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Research Article

Managing CO_2 Emissions through Focus on Energy Policies: Fresh Evidence from Iran's Agriculture Sector

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Abstract
CO_2 emissions as one of the environmental problems have intensified in the agriculture sector of Iran due to the increase in fossil energy consumption. Increasing the unequal distribution of CO_2 emissions and energy consumption requires a deep understanding of the effective and ineffective policies and plans. Therefore, this study aimed to analyze the effect of energy-related policies, plans, different kinds of energy (including gasoline, natural gas, and electricity) in the agriculture sector of Iran's provinces during 2001-16. To consider the regional differences, the Theil index, used to measure inequalities, and panel data approaches were applied to evaluate the effects of policies, plans, and inequalities on consumption. According to the results, first, the Theil index highlighted inequalities in energy consumption and CO_2 emissions. Provinces in a similar population or GDP grouping methodology have not a uniform distribution in energy consumption and CO_2 emissions. The estimated Fixed-Effect model for gasoline consumption indicated that some of the gasoline policies were not effective; however some of them could smooth the consumption. Subsidy removal phases had reduction effects on gasoline, but it would have a helpful impact if the difference in energy consumption had been considered. However, in the case of natural gas and electricity, policies were a great motivation to users. In summary, most of the policies were unsuccessful as they were not enough to control consumption and emissions as well, replaced the new non-renewable resources like natural gas and electricity, and intensified the inequalities. However, price-related policies could have significant effects on consumption.
Keywords: Electricity, Gasoline, Inequality, Natural gas, Theil index.

Introduction

CO_2 emissions as one of the environmental problems have been exacerbated worldwide through different activities due to the consumption of fossil energy sources (Zhang et al. 2019 and Pakrooh and Pishbahar, 2019). Increasing the unequal distribution of global emissions because of the differences in economic development, energy consumption, policies, and CO_2 emissions abatement targets have been discussed (Wang and Zhou, 2018); however it requires a deep understanding of the affecting factors.

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According to the Energy Information Administration (EIA), Iran, as an energy superpower accounts for the world's second-largest natural gas reserves and fourth-largest oil reserves. 98 % of Iran's total energy demands are generated from fossil fuels (EIA, 2015). Iran had the 9th rank in greenhouse gases (GHGs) emissions in 2016, and some megacities such as Ahvaz placed in the first ranking of the world polluted cities. CO_2 emissions is the most shared pollutant among all, which is increased from 690.09 million tons to 1418.3 million tons during the last decades. Total fossil energy consumption (including petroleum products, natural gas, electricity, and coal) is increased from 302.32 million barrels in 2001 to 585 million barrels in 2016 (Pakrooh et al, 2021; Environmental Assessment Agency, 2016, and Annual Energy Balance Sheet, 2001-16). Figure (1) shows the trend of total fossil energy consumption (including oil products, natural gas, electricity, and coal) and CO_2 emissions in Iran during 2001-16. According to figure, from 2005 and 2010 to 2014 there has been a different trend that may relate to the government policies and plans to reduce fossil energy consumption and CO_2 emissions. Besides, the Annual Energy Balance Sheet and World Bank statistics (2016) demonstrate that the GDP growth is not much as both energy consumption and CO_2 emissions growth. This status proves severs use of fossil fuels in economic activities, and as a result, Iran takes considerable ranks among intensive fossil fuel consumption countries and GHG emissions. Hence, this status is not sustainable in energy and environmental aspects, which needs more surveys.

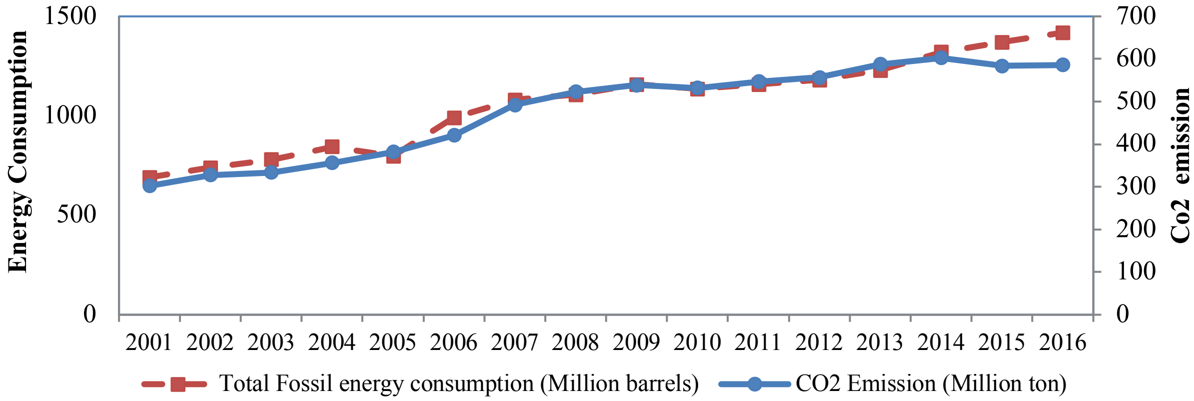

Figure 1. Fossil energy consumption and CO_2 emissions trends in Iran

For agriculture, as one of the vital economic sectors which has an essential role in providing food, employment, economic growth, and development, making a socio-economic balance among the sectors, and developing the non-oil exports (Agheli, 2015). In this regard, Iran's government has implemented policies and plans, such as mechanization of activities, subsidies for fossil fuel energies, and other incentives to provide food security and developing exports. However, mentioned proceedings have increased both energy consumption and environmental pollution during the last decade. Among all pollutants, CO_2 emissions due to agricultural activities are estimated more than 10% of Iran's total emissions and 98% of the sector's total pollutants. Therefore, it is evident that the agriculture sector, as one of the significant fossil energy users, can play an important role in CO_2 emissions reduction (Moghaddasi et al, 2018). According to Pakrooh et al. (2020), consuming intensive fossil fuel (e.g., gasoline, natural gas, electricity) for pumping water, irrigation, plowing with tractors, etc. activities is the primary source of CO_2 emissions in the agriculture sector of Iran during the last decades. This issue is evident in the figures (2:a-c); the agricultural sector has a fluctuating and increasing trend for energy consumption, CO_2 emissions, and renewable energies have no share in agricultural activists' energy mix. It supports the claims that the fossil fuels such as petroleum products, natural gas, and non-renewable electricity are the main sources of agricultural activities in the provinces of Iran (Sheikhdavoodi et al, 2015; Morovati et al, 2019).

Figure (2-a) indicates gasoline consumption and CO_2 emission trends in the agriculture sector of Iran. Gasoline consumption increased from 3852 million liters to 4553 million liters during 2001-10; however, it has declined since 2010. It seems that the government's energy-related policies reduced by about 30% of gasoline, yet it is still much more than the global average and similar resources countries. Besides, CO_2 emissions due to high fossil energy consumption rose one and a half times during 2000-16 when it enhanced from 302.3 to 585.8 million tones. According to figures (2-b,c), not only electricity but also natural gas consumption trend has been increasing over time. The non-renewable electricity consumption in the agriculture sector increased from 11079 million kwh per hour in 2001 to 36221 in 2016. It means that electricity consumption has tripled and, based on the reported figure, experienced a sharp trend after 2009. Natural gas, as one of the newborn energies in the agriculture sector, is another kind of fossil energy which consumption has increased eleven times since it has been supplied in this sector.

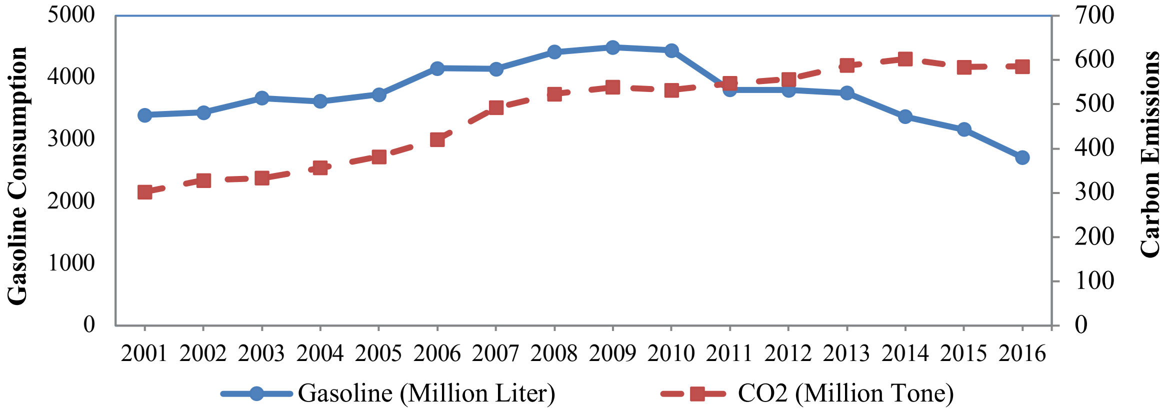

Figure 2. Gasoline consumption and Carbon emissions in the agriculture sector of Iran (Sources: Annual Energy Balance Sheet (2001-16) and World Bank (2019))

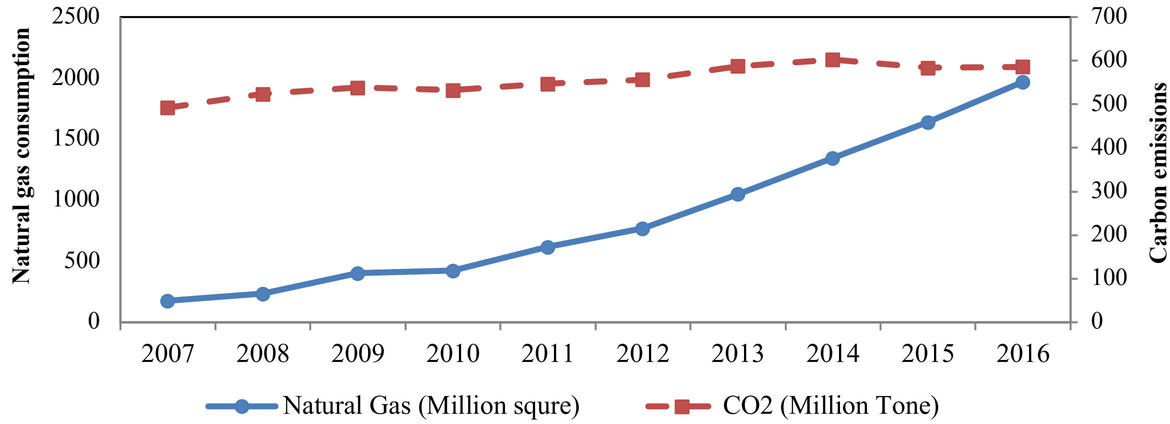

Figure 3. Natural Gas consumption and Carbon emissions in the agriculture sector of Iran (Sources: Annual Energy Balance Sheet (2001-16) and World Bank (2019))

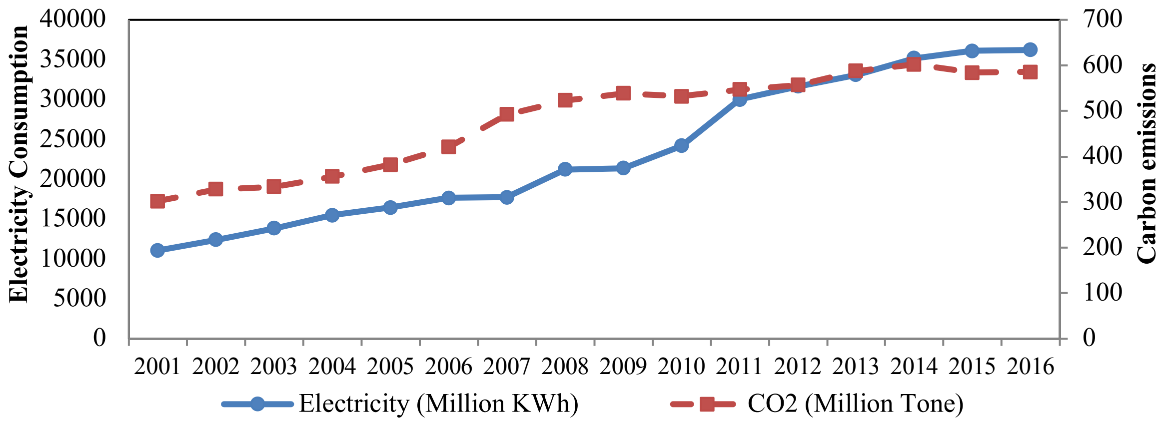

Figure 4. Electricity consumption and emissions in the agriculture sector of Iran (2001-16). (Sources: Annual Energy Balance Sheet (2001-2016), and World Bank (2019))

Due to the increase in energy consumption, Iran's government has commenced and implemented policies relates to fossil energy consumption, mainly focused on oil products, to promote both environmental and energy sustainability (Moghaddasi et al, 2018; Morovati et al, 2019). Some of the policies and plans have been held in common for all provinces and economic sectors; however, the amount of energy consumption, GDP level, population, and CO_2 emissions have been significantly different among sectors, even provinces (Pakrooh et al, 2020). Table (1) shows the summary of energy-related policies and plans in the agriculture sector of Iran, which are Energy standard, Electro pumps, Educational Training, Replacement of Fossil Fuels by Biomass, Greenhouse Development Plan, High-Quality Gasoline, Gasoline Subsidy, and Subsidy Removal Phases.

Table 1. Summary of energy-related policies and plans in the agriculture sector of Iran

	Title	Years of activity
Policies and plans	Energy Standard	From 2005 till 2012
	Electro pumps	Since 1998
	Educational Training	Since 2010
	Replacement of fossil fuel by Biomass	Since 2005
	Greenhouse Development Plan	Since 2011
	High-Quality Gasoline	Since 2005
	Gasoline Subside	From 1978 till 2010
	Subsidy Removal Phases	2010 and 2014

(Sources: Statistical Center of Iran (SCI), Annual Energy Balance Sheet, Ministry of Energy, Annual Agriculture Statistics Book, Ministry of Agriculture Jihad, and Organization of Forests, Range and Watershed Management (2001-16))

It is understandable through the presented figures that the policies have changed the energy-mix in agricultural activities; however, it couldn't mitigate the CO_2 emissions. So, it would have been sensible if policymakers had considered socio-economy differences among sectors or regions in energy policymaking. Finally, this status has propounded the question that is "which policies and plans have been effective or ineffective in energy consumption as well CO_2 emissions of the agriculture sector of Iran's provinces?". To answer the question, the study was organized to understand the effect of policies and plans on different kinds of energy consumption regarding differences in energy consumption and CO_2 emissions through measuring the inequality. Hence, the study would help policymakers to specify the effective and ineffective policies and plans concerning differences. On the other hand, it can help in managing the energy consumption, and thereupon CO_2 emissions through remove the ineffective policies and focus on efficient policies to provide a sustainable statue.

The remaining contents of this article structure are as follows: Section 2 shows a summary of studies. The methodology illustrates in section 3, the panel approach used to analyze the effect of energy-related policies on the different types of energy consumption, and we introduce the province's information. Section 4 performs empirically illustrates the proportion of this methodology by using province data. Finally, Section 5 makes some concluding remarks and particular policy implications proposed.

Literature Review

Several studies, according to Table (2), have analyzed the effects of the renewable and fossil energy policies on energy consumption, although almost have limited to the macro-level issues. Surveys on various studies are as follow. Some of them have focused on the effect of a specific country's policy on energy consumption and pollutant emissions. However, it could expand within the regional or sectoral analysis. Most of the studies have not addressed the inequality in energy consumption, pollutant emissions, and also income levels, as significant differences have been within energy consumption and pollutant emissions. According to Mckay (2002), inequality means the differences in something between populations also often relate to income and consumption. Hence, investigating the inequality issue in energy consumption and pollutant emissions at the provincial level is necessary and can provide an accurate survey on energy policymaking and pollutant managing.

Vehmas (2005) analyzed the effect of energy-related taxation on emissions in Finland during 1990-2003. The result of the historical analysis indicates that fossil energy-related taxation, as an environmental tool, was a fiscal purpose, and it could be possible to replace through carbon trading policy as that was effective. Borba et al. (2012) estimated the potential of energy-related GHG reduction in Brazil by AAC and NAC indexes in which the abatement cost of GHG emissions was examined. Implemented energy-related policies showed an approximately 27% reduction potential until 2030. Zhang et al. (2019) evaluated the effect of renewable energy-related policies within 29 selected countries from 2000 to 2015 by using a panel data method. Results of the Fixed Effect model indicated that the fiscal incentives, supporting policies, research and development, price policies, grants and subsidies, and strategic planning positively affected on renewable energy development. Caruso et al. (2020), investigated the relationship between renewable energy consumption, social factors, and health by a Panel Vector Auto Regression (PVAR) between 12 EU countries. They explored the link between renewable energy consumption, government policies, and general awareness, market lobbying activities, energy dependence, and health indexes during 1990-2015. Results highlighted the importance of having a stringent provincial policy for the development of renewable energy consumption. Lu et al. (2020), analyzed the sustainable energy policies for the promotion of renewable energy sources among the USA, Germany, UK, Denmark, and China through a critical review of historical data. According to a survey of the documents, the energy-efficiency standard was one of the most popular strategies for energy saving. Also, the Feed-in-tariff policy was applied as an incentive policy for renewable energy consumption, which was successful.

In contrast, some studies have highlighted the provincial examination, such as Yang et al. (2015). They analyzed energy-related pollution control and prevention policies in

China's Jing-Jin-Ji region based on historical documents from 1949 to 2014. Results indicated pollution reduction in the economic sectors through financial decentralization, historical reasons, and governmental division. Yi et al. (2015) examined the impact of provincial energy and environmental policies on air pollution control in China during 2002-2011 by applying spatial panel data methods. Results demonstrated policies, including environmental standards and public transportation, had positive, and electricity production from coal sources had a negative effect on the quality of local air. Si et al. (2018) analyzed the impact of energy-related policies on energy consumption in China's provinces from 2002 to 2013 by using a panel data approach. Results revealed that provincial policy, such as funding, subsidies and, none monetary awards decreased total energy consumption. Pollution reduction through loans for firms had negative effects on coke and biomass sources consumption; also funding and subsidies for researching and regional development increased both electricity efficiency and stalk resources consumption. Moreover, providing education and information for energy conservation decreased oil consumption. Finally, though many policies that have been expected to be effective on energy consumption were not. Xu and Lin. (2018) investigated the driving forces of various emissions levels in China's provinces during 2002-2016. The results of the panel quintile approach showed that economic growth, energy consumption, and urbanization have an impact on emissions. Financial capacity had the most significant effect on emissions. Hao and Dong. (2018), by using the Theil index and the GMM panel data approach analyzed the relationship between the urban-rural income gap and per capita electricity consumption in China's provinces from 1996 to 2013.

In this regard, the income gap measured through the Theil index and applied as an independent variable in the regression model, which showed a significant negative effect on per capita electricity consumption. Moreover, industrialization level, population structure adjustment, and the development of import-export trade have increased energy consumption. Liu et al. (2019) applied a spatial panel data approach to analyzing the energy-related policies' impact on selected pollutants in China's provinces during 2003-2016. Results highlighted that provincial pollution reduction policies reduced the PM10, though renewable energy policies decreased both PM2.5 and CO_2 emissions. According to the historical document, Wu (2020) evaluated the rural energy-policies and plans, including subsidies, rural electrification projects, and biogas projects in China from 1949 to 2018. Results showed the lack of comprehensive rural energy policies, unpredictable policies, disregarding inequality in energy policies, and policy implementation restriction had been the main problems in rural energy-policies. Baiardi et al. (2020) assessed the impact of energy efficiency and renewable energy policy on different types of pollutants in Italian provinces during 2005-15 through a panel data approach. According to results, renewable energy policies were most effective in terms of climate goals on the provincial scale; however, energy-related efficiency was so ineffective. Proque et al. (2020), analyzed the effects of land use and transportation policies on the spatial distribution of urban energy consumption in Brazil by general equilibrium model for 2010. Results of evaluation demonstrated an increase in gasoline price could reduce energy consumption directly. Vehicle fuel efficiency regulation reduced energy consumption in total, and increases to the agricultural land prices enhanced the energy efficiency and density. Adua et al. (2021), examined the relationship between energy efficiency policies on energy consumption in the USA through panel data approaches during 2009-2016. The result of the FE model demonstrated a positive relationship between energy efficiency policies and energy consumption. Efficiency improvement for energy use could reduce energy demand and contribute to sustainability.

Table 2. Summary of literature review

Author(s)	Region	Scale	Method	Main Results
Vehmas (2005)	Finland	National	Documentary	Trade policy has been effective.
Barba (2012)	Brazil	National	AAC and NAC	Energy policies showed a 27% reduction potential.
Yang et al. (2015)	China	Provincial	Historical data analysis	Pollution reduction is only possible through financial decentralization between sectors.
Yi et al. (2015)	China	Provincial	Spatial panel data approaches	Environmental standards, and public transportation have had positive, but energy resources have had negative effects.
Si et al. (2018)	China	Provincial	Panel data approaches	Loans have had negative effects on coke and biomass, funding and subsidies for R&D have had positive effects on electricity. Information for consumers has been effective on oil conservation.
Xu and Lin (2018)	China	Provincial	Quintile panel data approach	Financial capacity had the most significant effects on emissions.
Hao and Dong (2018)	China	Regional	Panel data approaches	Industrialization level, population adjustment, international trade, and inequality index have increased energy consumption.
Liu et al. (2019)	China	Provincial	Spatial panel data approach	Renewable energy policies could reduce PM10, PM2.5, and CO_2 emissions.
Zhang et al. (2019)	29 countries	International	Panel data Approaches	All Fiscal, supporting, research and development, price, grant, subside policies have been effective.
Wu (2020)	China	Regional	Historical data analysis	Subsidies, biogas, and renewable electricity project were effective.
Baiardi wt al. (2020)	Italy	Provincial	Panel data approach	Provincial Renewable energy policies were the most effective policies in terms of climate change.
Caruso et al. (2020)	12 EU countries	International	Panel Vector Auto Regression	Provincial and stringent policy for development of renewable energy consumption was the most important and effective policy.
Lu et al. (2020)	5 Countries	International	Historical data analysis	Energy-efficiency standards, and Feed-in –tariff have been successful policies in different areas.
Proque et al. (2020)	Brazil	Provincial	General equilibrium	A change in the gasoline price, vehicle fuel efficiency regulations, and a change in the price of agricultural land reduces energy consumption.
Adua et al. (2021)	USA	Provincial	Panel data approach	Energy-efficiency policies can reduce energy consumption and contribute to sustainability.

From above, it's clear that most of the studies were related to a specific country, and some others were at the provincial level. In this regard, it is helpful to remarking the significant matters from the reviewed studies as follows. Primary, regions, and provinces of a country have different characteristics in socio-eco-geo factors such as income level, energy consumption, and geography, so it would be precise and beneficial if studies carried out at the micro-level. According to Baiardi et al. (2020), sectoral analyses are detailed and clear as they include distinct features of activities in sectors like income, population, energy consumption, and pollution emissions. Second, inequalities in energy consumption and pollutants emission have not been addressed in many studies. However, inequality and the driving factor of that in different provinces or regions should identify and concern. As Hao and Dong (2018) and Pakrooh et al. (2020), inequalities and driving factors can lead us to achieve sensitive results in sustainable development goals and policymaking. Third, the agriculture sector as a main GHG emissions contributor has not been addressed in studies. Fourth, almost have been general studies in which they have focused on the effect of a specific policy. Therefore, in the study, we have tried to fill up the gaps between studies, which have mentioned above. This kind of study has innovation in terms of the following aspects. It has been specified as a comprehensive energy-policy study in the agriculture sector at a provincial level regarding differences between regions. The study have focused on the agriculture sector, as the main contributor of total GHG emissions, and has districted at a provincial level of the country where were engaged with high GHG emissions, because of the ineffective national and common energy policies.

Material and Methods

Econometric models are general tools to examine the impact of energy-related policies on consumption (Zhang et al., 2019). According to the study aims and data availability, panel data approaches were selected as an estimating method and quantitative evaluation. Besides, the inequality in energy consumption and CO_2 emissions computed through the Theil index before estimation procedures. Hence the Theil index were carried out to measure inequalities like Padilla and Duro (2006, 2011), Padilla and Serano (2006), Sinha (2015), Xu et al. (2019), and Pakrooh et al. (2020). The detail of the Theil index and econometric models were as follows.

Theil Index

Theil index has been used in studies related to energy consumption and pollutions to evaluate and measure inequalities. Theil index introduced by Theil (1967) based on statistical information theory. It capable of computing inequalities through income and population weights; it also was divided into two within and between groups decomposition to investigating the impacts of regional variations on the total value. The general form of Theil index and between and within-group decompositions were represented in equations (1) and (2).

$$Theil_t = \sum_{p=1}^{P} c_{i,t} \ln\left(\frac{c_{i,t}}{w_{i,t}}\right) \quad (1)$$

$$Theil_t = Theil_{within,t} + Theil_{between,t} = \sum_{p=1}^{P} c_{p,t}.Theil_{p,t} + \sum_{p=1}^{P} c_{p,t}.\ln\left(\frac{c_{p,t}}{w_{p,t}}\right) \quad (2)$$

Where, p is the total number of provinces, $c_{i,t}$ is the proportion of energy consumption or CO_2 emissions on the total amount, $w_{i,t}$ is the weight that can be the income or population of the sector in province i at year t.

Panel Data Models

Panel data processes have been implemented because of provincial-level data. This approach was able to consider time and cross-sectional heterogeneity, which provided informative and accurate results in the estimation. As a primary stage, stationary and co-integration tests were applied to avoid “spurious regression” and found out the stability of long-term relationships among variables during a assessment. In the second phase, the cross-sectional independence (CD) test was carried out to understand the independent sections in panel data models. In the third stage, a fit model could select as the following description for available panel data. A panel model have been divided into three main groups, which have known as Pooled (PLS), Fixed Effect (FE), and Random Effect (RE). They have been different in how heterogeneity has been imposed in the models. Among all, PLS is the simplest and most basic model in which a common intercept as the sectional heterogeneity provided for sections. However, in Fixed or Random models, sectional heterogeneity is applied through an individual intercept for each section and random factors. The following equations were general functional forms of different panel data approaches.

$$Y_{it} = \alpha + X_{it}'\beta + \varepsilon_{it} \qquad i = 1,....,N \qquad t = 1,...,T \tag{3}$$

$$Y_{it} = X_{it}'\beta + c_{it} + \varepsilon_{it} \qquad i = 1,....,N \qquad t = 1,...,T \tag{4}$$

$$Y_{it} = X_{it}'\beta + (\alpha + u_i) + \varepsilon_{it} \qquad i = 1,....,N \qquad t = 1,...,T \tag{5}$$

Where *Y, X,* β, ε, α, $c_{i,t}$, *u, I*, and *t* were dependent variables, independent variables, coefficients, error terms, a common intercept, individual intercepts, random factors, province, and time, respectively (Green, 2018 and Wooldridge, 2002).

The fourth stage, among all estimated models, one should select for further investigation. According to Pesaran (2015), the FE model is almost the fit model for short-term panel data (T<N), nevertheless the Hausman test was applied to select a model between FE and RE. If the Hausman test had a negative value, it had been possible to use the robust Hausman (Mundlak’s approach). After all, the selected model in the previous stage and PLS model evaluated through F, and LM (Breusch–Pagan) tests for the final decision. Hausman, F, and LM (Breusch–Pagan) tests were as following equations, respectively.

$$H = (\beta_1 - \beta_0)'[\mathrm{var}(\beta_0) - \mathrm{var}(\beta_1)]^{-1}(\beta_1 - \beta_0) \tag{6}$$

$$F = \frac{(R^2_{FE} - R^2_{Pls})(n-1)}{(1-R^2_{FE})(nt-n-k)} \tag{7}$$

$$LR = \frac{NT}{2(T-1)}\left[\frac{T^2\bar{e}'\bar{e}}{e'e} - 1\right]^2 \tag{8}$$

If the computed value of the Hausman test was more than a critical amount, the FE model and F test procedure would select for the next step. Otherwise, the RE model and the LM test process in the next step would select for further analysis. As a result, the computed and critical value of each test would be the main criteria for the next step.

At the final stage, autocorrelation and Heteroskedasticity issues were other significant processes before interpretation of results. Autocorrelation test was mandatory for macro panel data models (T is over 25), and Heteroskedasticity issues through Likelihood-ratio test (LR) was highlighted in micro panel data models (Pesaran, 2015; Baltagi, 2005; Green, 2018; Wooldridge, 2002, and Breusch and Pagan, 1980).

Data, Variables, and Econometrics Models

The study aimed to investigate the effect of energy-related policies and plans on energy consumption (gasoline, gas, and electricity) in the agricultural sector of Iran's provinces in regard to the inequalities. We collected per capita gasoline consumption, natural gas consumption, electricity consumption, energy-related policies, plans, and CO_2 emissions data at the provincial level from the Statistical Center of Iran (SCI), Annual Energy Balance Sheet, Ministry of Energy, Annual Agriculture Statistics Book, Ministry of Agriculture Jihad, and Organization of Forests, Range and Watershed Management during 2001-16. Table (3) represented both summaries of descriptive statistics of variables, units, and symbols. Gasoline consumption[2], natural gas consumption, and electricity consumption per capita were dependent variables. Gasoline price, natural gas price, electricity price, value-added (as a proxy of GDP), energy standard, gasoline subside, the number of electro pumps, educational training, subsidy removal phases, replacement fossil fuels instead biomass, high-quality fuel, greenhouse development plan, and biomass consumption were as in-dependable variables in Table (3). To avoid the Heteroskedasticity problem, variables were transformed to logarithmic level. Moreover, the following table was related to econometrics models so that two different models specified for gasoline consumption in which the first model was about reduction policies, and the second model defined differently. Then, econometric models of natural gas and electricity regarding inequality through Theil indexes were appointed in Table (4).

Table 3. Descriptive statistics and variables

Variables	Symbol	Unit	Mean	Std. Dev.	Max	Min
Gasoline Consumption	lcgasoline	Liter	4883.23	5692.39	50799.04	108.52
Natural Gas Consumption	lcgas	Liter	204.69	667.41	6604.114	0.016
Electricity Consumption	lcelectricity	Liter	2977.88	4030.61	25553.57	20.897
Gasoline Price	lpgasoline	Rial per liter	1522.58	1062.29	3285.87	379.3`
Natural gas Price	lpgas	Rial	650.75	617.27	3285.87	379.3`
Electricity Price	lpelectricity	Rial per kwh	135.75	65.50	244.55	51.85
GDP	l.lva	Million Rial	1.44	1.27	11.06	0.228
Energy Standard	lpolicy1	Liter per 100	226.25	14.10	237	203
Gasoline Subside	Lpolicy2	Rial	402932.9	570770.5	4690134	0
Number of Electro pumps	Lpolicy3	Number of Electro pumps	5346.31	7219.70	58460	25
Educational Training	Lpolicy4	Number of actions	0.5	0.61	2	0
Subsidy Removal Phases	Policy5	Number of actions	0.68	0.84	2	0
Replacement fossil fuel instead Biomass	Lpolicy6	Number of plans	1.91	2.58	10	0

(Sources: Statistical Center of Iran (SCI), Annual Energy Balance Sheet, Ministry of Energy, Annual Agriculture Statistics Book, Ministry of Agriculture Jihad, and Organization of Forests, Range and Watershed Management (2001-16)).

Table 4. Econometrics Models

Equations	
Gasoline (1)	$lcgasoline_1 = \beta_0 + \beta_1 l.lGDP + \beta_2 lp_{gasoline} + \beta_3 lpolicy_1 + \beta_4 lpolicy_3 + \beta_5 lpolicy_5 + \beta_6 Theil_1 + e_i$
Gasoline (2)	$lcgasoline_2 = \beta_7 + \beta_8 l.lGDP + \beta_9 lp_{gasoline} + \beta_{10} lpolicy_2 + \beta_{11} lpolicy_7 + \beta_{12} lpolicy_8 + \beta_{13} Theil_1 + u_i$
Natural Gas	$lcgas = \varphi_0 + \varphi_1 l.lGDP + \varphi_2 lp_{gas} + \varphi_3 lpolicy_5 + \varphi_4 lpolicy_6 + \varphi_5 lpolicy_8 + \varphi_6 lpolicy_9 + \varphi_7 Theil_2 + \vartheta_i$
Electricity	$lelectricity = \lambda_0 + \lambda_1 l.lGDP + \lambda_2 lp_{electricity} + \lambda_3 lpolicy_3 + \lambda_4 lpolicy_4 + \lambda_5 lpolicy_5 + \lambda_6 lpolicy_8 + \lambda_7 Theil_3 + v_i$

Results

Theil Index

Theil indexes measured for gasoline, natural gas, electricity, and CO_2 emissions regarding both GDP and population weights, then the proper indexes selected based on within-group or between-group variations. A low amount of within-group variation or high between-group variation gave the acceptable grouping methodology, and then the Theil indexes could be measure according to related grouping methodology. Table (5) indicated the between and within-group variations in both GDP and population grouping methodologies and weights, in which GDP grouping methodology and population weight for gasoline, population methodology, and GDP weight for natural gas, both population grouping methodology and weight for electricity, and both GDP grouping methodology and weight for CO_2 emissions selected because of low amounts of within-group variations. In this regard, 33.30% of inequality in gasoline consumption was related to between-group inequality; and 66.70% of non-uniform energy distribution followed by provinces within the same GDP group. It means that provinces at the same income level had significant differences in gasoline consumption during the study. Also, a remarkable difference in CO_2 emissions had been within similar income groups as about 59.09% of inequality in CO_2 emissions was followed by provinces. Also, groups of provinces presented 40.91% of GDP inequality in CO_2 emissions. Moreover, provinces, where they were at a similar population level, demonstrated about 32.26% and 68.37% within-group inequality in natural gas and electricity consumption during the study period. Natural gas consumers within the same group presented a uniform energy distribution in comparison to electricity users.

Table 5. Between and Within-group variations in percent (%)

Methodology	Population				GDP			
Weight	Population		GDP		Population		GDP	
Variation	BG	WG	BG	WG	BG	WG	BG	WG
Gasoline	22.34	77.66	24.47	75.53	33.30	66.70	17.07	82.92
Natural gas	24.51	75.49	67.74	32.26	19.15	80.85	22.95	77.05
Electricity	31.63	68.73	24.90	75.10	28.77	71.23	22.94	77.05
CO_2	18.5	81.5	20.94	79.06	18.66	81.34	40.91	59.09

According to the results of the previous part, Theil indexes are computed and represented in Table (6). The indexes were unique and not comparable to each other as they had different grouping methodologies and weights. Gasoline's Theil index presented the share of gasoline consumption to a population in the same GDP group of provinces that had a decreasing trend before 2008; while had been increasing during 2008-2016 due to the effects of the first and second phase of removing gasoline subsidy. It seems that subsidy reduction had changed gasoline distribution among provinces of a group and intensified the consumption differences between groups of provinces at the same income level. For instance, despite the implementation of gasoline consumption reduction policies, West Azerbaijan had not decreased the consumption while the similar group member, East Azerbaijan, had a significant amount decrease. On the other example, such as Khorasan’s and Kerman province, we were able to see the same process. The natural gas Theil index highlighted an unclear trend, but close to 0.36 during the period, in which implemented policies and plans like removing gasoline subsidy had reduced the non-uniform natural gas consumption between groups of the same population groups as well provinces. In this regard, Gilan and Golestan provinces, where placed in the same group, had doubled natural gas consumption during the policy implementation. A similar process was considerable between groups of provinces. The computed Theil index for electricity consumption showed an almost high value and gradual decreasing trend, which represented the reduction in strict non-uniformly consumption distribution between provinces of the same population group. It means that provinces had different amounts of enhancement in electricity consumption. Provinces of the same group as Kermanshah and Markazi where had increased electricity consumption three and five times during 2001-16, respectively, while that was around two or at most three times between groups of provinces. It seems that government policies and plans were effective on the electricity consumption of provinces. The following column of the table belonged to the CO_2 emissions Theil index, which was almost increasing during the time. The Theil index was around 0.2 and increased between 1-1.5 times between groups of provinces, where were at the same income level, while that was 1-2 times within a group of provinces. Despite implemented energy-related policies by that government, CO_2 emissions inequality intensified because of non-uniform increases in different kinds of energy consumption of provinces. Theil index as a statistical criterion could help us to understand the inequality and effects of policies on energy consumption, as well CO_2 emissions distribution in both within provinces of a group or between groups of provinces. From above, it seems that policies and plans in regard to energy consumption, such as removing gasoline subsidy in the first and second phases, had changed the energy-mix within provinces of a group at either population or income level. Hence, homogenous implementation of policy and schedule could intensify energy and CO_2 emissions non-uniform distributions between or within provinces.

Table 6. Theil indexes of energy consumptions and CO_2 emissions

Year	Gasoline	Natural Gas	Electricity	CO_2 emissions
2001	0.616	-	0.924	0.16
2002	0.573	-	0.925	0.13
2003	0.534	-	0.896	0.15
2004	0.469	-	0.945	0.19
2005	0.477	-	0.932	0.18
2006	0.393	-	0.912	0.21
2007	0.369	0.458	0.852	0.20
2008	0.383	0.393	0.866	0.22
2009	0.423	0.437	0.798	0.21
2010	0.418	0.415	0.768	0.19
2011	0.296	0.343	0.686	0.21
2012	0.357	0.327	0.714	0.18
2013	0.365	0.336	0.773	0.20
2014	0.362	0.317	0.732	0.20
2015	0.422	0.321	0.710	0.22
2016	0.458	0.321	0.732	0.23

Model Selection and Pre-tests

According to Baltagi (2005) and Pesaran (2015), stationary, co-integration, and cross-sectional independence issues were not necessary to control in studies that included relatively large N (sections) and short T (time). However, mentioned subjects were examined in the study as they had a short time (T was between 10-16 years). Stationary and cross sectional subjects were examined by the Im-Pesaran-Shin stationary test, Pesaran Cross-sectional Independence test (CD-test), and Kao co-integration test. According to the results in Table (7) and (8), most of the variables were stationary at I(0), and some of them had no result, however the co-integration test approved a long-term relationship between series. Also, there was no correlation problem between sections. In this regard, variables used at I(0) level in the following.

Table 7. Stationary and CD-test results

Variables	Stationary test	CD-test
Gasoline Consumption	-0.87	22.36***
Natural Gas Consumption	No answer	63.34***
Electricity Consumption	-1.53	58.56***
Gasoline Price	-1.10	77.76***
Natural gas Price	-1.76**	61.48***
Electricity Price	-0.92	77.76***
GDP	-2.15***	27.91***
Gasoline Theil Index	-2.48***	69.45***
Natural gas Theil Index	No answer	56.08***
Electricity Theil Index	-1.89***	40.26***
Energy Standard	-1.26	54.99***
Gasoline Subside	-1.96***	54.17***
Number of Electro pumps	-2.22***	73.26***
Educational Training	0.28	51.43***
Subsidy Removal Phases	No answer	22.36***
Replacement fossil fuel instead Biomass	No answer	42.54***
Biomass	No answer	22.36***

* Critical value for Im-Pesaran-Shin at 5% level error was -1.76.

Table 8. Kao co-integration test result

Equation	Results
Gasoline Consumption (1)	There was at least one Co-integration vector.
Gasoline Consumption (1)	There was at least one Co-integration vector.
Natural Gas	No Answer
Electricity	There was at least one Co-integration vector.

In the following, the Hausman test was applied for the selection of the appropriate model between Fixed-Effect (FE) and Random-Effect (RE). According to the computed value of the Hausman test, the null hypothesis was rejected for various energy types; hence, the FE model was selected for further investigations. After that, F-test was used to select the final model between Fixed-Effect (FE) and Pooled (PLS) as a final model. Results of the F-test for all energy types indicated the property of the Fixed-Effect (FE) model for interpretation. The results of the Husman and the F-test are presented in the Table (9).

Table 9. Result of Hausman and F-test

Equations	Hausman Test	(RE) or (FE)	F Test	(PLS) or (FE)
Gasoline Consumption (1)	181.22***	FE	35.75***	FE
Gasoline Consumption (2)	140.08***	FE	16.85***	FE
Natural Gas Consumption	401.74***	FE	9.74***	FE
Electricity Consumption	90.67***	FE	3.58***	FE

Note: Standard errors * $p < 0.1$, ** $p < 0.05$ and *** $p < 0.01$.

Heteroskedasticity issue was one of the other important subjects in the short-time panel data model that investigated in the study through the LR test. According to the results of LR tests in Table (10), all specified models engaged with variance Heteroskedasticity problem as the computed value of tests were more than critical amount, then the null hypothesis rejected for all energy kinds. Hence, the variance Heteroskedasticity problem was solved for all econometric models by using the robust or sandwich estimator of variances in the re-estimation process.

Table 10. Result of LR test for Hereroskedasticity Problem

Equations	LR Test	Heteroskedasticity
Gasoline Consumption (1)	79.41**	Yes
Gasoline Consumption (2)	44.83	Yes
Natural Gas Consumption	66.61**	Yes
Electricity Consumption	25.68***	Yes

Note: Standard errors * $p < 0.1$, ** $p < 0.05$ and *** $p < 0.01$.

The study measured inequalities in the different types of energy consumption through the Theil index and applied it as an independent variable in the econometric models. Specified econometric models estimated with and without Theil indexes to evaluate and understand the necessity of inequality factor in estimations. According to results in Table (11), on average, about 27.5% of the dependent variables in the per capita gasoline consumption were explained by Gasoline's Theil indexes, in which 21% and 34% belonged to the first and second equations, respectively. In the case of natural gas and electricity consumption, a significant difference was between equations, as 23% and 32% of per capita natural gas and electricity consumption was explained by inequality in consumption. The considerable inequality effects on energy consumption could explain through the differences in energy-mix because of limitation in gas facilities in Hormozgan, Bushehr, Sistan and Baluchestan, and Kermanshah provinces or farmer tendency to electro pumps, diversity in activities, and etc. Therefore, Theil index is an independent variable applied in models to survey the effects of policies on energy consumption.

Table 11. Result of models

Equations	Without Theil index	With Theil index
Gasoline (1)	44%	65%
Gasoline (2)	40%	74%
Natural Gas	65%	88%
Electricity	65%	97%

Estimation Results

Finally, econometric models for all types of energies were estimated and reported in the following tables. The first part of Table (12) represented the results of the gasoline reduction model, in which the estimated model provided sensible results than the intercept-only model, as the null hypothesis of the F-test was rejected. Independent variables including gasoline price, GDP, number of electro pumps, subsidy removal phases, and Theil index could explain about 65% of the per capita gasoline consumption. In this regard, gasoline price, GDP, number of electro pumps, subsidy removal phases, and Theil index were significant at 1%, 5%, and 10% level of standard error, though energy standard was not effective on per capita gasoline consumption. According to the result, a 1% increase in gasoline price led per capita gasoline consumption to decrease about 0.14%. Implementing any step to remove gasoline subsidies by the government decreased 0.18% of per capita gasoline consumption in the agriculture sector of Iran's provinces. 0.16% of farmer's gasoline consumption reduced due to an increase in the number of electro pumps. However, a 1% enhancement in farmer's income level increased 0.23% of per capita gasoline consumption. Also, any percent increase in the gasoline inequality rose 1.46% of farmer's gasoline consumption.

Results of the second model for gasoline consumption represented in the following part of Table (12). According to the results, 74% of per capita gasoline consumption was explained by gasoline price, GDP, subsidies, High-Quality gasoline, and the Theil index as well. Estimated coefficients were reliable for interpretation since the F-test was significant at a 1% level of standard errors. Gasoline price, GDP, subsidies, high-quality gasoline, and the Theil index were significant, while the greenhouses development plan was not effective on gasoline consumption. 1% increase in farmer's income and government subsidies for gasoline consumption, increased 0.24% and 0.15% of gasoline consumptions, respectively. Despite high-quality gasoline in the agriculture sector, energy consumption increased about 0.15%, although a reduction in per capita consumption was expected. Gasoline price had a reduction effect on consumption as was evident from coefficients sign, so that 1% increases in gasoline price, led farmer's to decrease 0.22% of the gasoline consumption in their activities. Moreover, a 1% increase in inequality of gasoline consumption increased gasoline consumption by about 0.6%. As a result, it is clear that some of the gasoline-related policies, like vehicle energy standards, greenhouse development were ineffective, and high-quality gasoline had a paradoxical effect on consumption. Outdated farm vehicles, easy access, and cheap gasoline could be a reason for the unexpected result. The rest of the gasoline-related policies had an optimal impact on consumption, in which price-related policies including subsidy was the most effective factor on gasoline consumption.

In the case of natural gas energy, the result of the estimated model was available in Table (13). According to the table, the F-test result confirmed the validity of estimated coefficients for further investigation. 88% of per capita natural gas consumption explained by independent variables in which farmer's income, energy price, biomass consumption, inequality index, and government policies such as replacement of fossil fuels instead biomass and subsidy removal phases were effective on natural gas consumption. Among all policies and plans, the greenhouse development plan was not effective, as also highlighted in the gasoline consumption model. A 1% increase in natural gas price, decreased about 0.12% of consumption between users. An increase in income level of farmer's developed the per capita natural gas consumption, in which 0.46% increase in consumption followed by a 1% increase in GDP.

Table 12. The empirical result of the gasoline models

Equations	Variables	Coefficient	S.E	P-Value
Gasoline (1)	Gasoline Price	-0.14*	0.09	(0.1)
	GDP	0.23*	0.14	(0.1)
	Energy Standard	-0.002	0.00	(0.19)
	Number of Electro pumps	-016**	0.08	(0.05)
	Subsidy Removal Phases	-0.18*	0.09	(0.06)
	Theil Index	1.46***	0.18	(0.00)
	R^2=66%		F=(6,190)=13.46***	Prob=(0.00)
Gasoline (2)	Gasoline Price	-0.22***	0.07	(0.00)
	GDP	0.36***	0.14	(0.01)
	Gasoline Subside	0.24**	0.11	(0.04)
	Greenhouses development	0.00	0.00	(0.90)
	High-Quality Fuels	0.15***	0.05	(0.00)
	Theil Index	0.6***	0.14	(0.00)
	R^2=74%		F=(6.168)=6.93***	Prob=(0.00)

Note: Standard errors * $p < 0.1$, ** $p < 0.05$ and *** $p < 0.01$.

Gasoline subsidy removal by the government increased 0.81% of per capita natural gas consumption. This action could be clear proof of an increase in gas consumption because of an increase in gasoline price. This action could be clear proof of an increase in gas consumption because of an increase in gasoline price in the provinces, where were not gas facility limitations. Due to a 1% increase in natural gas supply for the biomass user, energy consumption increased. This issue was obvious in biomass consumption coefficient as well. An increase in natural gas supply supported biomass sustainability, as most farmers used biomass for heating matters. Differences in natural gas consumption between provinces intensified the consumption. 0.42% of increase in per capita natural gas consumption was due to about 1% increase in the Theil index. Finally, according to the estimated coefficients, most of the natural gas-related policies were an incentive to people, who needs alternative energy, especially for biomass and gasoline users. This status has happened because of the subsidy removal phase's policy, which could replace one of the GHG contributors in this sector.

Table 13. The empirical result of the natural gas model

Equations	Variables	Coefficient	S.E	P-Value
Natural gas	Natural gas price	-0.12**	0.05	(0.02)
	GDP	0.46**	0.12	(0.04)
	Greenhouse development	0.07	0.07	(0.37)
	Biomass consumption	-0.02	0.10	(0.80)
	Replacement fossil fuels instead Biomass	0.33**	0.16	(0.05)
	Subsidy removal phases	0.81***	0.14	(0.00)
	Theil Index	0.42*	0.23	(0.07)
	R^2=88%	F=(7,32)=22.70***	Prob=(0.00)	

Note: Standard errors * $p < 0.1$, ** $p < 0.05$ and *** $p < 0.01$.

About electricity consumption, as if evident in Table (14), the estimated model and coefficients were valuable for assessment since the R^2 was 97% and the computed F-tests rejected the null hypothesis. Among all independent variables, electricity price, income, subsidy removal phases, greenhouse development plan, number of electro pumps, and also the Theil index were significant at the 1%, 5%, and 10% levels of standard errors. As expected, the energy price had a reduction effect on consumption, so that a 1% increase in electricity price, decreased about 0.10% of consumption between users. Any growth in income level was pushed forward the users to increase in electricity consumption. 0.17% of enhancement in per capita electricity consumption was followed by about a 1% increase in income level. About policies, most of them were an incentive for consumption while the greenhouse development plan smoothed sharp consumption. In this regard, gasoline subsidy removal phases in 2010 and 2014 decreased 0.18% of electricity consumption. It means that the user tried to consume more electricity as if explainable through the number of electro pumps increases, as well. The greenhouse development plan decreased the consumption in which a 1% increase in the area of cultivation in greenhouses could decrease about 0.4% of per capita electricity consumption. Educational training to agricultural activists could not be beneficial in electricity consumption. Regarding the Theil index, about 0.58% increase in per capita electricity consumption was due to a 1% increase in electricity inequality between provinces. To sum up, most of the electricity-related policies, like the case of natural gas, have been effective and successful in replacement to gasoline. Besides, they have been a great motivation to use more electricity in agricultural activities, while sustainable policies couldn't help for optimal consumption.

Table 14. The empirical result of the electricity model

Equations	Variables	Coefficient	S.E	P-Value
Electricity	Electricity price	-0.10***	0.03	(0.00)
	GDP	0.17***	0.06	(0.01)
	Subsidy removal phases	0.18**	0.08	(0.04)
	Greenhouse development	-0.04*	0.02	(0.10)
	Number of Electro pumps	0.12***	0.02	(0.00)
	Educational Training	0.09	0.06	(0.15)
	Theil Index	0.58***	0.04	(0.00)
	R^2=97%	F=(7,190)=32.43***	Prob=(0.00)	

Note: Standard errors * p < 0.1, ** p < 0.05 and *** p < 0.01.

Results of post-estimation tests were presented in Table (15). According to the results, all coefficients in different types of energy models were between upper and lower confidence intervals, therefore estimated coefficients were stable during the period. The null hypothesis of the Jarque-Bera tests rejected at 1% error levels which revealed the normal distribution for all models. Pesaran cross-sectional independence test results rejected the correlation hypothesis between residuals.

Table 15. The empirical result of post-estimation

Model	Coefficient Stability	Normality	CD
Gasoline (1)	All Coefficient was stable	14.04***	8.28***
Gasoline (2)	All Coefficient was stable	58.60***	10.10***
Natural Gas	All Coefficient was stable	57.83***	4.5***
Electricity	All Coefficient was stable	51.98***	11.29***

Note: Standard errors * p < 0.1, ** p < 0.05 and *** p < 0.01.

Conclusion

In the study, we tried to examine the effects of energy-related policies and plans on energy consumption (including gasoline, natural gas, and electricity) in the agriculture sector of Iran's provinces by considering the inequalities in energy consumption during 2001-2016. The study was carried out because of the following reasons. Primary, CO_2

emissions doubled in the agriculture sector of Iran's provinces due to the high amount of fossil energy consumption during the last decades, which needs more care in terms of energy-environment policies. In this regard, an investigation on the applied energy-environment policies to achieve a sustainable environment was a necessary matter. Second, the agriculture sector has been one of the world GHG emissions and climate change factors, which have not been addressed in studies related to energy-environment. Third, most of the energy-related policy studies have been general and not carried out at a specific sectoral level. Therefore, focus on agricultural energy policies could help us to evaluate the effects of implemented policies on consumption and to achieve a sustainable environment through precise policymaking. Forth, because of the differences in terms of socio-eco and geo features between regions, inequality and differences should be considered in small-scale studies. For this aim, first of all, inequality issue in energy consumption measured and analyzed by Theil index, then the effects of energy-related policies in regard to differences in energy consumption examined at the provincial-level through panel data approaches. Results of the Theil index highlighted the considerable difference in gasoline, natural gas, electricity, and also CO_2 emissions in a group of provinces. Differences increased after 2010 when the government tried to remove the small part of subsidy in gasoline prices, and farmers tried to a find a new alternative energy. It seems that this policy intensified the inequality in energy consumption between provinces of the group. According to the Hausman test, the Fixed-effect approach was selected for the following procedure. Results of the FE model revealed that effective and ineffective policies, in which greenhouse development, energy standards were not effective, and high-quality fuel had a paradoxical effect on gasoline consumption. Old and inefficient farm vehicles, cheap gasoline, easy access to gasoline were sensible reasons for the unexpected results. Subsidy removal phases had reduction effects, but according to the measured Theil index, it would have a helpful impact, if the difference in energy consumption had been considered. Among all, electro pumps could smooth the gasoline consumption through using electricity in water pumps. In the case of natural gas and electricity, policies were a great incentive to use more, and farmers tried to change the energy-mix with natural gas and electricity, which became one of the CO_2 emissions sources. The results of the study were similar to Agheli (2015), Si et al. (2018), Hao and Dong (2018), Zhang et al. (2019), Morovati et al. (2019), and Proqrue et al. (2020), but different with Barba (2012), Yang et al. (2015), Yi et al. (2015), Xu and Lin (2018), Zhang et al. (2019), and Adua et al. (2021).

To sum up, implemented policies to reduce gasoline consumption were not successful and not enough to control consumption, as they intensified inequality, and replaced the new fossil resources. According to the results, we suggest removing the unsuccessful policies such as gasoline standards, greenhouse development plans, high-quality gasoline, subsidy removal phases, and educational training for electricity reduction, unless the government tries to expand the utilization of new and efficient technologies between farmer. In regard to inequality issue, policies should be at the provincial scale and match with the economic and agricultural activities features. Price-related policies had significant effects on consumption; efficient regional price policies could be helpful for control. Besides, renewable energy policies like Feed- in- Tariff to the utilization of renewable sources could be beneficial at a regional scale.

It is for sure that researches will have some limitations and it is normal. However, it is critically important for us to be striving to minimize the range of scope of limitations throughout the research process. The limitations of the study were time period, and, lack of previous research studies on the topic. Future studies need to develop the research database, examine the potential of policies, and implement dynamic methods.

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