households, which increased their natural gas use.

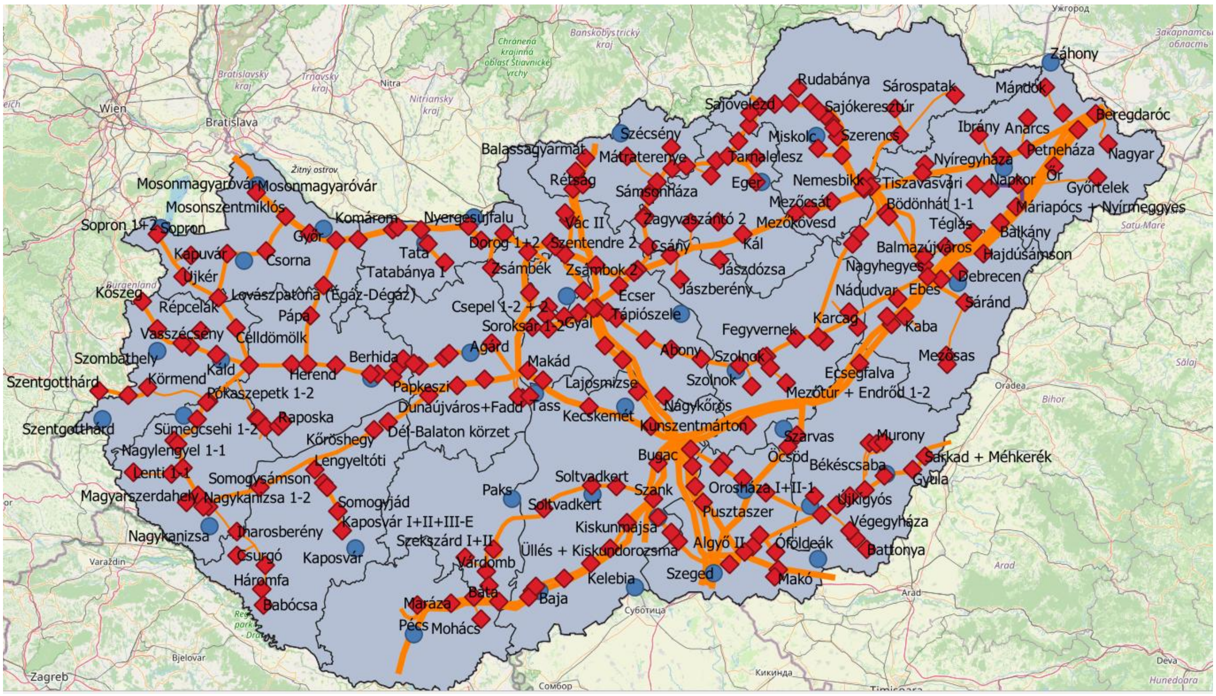
Based on the literature it can be claimed that although natural gas consumption is expected to be inelastic, due to the possibility of fuel switching we can expect demand adjustment.

3 Data and methodology

Our study relies on publicly available data relating to daily mean temperature, daily natural gas consumption and end-user regulated gas price. Daily data on natural gas consumption is reported by the Hungarian gas TSO FGSZ on each exit point from the transmission to the distribution system. Altogether 268 exit points of the transmission system were assessed on the 01.10.2018-31.12.2024 period. However, this flow does also contain non-household related gas consumption, such as industrial or services sector natural gas use. Public data on residential gas consumption is only available on an annual or monthly basis.

The daily gas consumption data correlates strongly with daily temperature data - or the heating degree day (HDD). Annex 3 of the Decree 11/2016 of MEKH clearly assigns the individual FGSZ exit points to the weather stations of the National Meteorological Service (OMSZ).[4] The 268 distribution exit points are linked to 37 meteorological measurement points (Figure 2).

Figure 2. Natural gas transmission pipelines (orange), distribution exit points (red) and associated meteorological measurement points (blue)



Source: own compilation

Data cleaning and imputation was performed for the daily average mean temperature by (i) either substituting the missing values with average temperature of the preceding and succeeding days, if only a few days were missing or (ii) substituting the missing values with measurement data of nearby stations.

As an illustration of the imputation applied, we present the temperature trends of the Nyíregyháza and Záhony measurement points. In the case of Nyíregyháza, no measurement data were available between 01.10.2018 and 03.11.2019, so we complemented the dataset with information of the nearest measurement point Záhony, which is about 50 km away. For the period 03.11.2019-31.03.2023, the temperature values of the two points coincide well with a small deviation: the absolute difference between the two measurement points is below 10% for 63% of the observed days and below 25% for 83% of the observed days. The correlation coefficient between the two time series is 0.99. (Figure 3)

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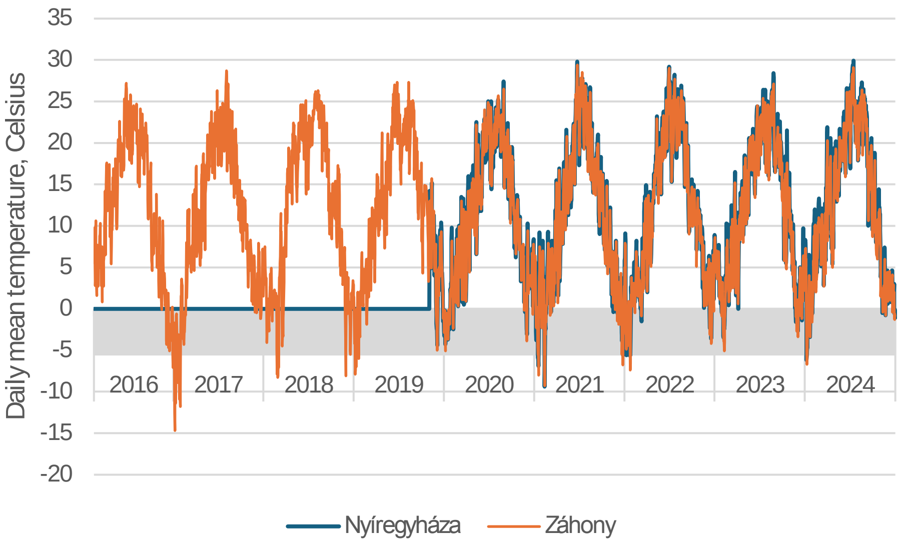
[4] 11/2016 (XI. 14.) MEKH Decree on the rules for the application of natural gas system usage fees, special fees and connection fees

Figure 3. Daily mean temperature data from Nyíregyháza and Záhony measurement points, Celsius.



Source: own compilation, data source ODP MET

In total, 5% of the measurement data had to be substituted with data from a nearby measurement point. In most cases, temperature data was missing from the beginning of the period analysed. (Table 1)

Table 1. Imputation for temperature data

Measurement point name	Lat, Lon	Missing period	Measurement point imputed	Lat, Lon	Missing input data ratio
Pécs	45.995, 18.235	2018.10.01.-2021.07.13.	Kaposvár	46.3628, 17.8739	62%
Szarvas	46.8697, 20.5275	2018.10.01.-2019.11.03.	Szentes	46.6131, 20.2861	24%
Szeged	46.2561, 20.0906	2018.10.01.-2019.11.03.	Kelebia	46.1956, 19.6064	24%
Nyíregyháza	47.9622, 21.8869	2018.10.01.-2019.11.03.	Záhony	48.3986, 22.1775	24%
Békéscsaba	46.6797, 21.1608	2018.10.01.-2019.11.03.	Orosháza	46.5442, 20.6875	24%
Soltvadkert	46.5908, 19.3414	2021.12.01.-2023.03.31.	Kiskunmajsa	46.4942, 19.745	30%

The daily natural gas consumption data for each distribution exit point has been collected for the period 01.10.2018-31.12.2024. For data verification purposes, the total consumption at the points was aggregated on an annual basis and compared with the annual statistics of FGSZ-MEKH[5] . In addition to the individual exit points, the consumption of industrial, power and heat plant users

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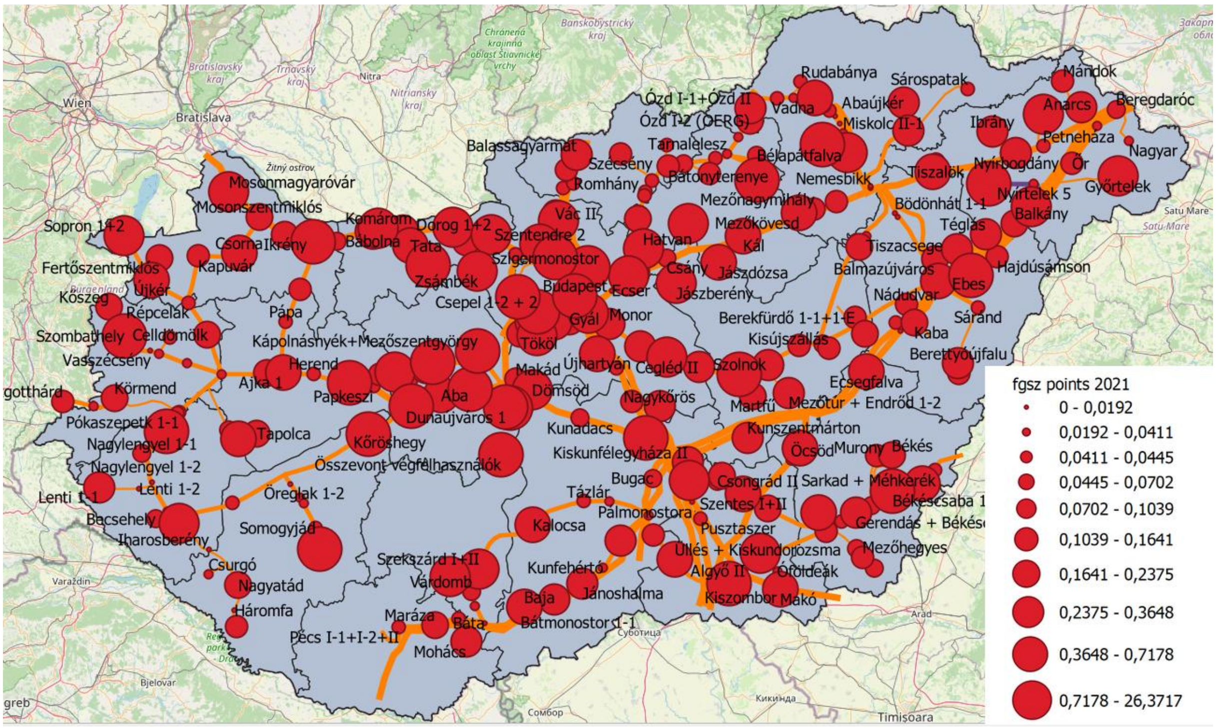
[5] Source: Data of the Hungarian natural gas system 2021, Table 2.6 Natural gas balance of the transmission system

directly consuming gas from the TSO network ("Aggregated Final Consumers") was also taken into account. The TSO does not provide individual data on the daily consumption of natural gas by final consumers due to commercial confidentiality, but publishes the consumption of all end-users at aggregated level. Weather profile of Budapest was considered for the aggregated final consumers.

Table 4 shows the annual aggregate consumption of natural gas by exit point. It can be seen that the consumption of large cities is supplied through several points (e.g. network points around Budapest or Miskolc).

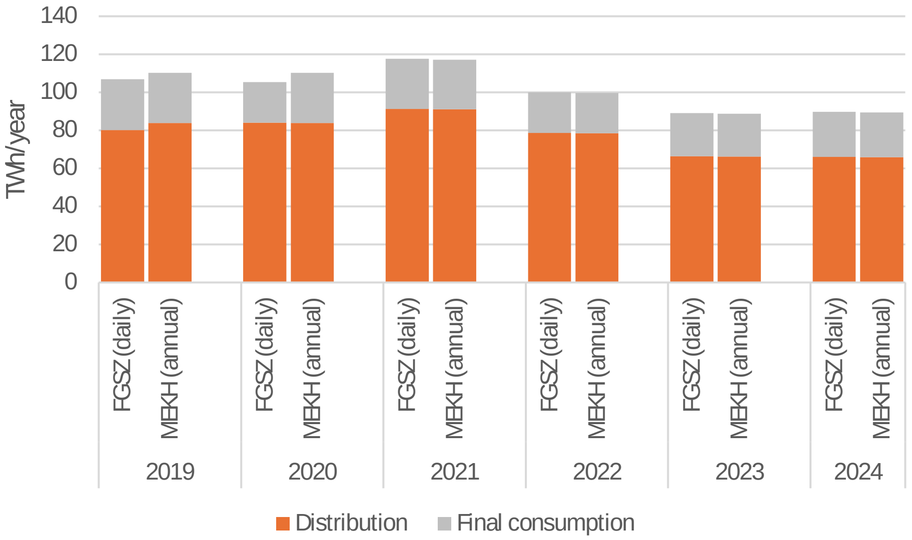
Figure 4. Annual gas consumption of FGSZ distribution exit points in 2021, TWh/year



Source: own compilation based on FGSZ

The difference between the consumption data collected as points and the annual statistics is shown in Figure 5. The data collected per exit point is shown in the column "FGSZ (daily)", while the aggregated annual data in "MEKH (annual)". It can be clearly seen that, apart from small differences, the consumption of natural gas measured per point reflects the figures of the annual statistics. This means that our data reflects the annual gas consumption correctly and can be used to estimate the total country-level consumption. (Figure 5)

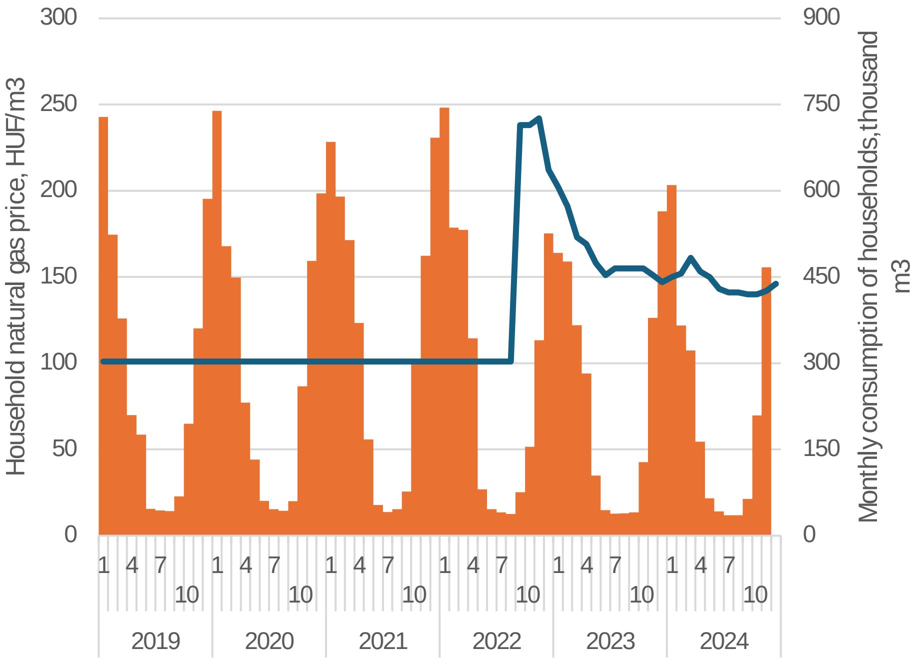
Figure 5. Comparison of natural gas consumption aggregated from metering points with annual statistics



Source: own compilation based on FGSZ and MEKH

To estimate the price elasticity, it is also necessary to match the residential gas price to the daily data used. Households pay a monthly average tariff and are not subject to day-to-day price developments. End-user prices are reported by the Central Statistical Office (KSH) of Hungary. The price of natural gas increased by almost two and a half times in the third quarter of 2022 and by almost twice in the first quarter of 2023. This means that around 80% of residential (ESZ) consumption remained below the threshold and 20% paid higher prices in the fourth quarter of 2022. In the first quarter of 2023, 85% of consumption remained below the threshold and 15% paid more. From the second half of 2023, the price estimated by the Statistical Office stabilized and was around HUF 150/m^3 in 2024 as well, which represents an approximate 50 percent increase compared to the previous uniform price of HUF 101/m^3. (Figure 6)

Figure 6. Evolution of residential fixed natural gas prices (HUF/m3) and evolution of residential natural gas consumption (million m^3/month)



Source: KSH 1.2.1.6 Average consumer price of selected products and services (raw data), monthly [6] ; MEKH Data of natural gas companies

4 Results

4.1 Estimating the decrease of gas consumption due to the regulatory change (model 1)

Since natural gas consumption is highly temperature dependent, the heating demand was characterized by the widely used Heating degree day (HDD). In addition, working day effects were taken into account - as natural gas consumption in businesses is more likely to be linked to working days.

Our regression is as follows:

$$GasConsumption_n = \beta_0 + \beta_1 HDD_n + \beta_2 Mon + \beta_3 Tue + \beta_4 Wed + \beta_5 Thu + \beta_6 Fri + \varepsilon$$

Where

$GasConsumption_n$ is the natural logarithm of daily physical gas flow from the transmission system to the distribution system for the network point ‘n’ in kWh [7]

HDD heating degree days calculated for network point ‘n’ based on daily mean temperature. The daily mean temperature data were used to derive the day degree number using the following method:

$$f(x) = \begin{cases} 0, & if\ t_n > 16 \\ 16 - t_n, & if\ t_n \leq 16 \end{cases}$$

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[6] https://www.ksh.hu/sajtoszoba_kozlemenyek_tajekoztatok_2022_08_08

[7] Source: FGSZ.hu, Physical gas flow, https://ipnew.rbp.eu/Fgsz.Tso.Data.Web/#main

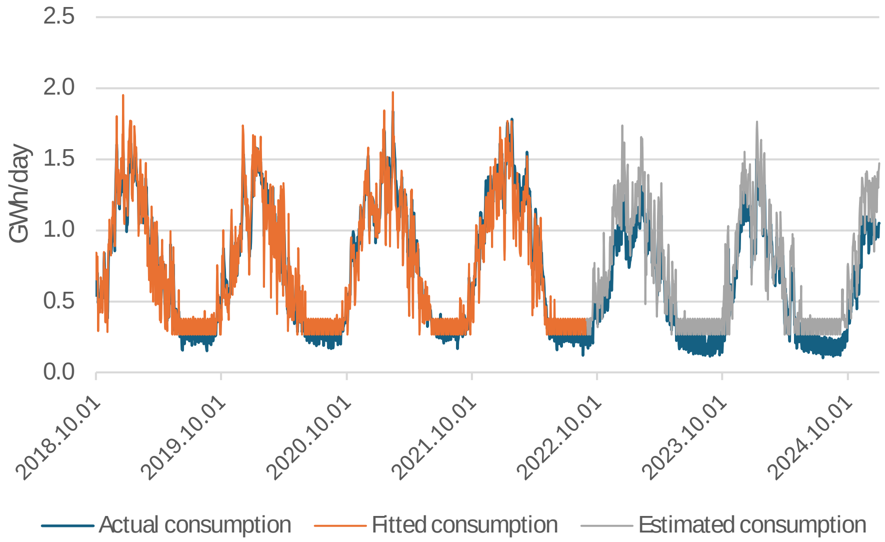
Mon, Tue, Wed, Thu, Fri dummy variables.

The regression was estimated for each measurement point separately for the period 01.10.2018 - 31.08.2022. Using the resulting regression coefficients, unique for each exit point, we estimated the natural gas consumption for the period before the regulation change (01.10.2018-31.08.2022) and the period after (01.08.2022-31.12.2024). If the fit of our estimates is good in the period before the regulation change, then the natural gas consumption estimated based on temperature and working days should not differ from the estimated values after the regulation change, if consumers show unchanged consumer behaviour. This means that the predicted consumption based on the behaviour of the previous period is a trend to which the actual consumption can be compared. The difference between the two mainly shows how households reacted to the price increase. It is worth noting that the difference between predicted and actual consumption may be influenced by other factors, such as mass disconnections or new connections of consumers. The emergence of new industrial facilities can have a similar effect in the case of individual exit points. Such cases may occur in some exit points, however, during the observed period, the number of national household gas users did not change significantly, nor did any other event resulting in a significant change in consumption occur. Moreover, growing risk-awareness among consumers related to natural gas supply and the news coverage on the European energy crisis might also have prompted demand adjustment.

In a first step, the daily physical gas flow (hereafter: natural gas consumption) in the period before the regulation change is estimated with the model presented above. Since we fit a unique regression for each distribution exit point, we present the results for one exit point as an illustration and report the statistics of the estimates for all points.

Sárospatak exit point was chosen as an illustration. Figure 7 shows actual natural gas consumption and estimated consumption based on temperature and working day effects. It can be clearly seen that the estimate matches the observations very closely matched until 31.08.2022, but the two time series diverge strongly after the regulation change.

Figure 7. Sárospatak exit point actual physical gas flow (actual gas consumption), fitted and estimated consumption based on temperature and working day (Model 1)



Source: own estimation based on FGSZ

Table 2. Sárospatak exit point actual and estimated natural gas consumption (TWh/year) Model 1

	Actual consumption	Estimated consumption	Estimated/actual deviation
	TWh/year	TWh/year	%
2019	0.26	0.26	2.1%
2020	0.27	0.27	1.8%
2021	0.30	0.29	-2.6%
2022	0.26	0.27	5.9%
2023	0.22	0.26	19.3%
2024	0.21	0.26	22.3%

This difference is even more striking when looking at annual gas consumption: before the change in regulation, estimated consumption differs by 2% from actual consumption, while after the change the difference is around 20%. (Source: own estimation based on FGSZ

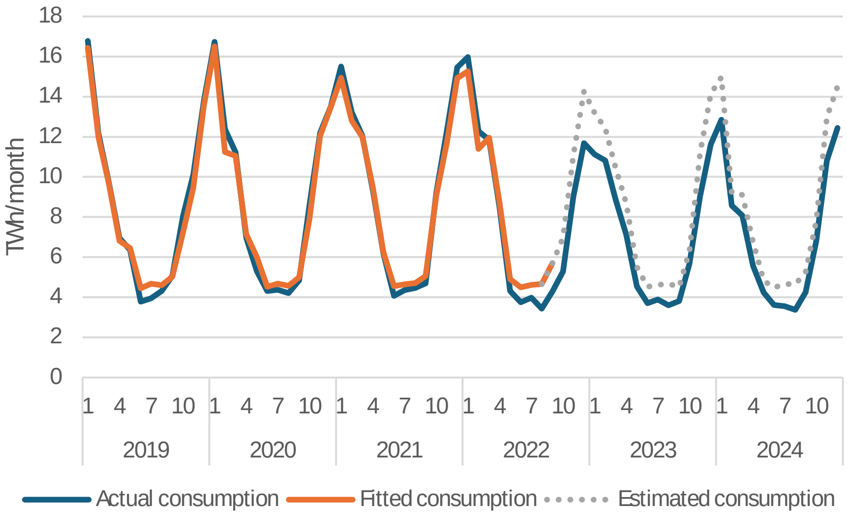
Table 2)

Aggregating each consumption point at the national level, we obtain what the natural gas consumption would have been for the exact same temperature. The value between the estimated and observed gas consumption is the effect of price regulation. This value for the calendar year 2023 would have been 100.2 TWh, while the observed actual consumption was 83.8 TWh; for 2024, estimated demand would have been 99.2 TWh while observed demand was 84.1 TWh. That is, for the given temperature and working day effects, the winter 2022/2023 consumption should have been 16% higher than the observed consumption.

Table 3. Actual and estimated Hungarian natural gas consumption, TWh/year (Model 1)

		2019	2020	2021	2022	2023	2024
Real	TWh	101.1	104.6	110.8	94.3	83.8	84.1
Estimated	TWh	100.3	104.1	110.1	104.0	100.2	99.2
Difference (Actual/ estimated)-1	%	1%	0%	1%	-9%	-16%	-15%

Figure 8. Actual and estimated consumption, TWh/month



Source: own estimation based on FGSZ

Network exit points can be easily assigned to Hungarian settlement types and counties. For the assignment by type of settlement, we have paired the KSH data with the name of the exit point, thus classifying the exit points into five categories (capital, large city, city, town, village). (Table 4)

Table 4. Actual and estimated natural gas consumption in Hungary for 2023, TWh (Model 1)

	2023			
	Actual	Estimated	Diff	Diff
	TWh	TWh	TWh	%
Capital	15.7	19.4	-3.8	-19%
Large city	16.4	20.0	-3.6	-18%
City	19.9	23.9	-4.0	-17%
Town	1.0	1.3	-0.2	-19%
Village	8.2	9.9	-1.7	-17%
Final consumers	22.7	25.7	-3.0	-12%
Total	83.8	100.2	-16.4	-16%

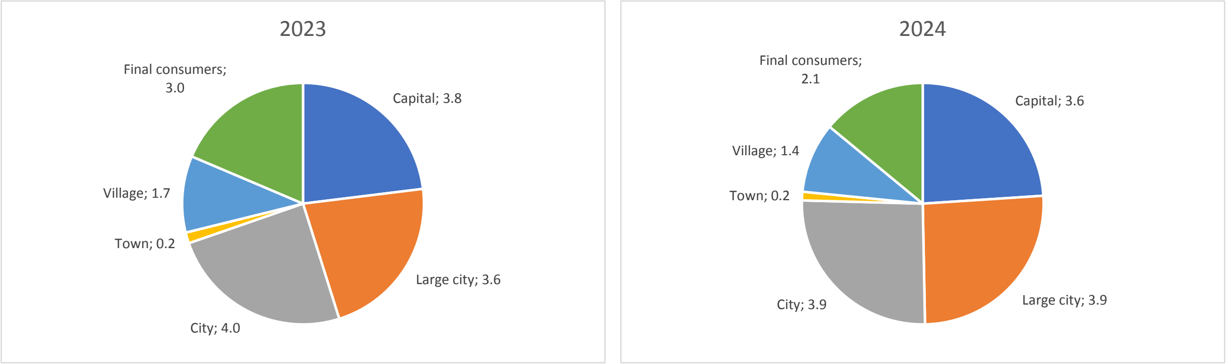
In 2023, there was no considerable difference between the type of settlements, all reduced their consumption by 17-19%. Final consumers connected to the transmission system reduced their consumption by 12%. Aggregated final consumers are power stations, heating plants or large industrial natural gas users such as chemical plants and factories. As this is a virtual national aggregate point reported by the TSO, the temperature data of the Budapest-Lőrinc measurement point was used to estimate their demand, which may bias the results. Altogether natural gas consumption was 16% or 16.4 TWh lower than expected based on past trends.

Table 5. Actual and estimated natural gas consumption in Hungary for 2024, TWh (Model 1)

	2024			
	Actual	Estimated	Diff	Diff
	TWh	TWh	TWh	%
Capital	15.5	19.1	-3.6	-19%
Large city	16.0	19.8	-3.9	-20%
City	19.7	23.6	-3.9	-16%
Town	1.1	1.3	-0.2	-14%
Village	8.3	9.8	-1.4	-15%
Final consumers	23.6	25.7	-2.1	-8%
Total	84.1	99.2	-15.1	-15%

In 2024, the effects are more diverse: the biggest relative demand adjustment is in the large cities and the capital (19-20%), while towns and villages curbed their demand by 14-15%. Final consumers are reduced their offtake by 8% compared to the estimate. Overall natural gas consumption was 15% or 15.1 TWh lower than the weather would have suggested.

Figure 1. Difference between actual and estimated Hungarian natural gas consumption for the period in 2023 and 2024, TWh



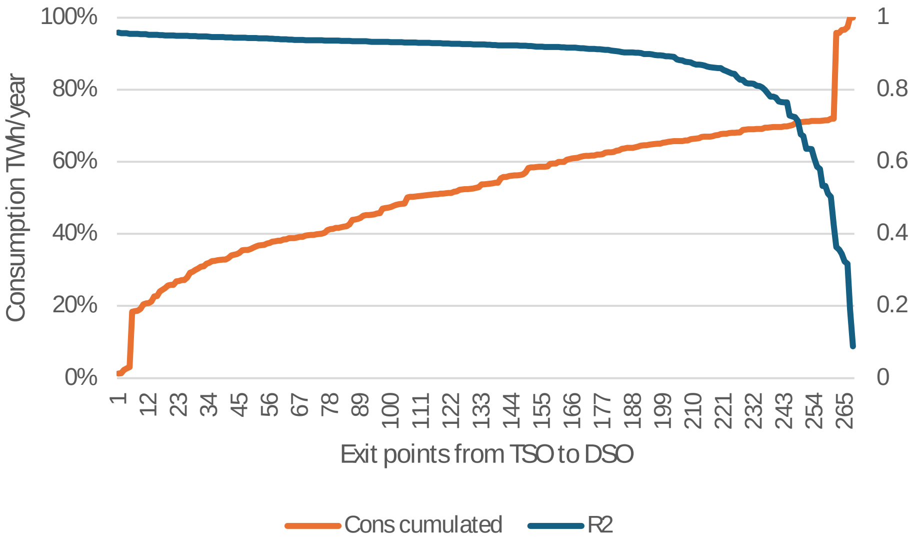
In most counties, the adjustment in demand was similar for 2023 (17-19%). Komárom-Esztergom county showing the smallest decrease (7%), while consumption fell by more than 20% in Hajdú-Bihar, Veszprém and Zala. Similar patterns were observed for 2024. (Table 5)

Table 6. Change of consumption in the capital city and counties for 2023 and 2024, TWh

	2023			2024		
County	Actual	Estimated	Diff	Actual	Estimated	Diff
Budapest	15.7	19.4	-19%	15.5	19.1	-19%
Bács-Kiskun	2.9	3.6	-19%	2.9	3.6	-20%
Baranya	1.2	1.5	-17%	1.2	1.5	-19%
Békés	1.8	2.2	-19%	1.7	2.2	-21%
Borsod-Abaúj-Zemplén	3.1	3.8	-18%	3.1	3.7	-15%
Csongrád-Csanád	2.4	2.9	-17%	2.4	2.9	-18%
Fejér	3.9	4.9	-19%	3.9	4.8	-19%
Győr-Moson-Sopron	2.8	3.3	-13%	2.8	3.2	-12%
Hajdú-Bihar	2.8	3.5	-22%	2.9	3.5	-18%
Heves	2.0	2.4	-19%	2.0	2.3	-15%
Jász-Nagykun-Szolnok	2.0	2.3	-16%	2.0	2.3	-17%
Komárom-Esztergom	2.7	2.9	-7%	2.6	2.9	-10%
Nógrád	1.0	1.2	-15%	0.9	1.1	-17%
Pest	6.4	7.8	-18%	6.3	7.6	-17%
Somogy	1.5	1.8	-17%	1.5	1.9	-20%
Szabolcs-Szatmár-Bereg	3.1	3.8	-17%	3.1	3.7	-18%
Tolna	0.8	0.9	-17%	0.8	0.9	-16%
Vas	1.4	1.8	-18%	1.4	1.7	-17%
Veszprém	1.9	2.4	-20%	1.9	2.4	-18%
Zala	1.7	2.1	-22%	1.6	2.1	-23%
Final consumers	22.7	25.7	-12%	23.6	25.7	-8%
Total	83.8	100.2	-16%	84.1	99.2	-15%

The individual equations had a strong fitting: 70% of cumulated consumption of the exit points had a correlation coefficient (R^2) over 0.7 (Figure 9). However, correlation coefficient for the final consumers, which accounted for 25-27% of gas consumption, was weaker than moderate (0.36). In the case of the virtual point containing the final consumers, a poor fit is an expected result, since their gas consumption is primarily determined not by the weather but, for example, in case of power plants by the wholesale price of electricity. A more precise estimation of the gas flow at the point is not part of our analysis.

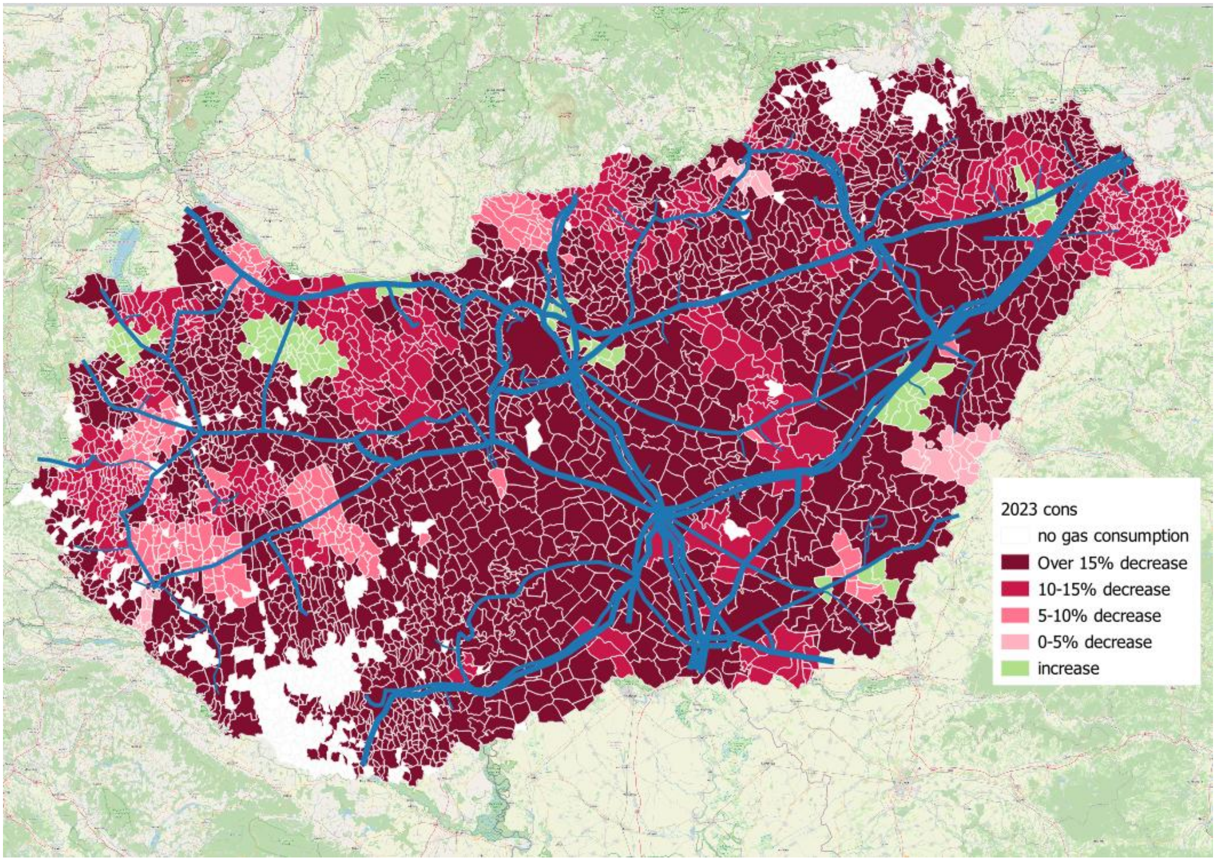
Figure 9. R^2 and cumulated consumption



Source: own estimation

Figure 10 shows the estimated decrease in consumption per municipality due to the price increase. When determining the change in consumption in each municipality, we obtained the estimated change at the exit point closest to the given town. From a territorial point of view, we did not find a characteristic pattern, the larger consumption decrease cannot be clearly linked to a single region. The increase in consumption is presumably observed near points where new factories and businesses were opened.

Figure 10. Consumption reduction due to the regulatory change in 2023, %



Source: own estimation

Based on our analysis, it can be said overall that the reduction in gas consumption was observed at the national level, which is also significant considering the factor of weather. Due to the price increase, the consumption in 2023-2024 was 15-16 percent lower than expected based on the previous years. The decrease was uniform for all settlement types and counties, and no clear pattern can be observed based on the size or location of the municipalities. The change in consumption can be considered long-lasting, as there is no significant difference between the years 2023 and 2024.

The behaviour observed in the case of final consumers differs from the exit points that also include residential consumers. Consumption by final consumers, which are industrial and power plant users, dropped by 12% in 2023 and 8% in 2024. Nevertheless, the correlation coefficient for this segment is relatively weak. In absolute terms, the largest decrease in consumption was in the capital and large cities.

It can be clearly stated that the households reacted swiftly and to a great extent to the price indication, which is particularly important under a regulation where the residential gas price has been unchanged for almost a decade. The result is also exciting from the point of view that, in addition to the block tariff, the price increase was only effective for a part of the consumers. However, based on the extent of the decrease, it can be concluded that not only those who were affected reacted to the price indication, but also consumers who were just afraid that their consumption would fall into the higher price range.

4.2 Estimating own price elasticity of gas consumption (model 2)

In addition to having determined the volume of consumption reduction linked to price changes, it is also worth examining what price elasticity values can be estimated for each exit point in this research framework and environment. Price elasticities per exit points indicate a good range in relation to the price elasticity of natural gas consumption by domestic households. Therefore, we changed our regression equation and the estimation period and included the retail price as an explanatory variable in our model.

Our second regression is specified as a log-log equation:

$$\begin{aligned} ln(GasConsumption_n) \\ = \beta_0 + \beta_1 HDD_n + \beta_2 Mon + \beta_3 Tue + \beta_4 Wed + \beta_5 Thu + \beta_6 Fri + \beta_7 ln(GasPrice_m) + \varepsilon \end{aligned}$$

Where

$ln(GasConsumption_n)$ is the natural logarithm of daily physical gas flow from the transmission system to the distribution system for the network point n in kWh[8]

HDD heating degree days calculated for network point n based on daily mean temperature. The daily mean temperature data were used to derive the day degree number using the following method:

$$f(x) = \begin{cases} 0, & if\ t_n > 16 \\ 16 - t_n, & if\ t_n \leq 16 \end{cases}$$

Mon, Tue, Wed, Thu, Fri dummy variables.

$ln(GasPrice_m)$ is the natural logarithm of the monthly average end-user natural gas price reported by the Central Statistical Office of Hungary in HUF/m^3.

The regression was estimated for each measurement point separately for the entire period 01.10.2018 - 31.12.2024. Due to the addition of the log price variable and fitting the regression to the entire period, deviation of estimated and observed consumption is considerably lower in the period after the regulatory change and higher before the change.

Aggregating the exit points to the national level we see that deviation after the change in regulation is around 1%.

Table 1: Actual and estimated Hungarian natural gas consumption, TWh/year (Model 2)

	2019	2020	2021	2022	2023	2024
Actual	101.1	104.6	110.8	94.3	83.8	84.1
Estimated	98.4	101.5	110.1	94.7	84.0	86.1
Diff	3%	3%	1%	0%	0%	-2%

The main added value of the log-log formulation is that we can interpret the coefficient as short-term own price elasticities. It is expected that the sign of the own-price elasticity is negative (i.e. the higher the price, the lower the consumption). Of the 268 exit points, 242 had negative sign while the remaining 26 had positive, out of which only 13 were significant on 5%. These 26 points account for 3.5% of national gas demand. The reason for the positive sign may be the increase in gas consumption throughout the period due to new industrial production.

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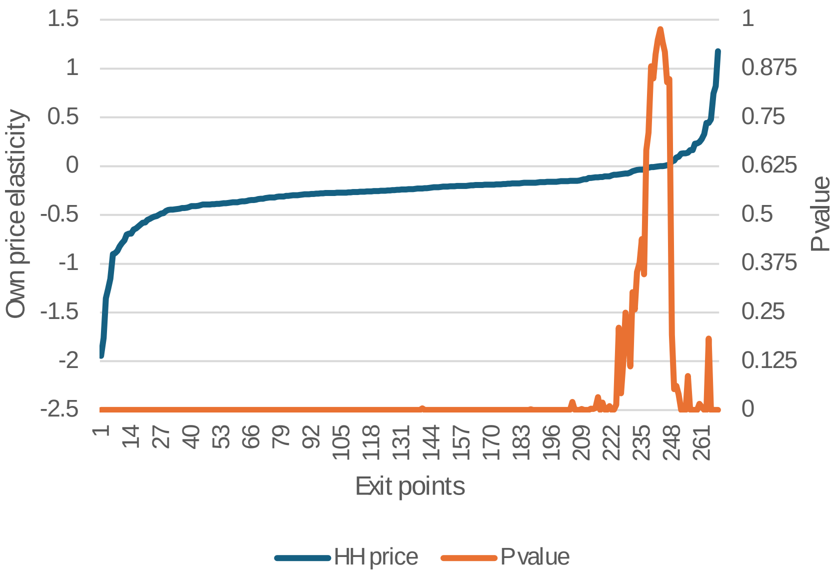
[8] Source: FGSZ.hu, Physical gas flow, https://ipnew.rbp.eu/Fgsz.Tso.Data.Web/#main

Consumption-weighted average of negative own-price elasticities was -0.3. This means that a 1% increase in price results in a 0.3% reduction in gas consumption. This is in line with the estimates of model 1, as the average price increase was 50% and this would incur a 15% reduction in demand. (Figure 11)

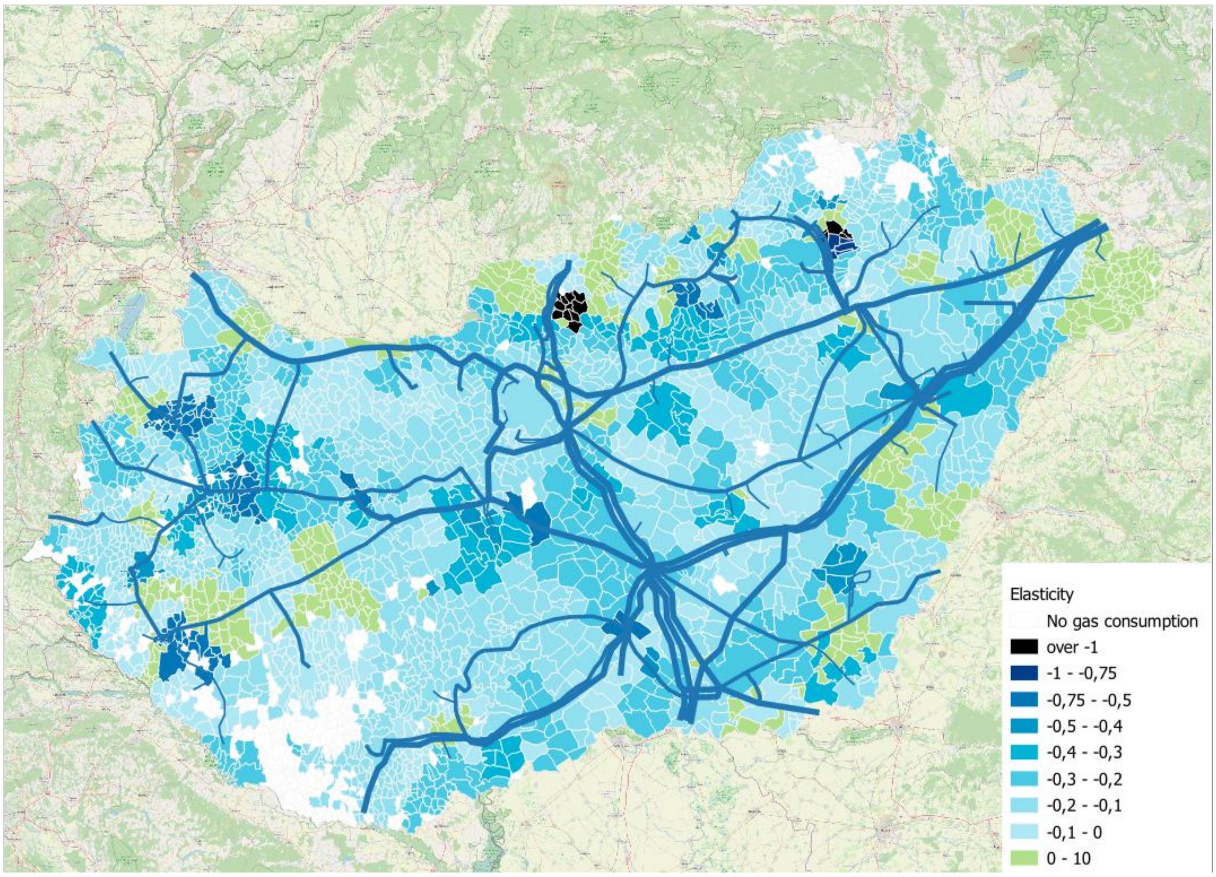
Figure 11. Own price elasticity of gas consumption vs. p value.



Source: own estimation

The figure below shows the estimated own-price elasticities by municipality in Hungary. As there were 268 exit points and over 3000 municipalities in Hungary, the municipalities were linked to the closest network point. Most exit points are estimated to have and elasticity between -0.2- -0.4 (Figure 12.) The map illustrates that the negative price elasticities are evenly distributed in Hungary, as well as the very few positive elasticities can not be linked to single region.

Figure 12. Estimated own price elasticities by municipality



Source: own estimation

4.3 Caveats

The regression model presented and the database used are not suitable for treating changes in consumption in the industrial, service and household sectors separately. The main reason for this is that the dependent variable (the daily quantity of natural gas measured at the exit points) cannot be further disaggregated by type of users. Therefore, the analysis does not show exactly what proportion of the decrease in consumption of each sector is reflected in the decrease in total consumption. An attempt can be made to estimate the impact of individual sectors using proxy variables (e.g. county GDP data, number of enterprises, etc.), but these are rather imprecise and the level of detail is lower both in time (annual values instead of daily data) and in space (county level data at most instead of exit points).

In further developing the study, another proxy variable that could be linked to industrial sector consumption could be the inclusion of the wholesale price of natural gas (e.g. Dutch gas exchange - TTF). It is important to note, however, that this could also distort the results, as the perceived gas prices of individual industrial players do not necessarily follow the daily evolution of the stock exchange.

5 Conclusion and recommendations

In our research, we created a dataset containing daily gas flows measured at the exit points of the Hungarian transmission network and linked the nearest daily temperature data of the given exit point between 01.01.2018 and 31.12.2024, using the daily data of the TSO FGSZ Zrt. and the daily temperature data of the National Meteorological Service.

Based on the dataset, we wanted to see how Hungarian natural gas consumption has changed since the entry into force of the universal service price regulation from August 2022 compared to previous patterns based on temperature. Our aim was to disaggregate weather related consumption change and regulation related consumption change. To this end, we estimated linear regressions using temperature data and dummy variables for workdays of the week for 268 exit points over the period 01.10.2018 – 01.09.2022. The explanatory power of the regressions was found to be significant, and we conclude that using these explanatory variables, consumption can be well predicted for the majority of exit points in the absence of significant changes in user behaviour.

The regression equations were then used to estimate the consumption that would have occurred in the absence of regulatory change, i.e. block pricing, for the period from September 2022 onwards. The resulting values were compared with actual consumption to estimate how much consumption decreased over the observed period presumably due to the price change. Based on this method, national consumption decreased by 16% (-16.4 TWh) due to the introduction of block pricing.

In our second estimation we have quantified in a log-log model the own price elasticity of natural gas and found that consumption-weighted average own price elasticity was -0.3. This means that an average 50% price increase would have caused a demand reduction of 15%, which is in line with the results of our first estimation.

The analysis has shown that the “punitive” nature of the block tariff caused consumer reaction even in consumer categories which would not be affected by the higher price. This can be a useful tool when designing carbon pricing schemes. Results did not reveal difference between consumers living in various settlement types. There were however differences between counties being Komárom-Esztergom on the lower end and Hajdú-Bihar on the higher. As there are socio-economic regional differences in Hungary that coincide with these results and future policy should take the social impact into account.

Besides the description of the regulatory change and the disaggregation of price and weather effects, we can easily argue that households did react to pricing policies and tariff changes. This can serve as a basis for future price regulation such as introduction of carbon pricing for fossil fuels in the household sector. The elasticities estimated can be used to design well-targeted tariff policies to drive the decarbonisation of the household sector.

6 Literature

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