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The Impact of Subsidies Reform on Electricity Consumption: A Data-Driven Province Selected in Iran (Dynamic Panel Data Approach)

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ABSTRACT

The initial study examines how subsidies impact electricity consumption in 15 selective Iranian provinces from 2012 to 2023. The model has been estimated using a dynamic panel data approach and generalized method of moment estimator. The variables, including household electricity consumption, and gas prices, demonstrate a positive influence according to the results. The provinces experience a significant decrease in electricity consumption due to variables like household electricity prices. Therefore, it is advised that energy policymakers implement suitable policies to regulate prices, particularly energy prices, in order to facilitate improvements in energy efficiency. Additionally, due to the positive effect of subscriber count on electricity usage, it is recommended to implement policies for a moderate increase in subscribers to enhance energy efficiency.

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1. Introduction

The supply and demand of energy is a highly critical issue in today's world. In financial decisions and advancing countries' development, electricity has a significant role today. Electricity is One of the most vital energies in the home sector; This is very important because of the capital-intensive and complex production process, which often uses non-renewable energy. This issue has become more sensitive due to restrictions on non-renewable energy, increasing subscribers, and population growth. In addition, our country experiences a significantly high production cost, and thermal power plants operate at an average production efficiency of approximately 37%. The substantial upfront investment and unfair sales prices discourage the private sector from entering this market. Many problems arise from the restrictions mentioned earlier when trying to increase the production and supply of electricity. Iran's unrealistic electricity price and government subsidies create obstacles to economic growth, infrastructure development, and the competitiveness of Iranian products. Implemented subsidy reform in 2010, and this study investigates the effect of this policy on electricity consumption (Dashti & Hooshmandzadeh, 2024). Electricity subsidy reforms, which typically involve reducing or removing government subsidies on electricity prices, have been implemented in various developing and middle-income countries to address fiscal burdens, improve efficiency, and promote sustainable energy use. Based on the provided sources, these reforms generally lead to reduced electricity consumption due to higher prices, with estimated demand reductions ranging from 7% to 16% in key case studies. However, the impacts vary by country context, reform pace, and accompanying policies like compensatory measures. Positive outcomes include fiscal savings, environmental benefits (e.g., lower CO2 emissions), and shifts toward energy efficiency, though challenges such as affordability for the poor and potential lock-in effects from delayed reforms persist. Sources highlight both direct demand-side effects and broader economic implications, with reforms often yielding welfare gains despite initial consumption drops

(Aryanpour et al, 2022). Nevertheless, subsidies can generate inefficiencies, distortions, and deficits if ill-designed. It can even impact economic competitiveness and the electric sector's sustainability. In part, this complexity is due to the targeting strategy. For instance, implementing poorly targeted subsidies for the entire residential sector in the form of discounts for electricity can substantially increase its fiscal burden, and environmental distortions and even deteriorate the protection of the most vulnerable groups (Batdelger & Zagdbazar, 2026). The effectiveness of subsidy reform in reducing consumption directly depends on this elasticity:

Short-Run versus Long-Run: Electricity demand is generally inelastic in the short run because consumers cannot immediately change major appliances or overhaul industrial processes. A price hike might only lead to minor behavioral changes (like turning off unused lights). In the long run, demand becomes more elastic as consumers and industries invest in energy-efficient technologies, insulation, or switch to alternative energy sources. Residential: Often exhibits higher short-run inelasticity, but long-run elasticity increases with the adoption of efficient appliances (e.g., replacing an old air conditioner. Industrial: Can be highly variable. Industries with easily scalable production or the ability to switch fuels might show higher elasticity than essential manufacturing processes (Gelan, 2017). Electricity subsidies significantly influence household and residential electricity consumption patterns, often leading to increased demand due to lowered effective prices, though targeted reforms can mitigate overuse and promote efficiency. Research across diverse contexts like Iran, Jordan, Indonesia, and Mexico reveals that subsidy removal or tiering reduces consumption, particularly among higher-income or high-usage households, while low-income subsidies may shift timing without substantially boosting total use. These effects highlight tensions between equity, efficiency, and environmental goals in energy policy design (Liu et al, 2025).

In this article at first express a problem that the Governments rely on subsidies reform as a critical tool to support consumers and producers. Subsidies reform is defined by economists using various concepts.

Government assistance in the form of subsidies allows consumers to access goods and services at reduced prices, while simultaneously increasing the earnings of producers. The inequitable distribution of national wealth and wastage of energy are caused by energy subsidies and low energy prices in comparison to the cost of production, transmission, and distribution of electrical energy. Direct subsidies are being removed from Iran's developing economic program, with a focus on energy. Additionally, in 2002, a policymaker implemented energy management as a top priority for the state. By examining electricity consumption before and after this policy's implementation, our study aimed to analyze its impact on household consumption in 15 provinces of Iran. Moreover, there has been a change in household electricity consumption, either a decrease or an increase, after the implementation of this policy. In this research there are some hypotheses that should be considered are mentioned.

- It seems that subsidies reforms decrease household electricity consumption.
- subsidies reform has a negative relationship with price elasticity.
- The reform of subsidies has had a positive and tangible impact on the cross elasticity of demand.
- The number of subscribers has significantly affected household electricity consumption during the subsidies reform.

This research outlines the method and the theoretical underpinnings of the library resources and articles. Electricity consumption, real income, residential electricity price, gas price, and household electricity subscribers are the variables. After employing dynamic panel data and generalized method of moments (GMM), the model's software, State, examines the hypotheses. One of the dynamic panel data method applications is when the number of periods is more than the time series. In this paper, the number of sections 15 and the number of years of time series is 10. Additionally, including lags of the dependent variable helps address co-linearity in the regression model. To eliminate correlation between disturbance terms and explanatory variables, an instrumental variable is used, which is the difference between variables. Then the validity of the applicable variables defined tested in the model used Sargan's test. In the next step, we test the autocorrelation of the Error sentences. Using the Dynamic panel data approach method and generalized method of moments (GMM), a study was conducted in fifteen provinces, including Tehran, Fars, Isfahan, Zanjan, Yazd, Kerman, East Azerbaijan, Khuzestan, Kermanshah, Golestan, Gilan, Mazandaran, Hamedan, Semnan, and West Azerbaijan, from 2012 to 2023. The total number of data views in our model is 750, with each of the five variables containing 150 data points. Different approaches are employed when calculating subsidies. Both the price gap method and the consumer subsidies are principal methods that can be used interchangeably. The distinction between domestic and global prices lies in the second method. Implementing subsidies bring about some advantages that are:

· Increase the economic system efficiency;
· Production structure Modification to use efficient energy technology;
· Controlling the domestic consumption development;
· Improving the government's financial transparency and state companies;
· Reduce corruption, rent, and resources waste;
· Promoting social justice (by reducing the gap between different income groups)
· Improving the environmental index because of fossil energy conservation.

For this objective, the rest of paper has been organized as follows: In second section, the literature review has been explained and in third section, the research method and empirical model have been specified. In fourth section, the main empirical findings have been reported and finally the fifth section has been devoted to the conclusion and policy recommendation.

2. Literature Review

In this section, at first the theoretical framework has been reviewed and then we present the main relevant empirical studies in the scope of electricity consumption and subsidy reforms.

2.1. Theoretical Framework

Subsidies reduce the consumer price of electricity below its true market value. When subsidies are reduced or removed, the relative price increases, triggering two key substitution and income effects. In substitution effect consumers substitute away from electricity toward: energy-efficient appliances, lower-consumption behaviors and alternative energy sources (e.g., solar). In income effect, higher electricity prices reduce real household income. Lower-income groups decrease consumption more strongly because electricity forms a larger share of their expenditure. As a result, electricity consumption falls after subsidy reform, with magnitude determined by price elasticity of demand. In demand electricity theory, electricity is typically price-inelastic in the short run but more elastic in the long run. In this case, reforms have cumulative effects that become stronger over time. At the behavioral view point, subsidies create a perception of electricity as cheap, encouraging: wasteful use overconsumption, little attention to efficiency. With this reforms, higher bills increase awareness and consumers adopt energy-saving habits and finally electricity becomes a controllable cost. Moreover, on the base of energy efficiency and technology adoption theory, higher electricity prices accelerate technological shifts: replacement of old appliances with efficient ones and insulation and building improvements and industrial process upgrades. This is confirmed by the induced innovation hypothesis, which states that price signals stimulate technological change. In the environmental economic theory, subsidized energy consumption creates negative externalities like CO_2 emissions, air pollution and overuse of fossil-fuel power plants. Subsidy reforms internalize part of these externalities by increasing energy prices (Sinha et al, 2026).

2-2. Empirical Studies

Batdelgar & Zagdbazar (2026) have been investigated the impact of energy subsidy removal on inflation and household living costs using a behavioral microsimulation model based on the Household Socio-Economic Survey and the Input-Output Table data. Our findings reveal that current electricity subsidies disproportionately benefit richer households. The complete removal of these subsidies will impose an additional 3.4 % burden on the poorest decile, compared to 1.8 % on the richest decile, while the average increase in household expenditures will be 2.7 %. Sinha et al (2026) estimated the effect of state-level open access (competition-enhancing) reform in India's electricity market on electricity prices and labor market outcomes, using administrative plant-level data. Results suggest that open access leads to a decline in electricity prices and an increase in labor share, with stronger effects for grid-dependent plants. The decline in price and increase in labor share are larger in states with higher electricity revenue (per kWh) from the agricultural sector. Mamipour et al. (2025) investigated the effects of delayed subsidy reforms on consumption patterns and demand elasticities, a state-space model was applied across five phased scenarios spanning 1985–2023. Results reveal pronounced temporal variation in both price and income elasticities: subsidies have dampened consumer responsiveness and entrenched reliance on low-cost energy. All reform scenarios demonstrate a positive relationship between tariff increases and price elasticity, underscoring the necessity of gradual, stepwise subsidy removal. Monjazeb et al (2025) aimed to introduce the concept of spatial econometrics using panel data from 20 provinces across the country. It presents practical models based on this technique and estimates the gap in residential electricity consumption through the Spatial Durbin Model (SDM), selected using the Wald test. The time period used in this study is from 2006 to 2018. The results of this study confirm its hypotheses, indicating that electricity prices have a statistically significant negative effect on residential electricity consumption across provinces. Analyzing the efficiency of electricity use in the residential sector (where high-consumption provinces exceed optimal usage levels) can provide valuable insights for policymakers. Dashti & Hooshmandzadeh (2024) have analyzed the supply chain of electrical energy from production to consumption at first. Then, using the defined target profit function, the cost and income of each are expressed, and then using the target profit function defined in this research, the profitability of the actors will be calculated and compared based on the equalized cost and the total sales price. And then the method of distribution of hidden subsidy in the electricity industry was investigated and it was determined that the distribution of subsidy in the energy tariff is different for the actors of the electricity industry. Alipourian et al (2024) investigated "factors affecting electricity generation from renewable energies (RE) in Iran" during the period of 1990-2020 using the system of simultaneous equations in the framework of E3 models. The results show that making the electricity market competitive through reducing SUB (and thus increasing the price of fossil fuels) leads to an increase in the share of renewable energies in electricity generation. Besides, the increase of CRPP, the allocation of TCG to renewable technologies and the increase of FDI share in development of renewable technologies have positive effects on the expansion of RE. Zarepour and et al. (2023), proved that the 2010 Iranian Energy Subsidy Reform caused a significant increase in energy prices. Using a detailed micro-panel dataset, this study analyzes the influence of the reform on the manufacturing sector's performance at the 4-digit ISIC level between 2009 and 2013. By implementing a quasi-experimental framework, the analysis examines the impact of the reform on all firms. Output and value-added saw a decline of 3% and 7%, respectively, following the subsidy reform. There was a nearly 9% decrease in profits. Based on heterogeneity analyses, the manufacturing sector has experienced impacts through three channels. We conclude that for successfully implementing an energy subsidy reform while maintaining growth in the manufacturing sector, direct and indirect costs have to be considered. The results have significant implications for energy reforms aimed at mitigating climate change. Lee and et al (2023) proved that the global economy continues to face challenges due to the COVID-19 pandemic, which has notably impacted energy usage. While national lockdowns have been enacted to prevent additional virus outbreaks, this has obstructed electricity delivery to industrial and residential customers. This study optimizes electricity consumption behavior through the introduction of an electricity break-off (EBO) policy employing simulation-based optimization techniques. Researchers measured the optimal time for providing electricity to industrial and household communities as well as calculated the optimal incentive rate for electricity shortfalls to minimize power crises under the EBO policy framework. Adopting this EBO policy allows industrial facilities to operate their systems for a limited duration through optimized electricity consumption. Barkhordar and et al. (2022) represent that Extensive awareness of end-use sector consumption patterns is necessary to study policy effectiveness on load management. The consumption pattern integrates electricity consumption's short-term fluctuations and long-term trends. This paper presents a decomposition method for extracting load curves from aggregate electricity data. The collected data is employed to examine fluctuations in consumption patterns of sectors like households. The estimated load profiles depict the behavior of a large group of consumers for several years. Load data for Tehran province in Iran is organized using the model from 2006 to 2018. Ren et al. (2022) represent that to empirically measure the effectiveness of energy policies, we propose a non-parametric method to examine the relationship between economic growth and energy consumption from both temporal and geographic perspectives. Specifically, we utilize a local linear dummy variable estimation (LLDVE) method to explore the time-varying province-specific trends, the common trend, and the coefficients based on panel data from 26 provinces in China from 1995 to 2017. Our findings indicate that the promotional impact of energy consumption on economic growth changes over time, as evidenced by the inverted U shape of the relationship. Moreover, the non-parametric model better captures such an effect than the parametric model. Maldonado et al. (2022), proved that in urban water provisioning, prices can improve efficiency and help achieve environmental objectives. However, household responses to price changes differ widely based on household characteristics. Analyzes performed at the aggregate level ignore the implications of water demand incentives at the individual household level. A large sample of household-level data enables estimation of econometric demand models, capturing heterogeneity in domestic consumption. This study estimated domestic water demand in the city of Valencia and its elasticity, along with demands of different districts and neighborhoods (intra-urban scale analysis). Water pricing structure in Valencia is completely different than other Spanish cities—it uses an increasing volume (increasing rate tariffs, IRT) structure. Jafari et al. (2022), contend that recent studies suggest that the economy-wide rebound effect approaches 100% in several high-income nations. However, the question remains whether the effect is similarly large in middle-income countries. Iran serves as a relevant case study as a middle-income nation that is also a major oil producer. We estimated the economy-wide rebound effect for Iran using a structural vector autoregressive model and quarterly data from 1988:3 to 2018:1. We identified the structural shocks through independent component analysis, a statistical identification technique that does not require imposing restrictions based on economic theory within the model. The results show that in response to an energy efficiency shock, energy use initially decreases but returns near its original level over time. The estimated economy-wide rebound effect in Iran is 84% after 6 years, with the confidence interval including 100%. This implies policies encouraging energy efficiency innovation will have limited long-term impact on energy usage. Hou et al. (2020) proved that the empirical literature on the relationship between energy price and energy efficiency yields mixed results. This study systematically examines the influence of energy price on energy efficiency in China based on data from 30 provinces between 2003 and 2017, using linear and nonlinear effect analysis. We found that the impact of energy price on energy efficiency in China was generally positive. However, there existed heterogeneous effects of energy price on energy efficiency across various regions, and the effect differed based on differences in energy efficiency levels according to the panel quantile regression analysis. Finally, the nonlinear effect analysis using the panel threshold model indicated that the effect of energy price on energy efficiency increased with higher levels of environmental regulation and economic growth rates, while it decreased with greater degrees of energy price distortion and economic development levels. Particularly, when the value of a region's economic development level and economic growth rate fell within a certain range, the impact was not statistically significant. Overall, these findings contribute to a deeper understanding of the effect of energy price on energy efficiency in China. Roos & Adams (2020) declared that the assumption of energy support sweetened the net volume of business and executed a combined consequence for industries. The analysis of the impact of implementing this policy in 2010 on electricity consumption in selected provinces of Iran was conducted using dynamic panel data. Moreover, this model incorporates both theoretical and empirical knowledge in the innovation study. Sarrakh et al. (2020) offered a price-gap method that revealed that cash transfer to social and health sectors in Saudi Arabia would thoroughly concern limited and low-income households. Some others investigated the impacts of energy subsidy policies on energy and emission. Liu and et al. (2020) stated that following China's substantial economic growth after instituting reforms and an open-door policy, the problem of environmental deterioration has become increasingly severe. To achieve a balance between economic expansion and environmental protection, enterprises are encouraged to conduct green technological innovation. However, due to inherent risks and uncertainties, the government provides research and development (R&D) subsidies while also implementing environmental regulations. As the Organization for Economic Co-operation and Development (OECD) divides green technological innovation into green product innovation and green process innovation, this study focuses on the latter to better examine its relationship with environmental regulations and government subsidies. Panel data from 30 Chinese provinces and cities from 2009 to 2017 is selected for empirical analysis using a system generalized method of moments model and threshold effect model, excluding Tibet, Hong Kong, Macao, and Taiwan due to lack of available data. In their study, Timilsina & Pargal (2020) observed that the economic impact is contingent upon the redistribution of revenue from ending subsidies. Shehabi (2020) examined how energy subsidy reform affected Kuwait's economic diversification. The results showed that an environmental regulation policy can reduce the excessive reliance of economic growth on resources and the environment, promote diversified industrial growth in resource-based countries, and alleviate the "Dutch disease" phenomenon. In another study, Chen & Qian (2020) used panel data from coastal provinces in China spanning from 2004 to 2017 to investigate how different approaches to aquatic environmental regulation affect industrial facilities in the manufacturing industry and the transfer of polluting industries. This highlights the importance of command-and-control regulation in fostering technological innovation and enhancing the industrial landscape. Similarly, governments will be qualified to sustain and pay money on more essential matters such as climate change, renewable energies, infrastructures, etc. Supporting specific sectors and households for two or even more decades without improving their welfare, productivity, and economic trouble indicates more support and a considerable limitation on the government appropriation. Khalid & Salman (2020) commented that many types of research concentrated on the distributional outcomes of these policies by utilizing diverse strategies.

According to Pan et al (2019) high-quality output relies on the economy's continuous development from existing industries to more specialized ones with higher capital intensity, in order to enhance industrial diversification. The economy depends on diminishing returns when relying only on capital acquisition or labor inputs for quantitative growth. Any economic performance that varies from relative benefit is insufficient. When a country consistently adjusts its financial system to enhance the modification of comparative advantage, its economic vitality will keep improving. The economic remains will expand, and the economy will demonstrate extraordinary competitiveness. The market instrument of free competition is seen as the optimal mechanism to transfer resource factors to the high-tech industry during a country's industrial structure evolution. The responsibility lies with policymakers to select the best approach for fostering economic expansion and reshaping industries. Avagyan & Bhaskar (2019) stated that governments provide subsidies to address current economic issues and reduce the burden on their spending, either by completely or gradually phasing out these supports. Likewise, estimates indicated that deduction of fossil fuel subsidies in G20 nations could diminish GHG emissions by 21% and casualties of fossil fuel air pollution at 55%. regardless, the magazines on energy subsidy reform policies are influential, examining distant policy factors. Besides, Barkhordar et al. (2018) asserted that the first stage of energy subsidy reform in Iran led to more than 80 PJ energy-saving possibilities, analogous to diminishing CO2 emissions by 8.54 million metric tons. According to the Asian Development Bank (2015), the fuel subsidy reform in Indonesia results in a decrease of more than 10% in final energy consumption by 2030. Acharya and Sadath (2017) demonstrated that fossil fuel subsidy reform reduces energy consumption in India using econometric techniques. Ribeiro & Kruglianskas (2015) expressed that the combination of environmental regulation issues, the sophistication of the regulatory mechanism, and diverse regulatory intents appoint the diversification of ecological regulatory policy instruments and the complexity of their industrial results. Lin (2012) proved that developing countries experience increased market failures and substantial risks during industrial transformation. The contribution of this article in comparison with other similar studies such as lin (2012), Acharya and Sadath (2017) and Avagyan & Bhaskar (2019) is that in current study the effect of subsidies on electricity consumption in 15 selected Iranian provinces from 2012 to 2023 has been analyzed by applying dynamic panel data model.

3. The Econometric Model

By employing the GMM method, this article examines the influence of subsidies on household electricity consumption. The GMM dynamic Panel data is an effective econometric method for decreasing variable correlations. The GMM offers advantages like considering heterogeneity and additional information, removing biases in cross-sectional regressions, providing more accurate and efficient estimates, and offering non-linear estimates. Method GMM Dynamic panel is used when the number of cross-sectional variables (N) is more than the number of times and years (T), which is (N>T). In general, GMM Dynamic has advantages over other methods:

1- Solving the indigenousness of variables
2- Reducing or eliminating multicollinearity in model
3- Eliminating contest variables over time 4- Increasing the variables period.

a. Dynamic Panel Data Specification

To estimate the panel model with the mentioned features of the Arellano-Bover/ Blundel- Bond Dynamic Panel Data Two-Step Estimator[1] considering a dynamic panel model (DPD):

$$y_{it} = \sum_{j=1}^{p} \alpha_j y_{i,t-j} + x_{it}\beta_1 + w_{it}\beta_2 + v_i + \varepsilon_{it}$$

α_j : The number of p parameters to be estimated.

x_{it} : A vector of $1 \times k_1$ which is a Strictly exogenous covariate[2].

β_1 : A vector $k_1 \times 1$ that the parameters will estimate.

w_{it} : It is a vector $1 \times k_2$ of predefined or exogenous variables.

β_2 : A vector $k_2 \times 1$ that the parameters will estimate.

v_i : Panel level effect (It may be correlated with explanatory variables).

ε_{it} : an independent identical distribution throughout the sample with variance σ_ε^2.

In addition, it is assumed that ε_{it} and $v_i$are independent throughout the t period.

1 Arellano-Bover/ Blundel- Bond Dynamic Panel Data Two Step Estimator
2 Strictly exogenous covariate

Also w_{it} and x_{it} may include lagged exogenous (independent) variables and virtual variables.

In addition, we assume $X_{it}^{L} = (y_{i,t-1}, y_{i,t-2}, \dots, y_{i,t-p}, x_{it}, w_{it})$ a vector $1 \times k$ of variables throughout t period. So that $\mathrm{K} = \mathrm{p} + \mathrm{k}_1 + \mathrm{k}_2$and p is the lagged. In addition, $k_1$the number of variables is utterly exogenous for x_{it} and k_2 the number of variables for w_{it}.

Estimating the variables involves assuming perfect balance and no strict exogenous variable. The purpose of this assumption is to simplify equation specifications by treating a strict exogenous variable as predetermined, as discussed by Arellano and Bover (1995).

$$y_{it} = \alpha_2 y_{i,t-1} + \alpha_2 y_{i,t-2} + v_i + \epsilon_{it}$$

$$\Delta y_{it} = \alpha_1 \Delta y_{i,t-1} + \alpha_2 \Delta y_{i,t-2} + \Delta \epsilon_{it}$$

α_j : The number of p parameters to be estimated.

ε_{it} : an independent identical distribution throughout the sample with variance σ_{ε}^2.

After estimating the coefficients, it is necessary to use Sargan’s test to check the validity of the defined instrumental variable. The instrumental variable's correlation with error terms is not observed in this test, according to Hypothesis Zero. The degrees of the chi-square distribution associated with the Sargan's test statistic are equal to multiple excessively specified constraints.

Hypothesis zero of this research rejects the association between residual variables and instrumental variables, suggesting the validity of the model's instrumental variables.

b. Model Specification

Researchers have conducted numerous studies to estimate the electricity demand function in residential, commercial, and industrial sectors. The rise in consumption makes the household sector important. Research shows that demand depends on variables like electricity prices, disposable income, gas prices, number of subscribers, and non-economic factors such as temperature and number of electrical appliances used. In this research, as in domestic and foreign studies, the variables of electricity consumption, electricity price, per capita income, gas price, and the number of subscribers has been used, and the model is as follows:

$$\ln ce_{it} = \mu_i + \alpha_1 \ln ce_{i,t-1} + \alpha_2 \ln ri_{it} + \alpha_3 \ln pe_{it} + \alpha_4 \ln pg_{it} + \alpha_5 \ln sub_{it} + u_{it}$$

So that

$\ln ce_{it}$: indicate electricity consumption of the home sector for the province i in the period of t

$\ln ce_{i,t-1}$: shows electricity consumption with a delay period.

α_k: Explanatory variables Coefficients a K=1, 2…,5.

$\ln ri_{it}$: Real income per capita for the province i in the period t.

$\ln pe_{it}$: Household electricity prices for the province i in the period t.

$\ln pg_{it}$: Natural gas prices for the province i in the period t.

$\ln sub_{it}$: Household electricity subscribers for the province i in the period t.

4. Variables of Model

In this study, variables such as household electricity consumption, delayed electricity consumption, real per capita income, residential electricity price, and natural gas price are considered. Other variables are influential, but they have been omitted due to the lack of detailed information.

Electricity price: Electricity price is one of the critical variables of electricity consumption. Electricity is an essential energy source for various industries and an important gauge of societal prosperity. Electrical energy has gained increased attention due to factors such as ease of use, conversion, low risk, and environmental considerations. The production, transmission, and distribution activities of the electricity industry must be prioritized for investment. Financial constraints and lack of necessary investment in these three sectors lead to slow development projects in this industry. Meeting demand in all sectors of this industry requires significant investments. Electricity subscribers in Iran pay not based on prices. Instead, it is based on various economic, social, and political issues that have been influenced. So, this leads to electricity price disproportion with capital expenditures. The increase in subscribers' electricity consumption is substantial, and if costs are not adjusted accordingly, it could lead to excessive usage. The electricity industry is at risk due to the absence of tariff coverage, competition, and investment. There are different types of electricity prices such as household, general, industrial, agricultural, etc., which also vary based on seasonal and regional differences. Determining the household electricity price relies heavily on the maximum temperature.

Per capita income: Increased production and national revenue, both in demand and supply, affect the economy and increase production and consumption. Economic growth leads to an increase in per capita income, followed change in energy consumption patterns; with the rise in per capita income and the impact on consumption patterns, households' consumption of energy increases. Also, economic growth will lead to more energy consumption. Of course, it is not valid for all conditions. Technological and technical improvements can lead to decreased energy consumption by increasing efficiency.

Gas prices: According to research, natural gas can be considered a substitute for domestic electricity consumption. In our country, natural gas is priced by the government, and pricing policy is price stability in the long run. The gas pricing efficiency will meet if the gas price is accurate. If this principle is not reflected in pricing, energy consumption will not be optimal. The subsidized price of natural gas in our country leads to uncontrolled energy consumption as consumers bear production and supply costs. The goal of gas pricing is income redistribution with social justice. Take natural gas subsidies as an example - they contribute to increased consumption and reduced efficiency. If it is not practical, consumers with low financial resources and low gas appliances use less of this subsidy. At the end of 2010, with the law's implementation on subsidies reform for gas prices, natural gas consumption, like electricity consumption, has progressed efficiently.

The number of subscribers: The number of subscribers is one of the influential variables in household electricity consumption. Provinces with a larger number of households experience an increase in electricity consumption.

a. Specifying the econometric model and defining the virtual variable

The following relationship shows the model for electricity demand in the home sector:

$$\ln ce_{it} = \mu_i + \alpha_1 \ln ce_{i,t-1} + \alpha_2 \ln ri_{it} + \alpha_3 \ln pe_{it} + \alpha_4 \ln pg_{it} + \alpha_5 \ln sub_{it} + \alpha_6 d_t + \alpha_7 d_t \ln pe_{it} + \alpha_8 d_t \ln pg_{it} + \alpha_9 d_t \ln sub_{it} + u_{it}$$

So that

$\ln ce_{it}$: Electricity consumption of the home sector for the province i in the period of t

$\ln ce_{i,t-1}$: shows electricity consumption with a one lag delay.

α_k: The explanatory variables Coefficients k=1, 2,…,6.

$\ln ri_{it}$: Real income per capita for the province i in the period of t.

$\ln pe_{it}$: Household electricity prices for the province i in the period of t.

$\ln pg_{it}$: Natural gas prices for the province i in the period of t.

$\ln sub_{it}$: Number of household electricity subscribers for the province i in the period of t.

d_t : A virtual variable whose value is one for the years 2019 and 2020 and zero for the rest of the years.

b. Descriptive statistics

At first, table 1 indicates statistic-descriptive variable, that result:

Table (1). Descriptive Statistics

Descriptive Statistics	Lce	Lpg	Lpe	Lri	Lsub
Mean	7.05	4.50	4.89	16.21	6.41
Maximum	9.36	6.19	6.18	16.66	8.47
Minimum	5.41	3.89	4.44	15.83	4.97
Std. Dev	0.82	0.62	0.49	0.18	0.76
Observations	150	150	150	150	150

Source: Research Findings

In the table above, the state software calculates descriptive statistics for the natural logarithm variables, including electricity consumption, gas price, electricity price, per capita income, and the number of subscribers—minimum, Maximum, Mean Std. Dev represents the mean, maximum and minimum, and standard deviation of the mentioned variables, respectively, and observation represents the number of observations.

c. Model estimation and study of the impact of subsidies reform on household electricity consumption

The estimation of the model in this section is done using GMM with a dynamic panel model, which accounts for lagged explanatory variables and province-specific unobservable effects. At first, the instrument variables, which are lagged unrelated variable, is determined. To ensure greater stability and reliability in this model, a large number of observations is essential. With a small number of observations, interpreting the results becomes difficult due to high bias. The model estimation results are represented in the table below. The results of the model estimation reveal that lagged electricity consumption (Lce_{t-1}), gas price, and number of subscribers positively and significantly affect household electricity consumption, while electricity price and per capita income have a negative association. The dummy variable D played a crucial role in determining the negative and significant impact of subscribed reform on electricity consumption in this model. As a result, the subscribed reform leads to decreasing electricity consumption. In this method, the term of intercept has been eliminated because of first differencing of variables in the equation. The coefficient of first lag of electricity consumption is 0.84 which between zero and 1. This coefficient shows the convergence of dynamic model. We also used Sarang's test to evaluate the accuracy and validity of instrumental variables, which indicates that the hypothesis of the null hypothesis is not rejected and instrument variables are valid. Also, Arellano and Bond[1] Test statistics show the lack of second-order autocorrelation between the disorder sentences. We have used that the results indicate the absence of second-order autocorrelation between the disturbance term.

Table (2). Results of estimating the impact of subsidies reform on household electricity consumption

Explanatory variable	Coefficient	Prob	
Lce t-1	0.84	0.000	
Lpe	-0.22	0.001	
Lpg	0.08	0.03	
Lri	-0.05	0.79	
Lsub	0.58	0.003	
D	-0.38	0.09	
Number of obs	120	Wald chi2 (6)	1721.95
Number of groups	15	Prob> chi2	0.000
Sargan Test	chi2 (20) = 10.0970		
	Prob> chi2 = 0.9664		
Arellano-Bond Test	Prob> z	Z	Order
	0.04	-2.11	1
	0.24	-1.62	2

Source: Research Findings

d. Estimating the model and examining the effect of subsidies reform on the household electricity prices elasticity

To investigate the effect of subsidies reform on the price elasticity of household electricity, a virtual variable d and lpe Multiply (in the below table,

[1] Arellano and Bond.

represented with the cross term) is used in this model, then estimated by the generalized method moments (GMM). The table above confirms that, as expected, there is a meaningful and negative relationship between electricity prices and household electricity consumption. Economic theory suggests a direct relationship between per capita income, number of subscribers, and household electricity consumption. To evaluate the subsidies reform on the price elasticity of household electricity, we use cross variables because the coefficients sum of the variables cross and lpe have a negative value. Subsidies reform has a meaningful and negative impact on electricity consumption elasticity of demand. In this approach, the term of intercept has been eliminated because of first differencing of variables in the equation. The coefficient of first lag of electricity consumption is 0.84 which between zero and 1. This coefficient shows the convergence of dynamic model. The validity and accuracy of instrumental variables are assessed by Sargan's test, and it is found that the null hypothesis is not rejected and the instrumental variables are valid. Also, Arellano and Bond Test statistics show the lack of second-order autocorrelation between the disorder sentences. Based on our analysis, there is no evidence of second-order autocorrelation in the disturbance term.

Table (3). Examines the effect of subsidies reform on price elasticity

Explanatory variable	Coefficient	Prob	
lce t-1	0.39	0.002	
Lpe	-0.12	0.071	
Lpg	-0.07	0.24	
Lri	0.32	0.000	
Lsub	0.77	0.000	
Cross	0.019	0.051	
Number of obs	120	Wald chi2 (6)	2225.68
Number of groups	15	Prob> chi2	0.000
Sargan Test	chi2 (20) = 12.1727 Prob> chi2 = 0.9994		
Arellano-Bond Test	Prob> z	Z	Order
	0.01	-2.56	1
	0.13	-1.51	2

Source: Research Findings

e. Model estimation and the effect of subsidies reform on cross-price elasticity

To investigate the effect of subsidies reform on cross-elasticity, virtual variable d, and lpg multiply, which display by cross1, and enter the model. Finally, using the GMM method to estimate.

Table (4). Model estimation and study of the impact of targeted subsidies on cross-elasticity

Explanatory variable	Coefficient	Prob	
lce t-1	0.51	0.000	
Lpe	-0.15	0.000	
Lpg	-0.04	0.19	
Lri	0.24	0.000	
Lsub	0.68	0.000	
Cross1	0.017	0.035	
Number of obs	120	Wald chi2 (6)	1106.2
Number of groups	15	Prob> chi2	0.000
Sargan Test	chi2 (7) = 8.8071 Prob> chi2 = 0.2668		
Arellano-Bond Test	Prob> z	Z	Order
	0.02	-2.32	1
	0.15	-1.44	2

Source: Research Findings

Based on the table above, electricity prices have a significant negative impact on household electricity consumption. Based on economic theory, the per capita income and number of subscribers' variables are directly related to household electricity consumption. Cross-elasticity was evaluated through the use of the cross1 variable in relation to subsidy reform. Also, a variable lpg is not meaningful, and the coefficient cross1 is very small. The impact of subsidies has rendered the cross-elasticity reform insignificant. In this method, the term of intercept has been eliminated because of first differencing of variables in the equation. The coefficient of first lag of electricity consumption is 0.84 which between zero and 1, This coefficient shows the convergence of dynamic model. Sargan's test assesses the accuracy and validity of instrumental variables (second lag of dependent variable), indicating that the null hypothesis is not rejected and the instrumental variables are deemed valid. Also, Arellano and Bond Test statistics show the lack of second-order autocorrelation between the disorder sentences. The results indicate that there is no second-order autocorrelation between the disturbance term.

f. The model estimates and evaluate the number of subscribers and the effect on household electricity consumption

To investigate the effect of the number of subscribers on household electricity consumption during the subsidies reform, multiply the virtual variable in the number of subscribers' logarithm and call the cross3. Finally, to estimate the model by the GMM method.

Table (5). Examines the impact of the number of subscribers on household electricity consumption during subsidies reform

Explanatory variable	Coefficient	Prob	
lce t-1	0.58	0.000	
Lpe	-0.17	0.002	
Lpg	-0.017	0.71	
Lri	0.23	0.000	
Lsub	0.65	0.000	
Cross3	0.0098	0.09	
Number of obs	120	Wald chi2 (6)	1152.03
Number of groups	15	Prob> chi2	0.000
Sargan Test	chi2 (7) = 10.4406 Prob> chi2 = 0.1649		
Arellano-Bond Test	Prob> z	Z	Order
	0.0163	-2.40	1
	0.15	-1.45	2

Source: Research Findings

The above table reveals a negative and significant relationship between electricity price and household electricity consumption. Moreover, per capita income and number of subscribers demonstrate a direct association with household electricity usage, consistent with economic theory. The natural gas price variable has a negative relationship with electricity consumption and because it is not significant, its interpretation is omitted. To examine the effect of the number of subscribers of household electricity consumption during the targeted subsidies of the variable cross 3 has been used. Because the coefficient of this variable is very small, the impact of the number of subscribers on household electricity consumption during targeted subsidies is very small. According to the table above, the effect of electricity prices on household electricity consumption is negative and meaningful. Household electricity consumption is directly related to per capita income and number of subscribers, according to economic theory. The cross3 variable was used to evaluate the subsidy reform on the number of subscribers. The coefficient of this variable is very small, and the relationship between subscriber count and consumption is not significant. The accuracy and validity of instrumental variables are evaluated by Sargan's test, which supports the null hypothesis and validates the instrumental variables. The disorder sentences do not exhibit second-order autocorrelation, as shown by the Arellano and Bond Test statistics. Based on the results, it can be concluded that there is no second-order autocorrelation in the disturbance term.

g. Hypothesis of Research

First hypothesis: the subsidies reform affects household electricity consumption because the d variable is meaningful, but this has a negative coefficient, resulting in by implementing this policy, the electricity consumption decreased, so the first hypothesis is not rejected.

Second hypothesis: according the 3-4 table, the sum coefficient of lpe and cross is negative. The price elasticity is significantly affected by the subsidies reform, and the second hypothesis stands unrefuted. Third hypothesis: the impact of subsidies reform on cross-elasticity used the cross1variable. Table 4-4 shows that the effect of this policy on cross-elasticity is not significant, leading to the rejection of the third hypothesis. To investigate the impact of subscriber, count on household electricity consumption during the subsidies reform, the fourth hypothesis utilizes the cross3 variable according to the 5-4 table. The impact is not significant enough to support the fourth hypothesis, leading to its rejection.

h. Regression Analysis

Statistical methods in regression analysis are used to assess relationships between dependent and independent variables. It is used to estimate the relationship's strength between variables and to model the prospective association between them. R-Squared (R^2) is a statistical measure indicating how much of the dependent variable's variance can be explained by the independent variable in a regression model. In simpler terms, r-squared measures the degree of fit between the data and the regression model.

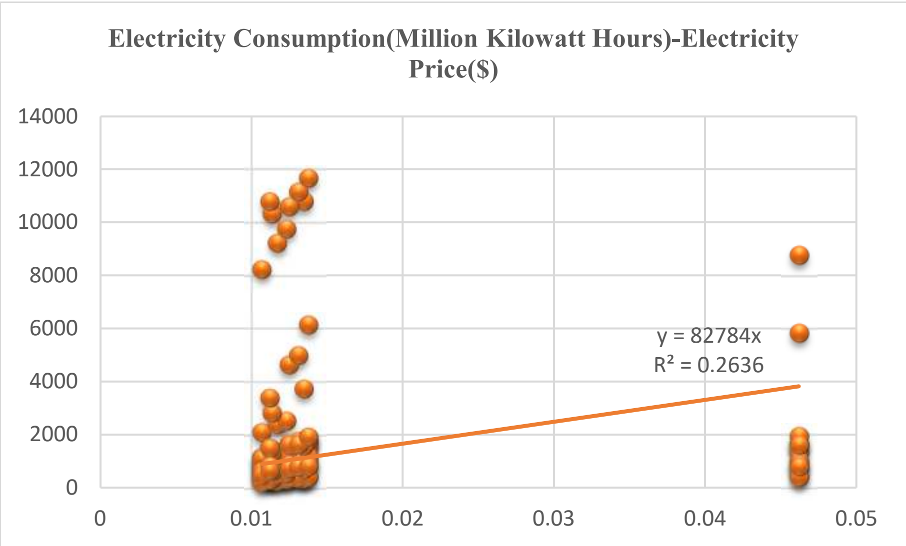

Fig1. Regression line for 165 points around the line (Electricity Consumption (Million Kilowatt Hours)-Electricity Price ($))

Fig 1 shows the slope of the line is equal to 0.2636, which means that the amount of electricity consumption changes for each unit changes in the price of electricity. According to figure 1, the coefficient of determination is equal to 0.2636, it is concluded that 26.36% of the changes in the dependent variable Y are explained by independent values. In addition, if the determination coefficient is close to 1, the regression model of the ($R^2=0.$ ılue could closest to the fitted line.

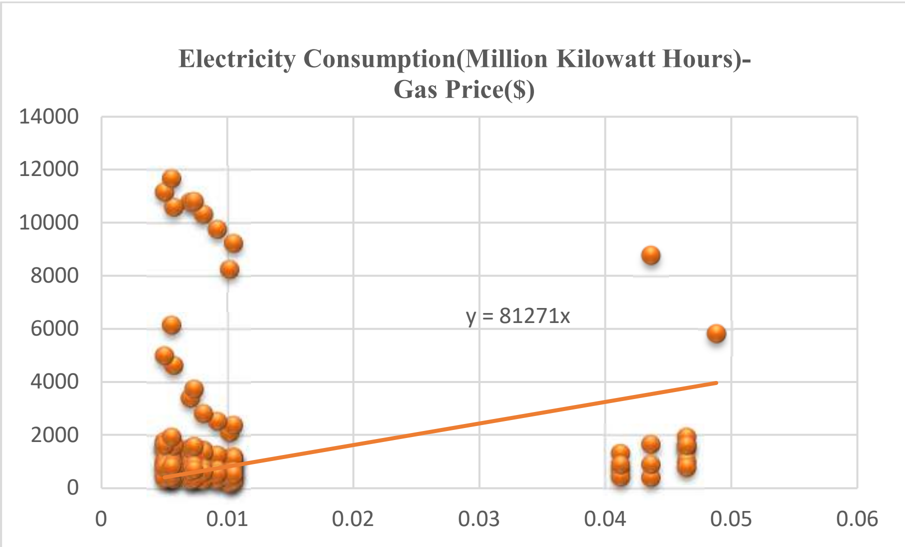

Fig 2. Regression line for 165 points around the line (Electricity Consumption (Million Kilowatt Hours)-Gas Price ($))

Fig 2 shows the slope of the line is equal to 0.272, so the amount of electricity consumption changes for each unit changes in the price of gas. According to figure 2, the coefficient of determination is equal to 0.272, it is concluded that 27.2% of the changes in the dependent variable Y are explained by independent values. In addition, if the determination coefficient is close to 1, the regression model of the observed value could closest to the fitted line.

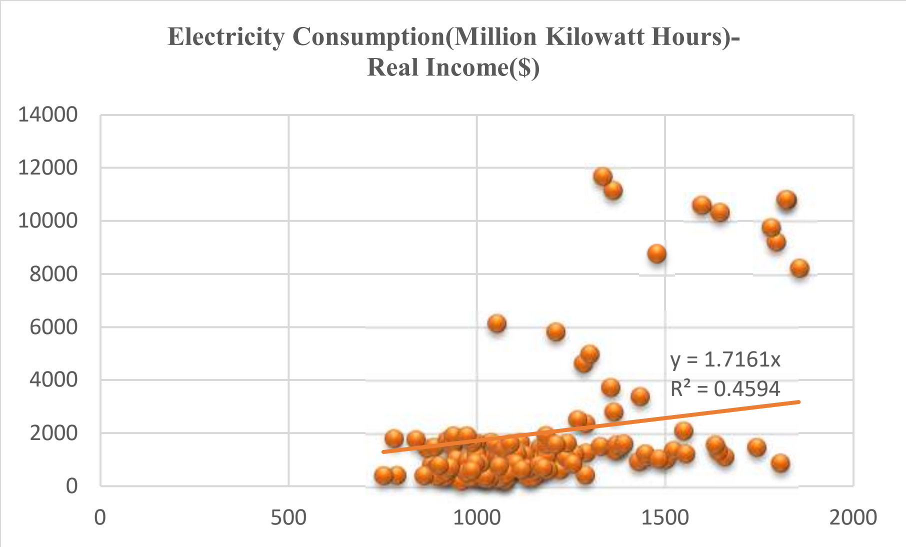

Fig 3. Regression line for 165 points around the line (Electricity Consumption (Million Kilowatt Hours)-Real Income ($))

Fig 3 shows the slope of the line is equal to 0.4594, so the amount of electricity consumption changes for each unit changes by real income. According to figure 3, the coefficient of determination is equal to 0.4594, it is concluded that 45.94% of the changes in the dependent variable Y are explained by independent values. In addition, if the determination coefficient is close to 1, the regression model of the observed value could closest to the fitted line.

Fig 4 shows the slope of the line is equal to 0.9072, so the amount of electricity consumption changes for each unit changes by real income. According to figure 4, the coefficient of determination is equal to 0.9072, it is concluded that 90.72% of the changes in the dependent variable Y are explained by independent values. In addition, if the determination coefficient is close to 1, the regression model of the observed value could closest to the fitted line.

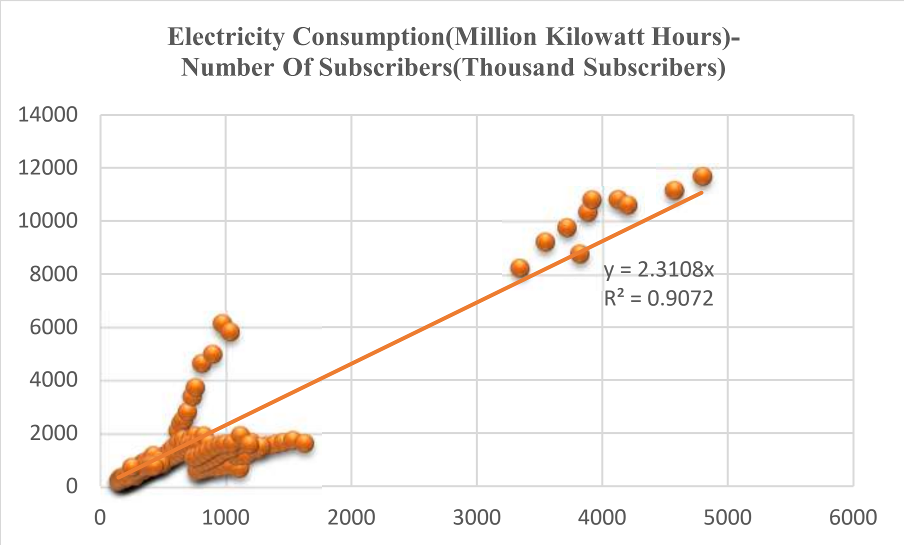

Fig 4. Regression line for 165 points around the line (Electricity Consumption (Million Kilowatt Hours)- Number of Subscribers (Thousand Subscribers))

5. Conclusion and Policy Recommendations

Unreasonably low prices caused by subsidies result in a significant rise in consumption. Domestic production does not supply consumption; therefore, part of this need is met through imports. The government's financial resources are burdened every year by subsidizing to compensate for the significant difference between domestic and foreign prices. Enterprises' innovation, technology change, and empowerment have been hindered by cheap energy and improper management. For example, in some industries, energy costs account for up to 15% of total costs. Besides the mentioned problems, there are problems of deviation in investments because of incorrect market signaling, the increasing resistance to change and the more difficult reform of the subsidy payment system, the increase in waste of resources, and the intensification of environmental degradation. At first descriptive statistics such as mean, standard deviation, maximum, and minimum are defined using software State. then estimate the model by the generalized method of moments

(GMM), Which is based on a dynamic panel model. The validity of the instrumental variable and the absence of autocorrelation between the disturbance term are tested using Sargan's and Arellano and Bond Test statistics. Investigate the impact of subsidies reform on household electricity consumption using the virtual variable. It is negative, so the electricity consumption has decreased. Additionally, by eliminating subsidies, it is possible to decrease excessive electricity consumption, as the price elasticity of electricity is -0.2336156. Iranian households consider electricity as an important necessity. The study suggests that eliminating subsidies can result in a 0.23 percent decrease in electricity consumption for every one percent increase in price. The results of this study have been consistent with the theoretical framework and empirical studies such as Mamipour et al (2025), Dashti & Hooshmandzadeh (2024) and Zarepour et al (203). Based on the results, the policy implications have been suggested to the economic planners and managers:

- ✓ Because of the negative and meaningful impact of the province's electric consumption price, the energy policy implemented an appropriate approach to control prices, especially energy prices that improve energy efficiency.
- ✓ Because of the positive and meaningful impact of the number of subscribers, the energy policy implemented an appropriate policy to increase the number of subscribers to improve energy efficiency
- ✓ Evaluating energy indicators such as energy intensity, energy coefficient, energy efficiency, and per capita energy consumption represented the irregular and inefficient electricity consumption. Therefore, it is recommended that the cost of subsidies reform be spent on infrastructure and technology development.

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Authors' contributions

All authors had contribution in preparing this paper.

Conflicts of interest

The authors declare no conflict of interest

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