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### Article

# The dynamic of discriminatory reform: How does discretionary pricing neutralize the productivity gains of energy subsidy reform in Iran?

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#### APPLIED ECONOMETRICS

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## The dynamic of discriminatory reform: how does discretionary pricing neutralize the productivity gains of energy subsidy reform in Iran?

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#### ABSTRACT

A distortion caused by previous policies could distort the results of reforms. This may explain why policies to reduce industrial fuel subsidies have not necessarily resulted in increases in aggregate productivity in countries with mandated pricing. To identify and measure these distortions' effects, we estimate a structural dynamic firm model with endogenous technology adaptation using data from the manufacturing firms in Iran. By connecting two price distortions and their results on the real sector, results suggest significant room for a distributional policy. We estimated dispersion elasticity comparable to the price elasticity of energy consumption in the manufacturing sector. Results suggest that the intensive margin is the primary driver of energy price elasticity, whereas the other channels mostly offset it. Moreover, total factor productivity slightly improves in light of a reduction in energy consumption if, at the same time, the redistribution policy boosts the aggregate demands.

#### **ARTICLE HISTORY**

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#### **KEYWORDS**

Energy reform; firm dynamics; structural estimation; subsidy policy

#### 1. Introduction

What are the consequences of energy policies when firms endogenously decide about entry, exit, technology adoption, investment, and employment of other inputs? A standard recommendation would be to cut price interventions so that the market can determine prices. From a budget perspective, this suggestion is the first best, but the effects on the industry and total production are unclear. However, there is no such thing as "energy good", and different firms with heterogenous production functions face baskets of energy with varying prices. Consequently, firms choose their energy inputs based on their specific production methods. It is worth considering that these heterogeneous production methods are probably the result of the previous intervention policies of policymakers.

Unfortunately, some of these changes are fundamental and irreversible, while others have political and social costs that make it practically impossible to return to non-

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intervention and first-best policies. In this situation, it must be asked how the discrepancy in rates of various energy inputs translates to efficiency in the manufacturing sector. In addition, do these policies cause manufacturing firms to misallocate resources?

This article examines the effects of these policies on the formed production function as well as the energy price of firms. These methods imposed on the company are considered exogenous shocks, which answers the question: Would removing the energy tariff necessarily improve the welfare of the enterprise and increase productivity? It does not directly investigate the reason for energy price and aggregate productivity heterogeneity. For this goal, the production function and fuel type of a firm are calibrated based on Iranian manufacturing data. After calibrating the shocks and firms' behavior, dynamic coefficients are estimated with and simulated method of moments (SMM). In the SMM, the effective coefficients in the dynamic behavior of the firms are matched to the moments of the data to measure the welfare effects of the reform.

A reform can influence the industry in four channels. Higher energy prices make firms consume less energy; therefore, they turn out to be smaller than an economy with subsidized energy prices. Literature has studied and understood this channel called intensive margin. However, an energy reform will alter profits on margins; consequently, it forms the dynamic and distribution of firms. Subsidy removal eliminates rents to the incumbent firms and expedites exit as well as entry. The third channel is the desire of firms to employ less-intensive energy equipment. Finally, the reform produces revenues for the government. Her decision on how to re-distribute is critical on aggregates. The channels are inter-connected but act in diverse respects on macro variables.<sup>1</sup>

This paper constructs and estimates a firm dynamic model suitable to study an energy reform to quantify the extensive margin, the intensive margin, the technology channel, and the re-distribution policy. Energy is an intermediary in the production process. Nonetheless, the level of energy use is endogenous concerning both productivity and energy technology. The paper estimates the production function with mild timing assumptions and instrumental variables. In this framework, by knowing the energy prices and productivity as well as the distribution of competitors, the firm decides on technology, entry and exit, investment, energy consumption, and the extent to hire labor. The equilibrium is a time-invariant distribution that clears the labor and goods market. We estimate the structural parameters using moments from the Iranian Manufacturing Plant Survey.

Using the structural model, we introduce two types of reforms (1) increasing the energy prices for all firms, and (2) reducing the dispersion of energy prices while keeping the average as before. We find that distributional policy is as significant as the policy that reduces the rates. Therefore, we find that the distributional analyses of energy reform are of crucial significance. Interestingly, we show that when we allow for the entry and exit of firms, a distributional policy manifests itself as intensive margin as well as extensive margins. The findings establish that technological adaptation plays a small role in energy reforms. In contrast, the policy on how to re-distribute revenues matters significantly.

Regarding the data, we observe three stylized facts about energy pricing in the Iranian industry in the period starting from 2011 to 2017. First, unlike the period 2010–2011,

<sup>&</sup>lt;sup>1</sup>This decomposition has a vast literature. see Farrow and Krautkraemer (1989)–Dedola et al. (2021)–Knittel and Sandler (2011)

when there was a sharp increase in tariffs due to reduced energy subsidies, the relative price of fuel in this period is almost constant (Figure 2). Second, as we discussed in the data section, we expect fuel price heterogeneity in this data. Finally, it is the government's annual price control of different fuels, which does not necessarily follow global price fluctuations. As we discuss in the data section, natural resource is abundant in Iran and the government failed several times in reforming its energy sector and reducing its energy subsidies. Compared to the prices in the U.S, the gas rate is about one-tenth, and the price of electricity is one-third on average. The energy subsidy accounts for more than 20% of GDP (see Bárány and Grigonytė (2015), Coady et al. (2017), Davis (2014) and Del Granado et al. (2012)) and is about \$ 35 billion annually (Shirai & Adam, 2017). Moreover, there exist substantial variations in energy prices mainly because of differences in fuel carriers, geography, and plans to support specific industries. The extent and the distortion in subsidies make it an important policy question to study.

The organization is as follows. The second section reviews the literature on firm dynamics and energy policies. In the third section, we introduce data and the economic environment. Section IV introduces the model and section V explains the estimation approach and estimated parameters. Section VI examines counterfactuals for policy reforms and concludes the final section.

#### 2. Literature review

Several aspects of this article contribute to the advancement of energy-related literature: It has been examined whether fuel tariffs have an effect on productivity, production, and welfare in a country that has spent one of the highest amounts on fuel subsidies. In addition, this article advances the technique of identifying the effect of asymmetric tariffs and allocation inefficiencies on industry efficiency in a structural model and determining the impact of any distortion on total productivity.

Firstly, this article examines the behavior of the industry in one of the countries with the highest subsidy rates and estimates the effect of fuel prices on the real sector by examining the behavior of the industry. With a similar goal, Olson (1988) and Hamilton (1988) show that inflation in fuel prices reduces production. In contrast, Kilian (2008) shows that this finding on GDP is not generalizable for all oil shocks. Kilian (2009) highlights the simultaneous effect of oil shocks and demand on the economy. Energy price movements have asymmetric effects among suppliers and consumers. Jimenez-Rodríguez and Sanchez (2005) investigate the asymmetric effects of oil shocks under a VAR framework. In a panel model of oil-producing countries, Mehrara (2007) concludes that raise in domestic energy prices does not necessarily lead to a recession. Moreover, Mehrara and NIKIOSKOUI (2006) find insignificant effects of energy price liberalization on economic growth. In a review of literature, Ozturk (2010) shows findings are inconclusive in energy-abundant countries.

Additionally, energy subsidy has a direct effect on welfare. It may lead to inefficient consumption according to allocation cost (Davis & Kilian, 2011), externalities, and environmental costs (Tiba & Omri, 2016). To evaluate the cost of energy subsidy, Coady et al. (2015) provide a worldwide estimate of energy subsidy welfare loss of around 5%, ranging from 14% in the Middle East to 2.5 % in advanced economies. Davis (2014) finds the annual economic loss of global fuel subsidies is about \$44 billion.

The contribution of this article regarding the effect of price on the real sector and welfare is limited to studying this issue in a specific setting (Iran after the removal of energy subsidies).

This article also identifies for the first time the distortion caused by asymmetric pricing of energy inputs for Iranian manufacturing firms. Interestingly, it measures this distortion effect on aggregate productivity and concludes that this inefficiency is on par with the subsidy effects in Iran for reducing productivity. Several studies quantify the impact of distortions and misallocation on various performances: Restuccia and Rogerson (2013) on production, La Porta and Shleifer (2014) on the extent of informal activities, and Hsieh and Klenow (2009) on aggregate productivity. Restuccia and Rogerson (2008) study the impact of regulation on the entry and exit of firms and their efficiency costs. Similarly, Hopenhayn (1992) had analyzed The effect of entry and exit policies in a dynamic stochastic model. Interestingly, Schutze et al. (2019) compare the impact of capital and energy distortion on aggregate productivity in Brazil using manufacturing data. They find that the distortion in energy productivity is secondorder compared to the inefficient investment, which suggests industry reforms. Singer (2019) examines the effect of electricity pricing and its dispersion on Indian industrial efficiency. He finds that total welfare losses are large and equivalent to 31% of sales, and the cost transfers to consumers.

The article also discusses factors influencing long-term changes in production function and technology adoption. This article's results are important because they estimate the effects of energy prices in an economy with one of the lowest energy prices in the world. Similarly, Peretto (2003) in an endogenous market structure examines the effect of trade barriers (e.g foreign good tariffs) on technology in manufacturing firms. Lambertini and Mantovani (2010) study a general equilibrium framework to address incentives in the diversity of products and cost reduction. With a similar structural approach, Bondarev et al. (2021) show that technology transformation in both incumbents and start-ups depends on the attractiveness of new technology. Moreover, Bondarev et al. (2021) examine (1) pollution tax, (2) standard pollution, (3) and standard efficiency on technology adaptation.

This paper also studies the response of aggregate variables to alternative policies. Similarly, Acemoglu et al. (2012) compare two pollutants and low-cost technology versus clean and expensive ones. They find that a temporary tax makes firms adopt clean technology, so earlier intervention is optimal. Golosov et al. (2014) take a step forward and solve the social best intervention in input prices under a general equilibrium framework. Our study has many similarities with these papers in terms of its general equilibrium technology adoption framework, in addition to the structural estimation of parameters.

In conclusion, it should be noted that this article has followed the path of several articles with many references in the literature from the perspective of research methodology. On the subject of misallocation calculations and distortion effects, we used the framework of Hopenhayn and Rogerson (1992) and (H. Hopenhayn & Rogerson, 1993). This article, however, focuses on the frictions caused by asymmetric pricing, rather than the policies in the field of wages and exit from the labor force. Using Linn's (2008) production function, it addresses the use of energy in the production function and the concept of technology adoption. As opposed to the regression approach of that article, the concept of technology choice has been measured in a general equilibrium model and simulation. Further, this study examines the impact of asymmetric price policy on productivity loss rather than the very existence of technology adoption.

According to the literature, Levinsohn and Petrin (2003) has used a proxy approach for the estimation of productivity in the estimation of the production function. Nevertheless, based on the research question and the limitations of the introduced method, it was necessary to generalize the method, which is discussed in detail in the appendix.

#### 3. Data

The Statistical Center of Iran (SCI) collects panel data of manufacturing firms with 10 employees and more since 1975.<sup>2</sup> We focus on relatively consistent and less volatile real energy price years from 2011 to 2017.<sup>3</sup> Data provide information on labor counts, volumes, and expenses of intermediaries in particular energy carriers, investment, and capital value of plants.

To see the difference between fuel prices in Iran and the other countries, Table 1 compares the prices of two common fuels in Iran and the U.S. The reason for choosing the United States in this table is just for motivation sources, and it could be shown<sup>4</sup> in most countries fuel prices are significantly higher than in Iran, and even oil-exporting countries such as Qatar and Saudi Arabia have higher prices. It documents that energy price is much cheaper in Iran. Electricity tariffs on average are one-third the prices in the US and the rates for natural gas are about one-fourth. The median tariffs are 2.47 USC/ KWh and 0.89 USD/kcf for electricity and natural gas, respectively. In Iran, the energy supply is reliable compares to many countries. Natural gas is supplied nationwide to all firms and there are many policies to promote firms' move to natural gas as their input of

	Elect	Electricity		al Gas
Year	U.S.	IRAN	U.S.	IRAN
2012	6.67	2.43	3.88	0.90
2013	6.89	2.02	4.64	0.79
2014	7.1	2.53	5.62	1.04
2015	6.91	4.91	3.93	1.13
2016	6.76	2.53	3.51	1.09
2017	6.88	2.91	4.08	0.96
Average	6.87	2.89	4.28	0.99

 Table 1. Energy price in manufacturing sectors of Iran and US, 2012–2017.

Note: Average price of energy in the manufacturing sector. Data for U.S. firms from Energy Information Administration in 2017. Averages for Iranian firms are computed using Survey on Manufacturing Establishments. The price of electricity is USC/KWh, and for natural gas is USD/Kcf. We use the market exchange rate in Iran to convert Rial to Dollar.

<sup>&</sup>lt;sup>2</sup>For further description and application using this survey see Pilevari and Rahmati (2019) and Rahmati and Karimirad (2017). This data has limited access.

<sup>&</sup>lt;sup>3</sup>The SCI survey all firms with more than 50 employees but a sample of firms between 10 to 50 personnel.

<sup>&</sup>lt;sup>4</sup>For simple comparison see https://www.globalpetrolprices.com for different sources.

energy.<sup>5</sup> The country provides subsidized energy which boosts and economizes firms' production, even for low productive plants, and in return benefits from their political support. The subsidy is practically possible because Iran is the second-largest reserve of natural gas, and its export is very limited.

In our data, the largest annual natural gas for one firm is about 346 billion $m^3$ , Moreover, the top 1% and 10% of firms consume about 74% and 46% of total natural gas in the manufacturing sector, respectively.

Table 2 describes measures of firm productivity by employment size in 2017. Firms with more than 1200 employees account for 0.7% of observations but produce more than one-third of value-added. On the other hand, firms with less than 20 employees are 29% in counts with less than 5% shares in total value-added. Capital productivity, defined as the ratio of value-added to capital stock, declines as employment size gets larger. Industrial concentration on capital incentive sectors (i.e., steel, refineries, and petrochemicals) and the incentive toward capital-intensive machinery make these patterns. Likewise, the ratio of value-added to labor increases by firm size, suggesting a higher share of labor in small plants. A cross-sectional study of firms shows that energy-intensive firms face cheaper energy rates. Moreover, the energy intensity is negatively correlated with export orientation. The impact of energy prices and technology choices on export is beyond the scope of this paper.<sup>6</sup>

According to Table 2, energy productivity is higher in large firms, measured as the ratio of value-added to energy expenditures. Nevertheless, it depends significantly on the industry; for petroleum and coal products the measure is 0.18 compared to 0.06 in the food sector. Similarly, the value added to labor is also increasing by size. However, the

	Share in	Value-added to			
No. labors	Value-added	Capital	Labor	Energy	
<20	5%	3.55	1.58	0.05	
		(10.15)	(4.38)	(0.09)	
20–50	8%	4.12	1.64	0.06	
		(11.84)	(2.68)	(0.12)	
50–150	11%	3.46	1.95	0.08	
		(10.21)	(3.25)	(0.17)	
150-400	17%	1.73	2.8	0.07	
		(3.58)	(4.49)	(0.14)	
400-1200	26%	1.79	4.52	0.11	
		(5.42)	(10.66)	(0.27)	
1200<	33%	1.02	6.79	0.13	
		(1.17)	(10.19)	(0.33)	
All	100%	3.57	1.75	0.06	
		(10.21)	(4.1)	(0.12)	

Table 2	Measures	οF	productivity	across	firm	sizes	2017
	• Micusuics	U.	productivity	uci 055		51205,	2017.

Note: Energy price is the current price per "equivalent energy" (Btu). Labor is the sum of all the workers. Value-added per these variables are ratios of their expenses. Firm weights by SCI are applied to compute results. Numbers in parenthesis are standard deviations in each group.

<sup>6</sup>For further discussion on energy price, technology choice and export in Iranian manufacture sector refer to Rahmati, M. H., & Karimirad, A. (2017)

<sup>&</sup>lt;sup>5</sup>Rahmati, Seyedi, and Vesal (2019) provide detailed information on the national natural gas grid. More than 90% of home consumers use natural gas for heating and cooking purposes, and the national pipeline grid is connected to more than 97% of cities nationwide.



Figure 1. Distribution of Electricity and Natural Gas Prices, 2017. Note: see the calculation of the energy price. In the left figure, the dispersion in electricity prices charged by firms is in contrast to the right box and natural gas price. We see more variances in natural gas in contrast to electricity. All figures are depicted after cleaning the 1% of outliers. The source is the same.



Figure 2. Energy Price Distribution, 2012–2017. Note: Prices are non-dimensional by normalizing to the average wages. The middle line shows the average energy price each year. The distance between the bottom and upper line represents t5r% of the firm's energy price. The energy calculation is the same.

value added to capital declines as firms gets larger. This suggests that the study must consider and model the relationship between three inputs in a unified framework.

Figure 1 shows that the dispersion of energy prices is considerable. The average electricity price is 3.1 USC/KWh, the median is 2.9 USC/KWh and the rate is 4.2 USC/ KWh for the top 1% of firms. Similarly, the average natural gas price is 1.6 USD/kcf, the median is 1.4 USD/kcf, and the 90 percentile is 2.25 USD/kcf. The ratio of average electricity and natural gas prices of the top 10% and bottom 10% of firms are both 2.1. This variation stems from central pricing by the government. Natural gas and electricity

Panel a: Electricity price dispersion

Panel b: Natural Gas price dispersion

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distribution companies are public entities. The prices vary with geography, plant production, input voltage, establishment year, and special zone location, among other factors.<sup>7</sup> All these factors are set by the central government, not a market variation. We see some energy price variations in the US, but we argue that they are mainly the results of market interactions.<sup>8</sup> In the Us, if the transport of energy is costly to a location, the firm must pay higher rates. In addition, Figure 2 shows that both the average and the distribution of energy prices vary over time. A mild increase in the average energy price in 2015 is associated with an extensive dispersion in its distribution. This highlights the significance of stochasticity in energy prices.<sup>9</sup>

#### 4. Model

The model economy is populated by households, the government and the heterogenous firms: A household demands goods and supplies the labor force, the government sets energy prices and distributes tax revenues, and two types of firms: manufacturing and non-manufacturing sectors.

At each period, perfectly competitive manufacturing firms employ capital, labor, and energy to produce. For simplicity, the non-manufacturing sector relies only on labor. The household seeks to maximize utility and the firm maximizes profits. In contrast, the government is passive and set a Markov process for energy prices. We are interested in the heterogeneous behavior of firms on their technology adaptation, as well as their entry and exit decision. Therefore, we need stochastic uncertainty on both productivity and energy prices shocks.

The problem of each sector is as follows:

Similar to Hopenhayn and Roggerson (1993), firms are either incumbents or entrants. An incumbent, knowing her specific energy price  $(p_{it}^E)$  and productivity  $(A_{it})$ , decides the optimal energy consumption  $(E_{it})$  and the labor demand  $(L_{it})$  by maximizing her static profit.

$$\pi^* \big( \mathbf{K}_{it+1} | \mathbf{K}_{it}, A_{it}, A_i^E, p_{it}^E, \mathbf{p}_t^L, \mathbf{P}_t \big) = \max_{l_{it}, E_{it}} \big\{ \big( \mathbf{p}_t \mathbf{Y}_{it} - \mathbf{p}_{it}^E \mathbf{E}_{it} - \mathbf{p}_t^L \mathbf{L}_{it} \big) - \mathbf{H}(\mathbf{K}_{it}, \mathbf{K}_{it+1}) - c_{Fi} \big\}$$
(1)

A firm's profit( $\pi^*$ ) at each time is determined by capital productivity( $K_{it}$ ), energy usage technology( $A_i^E$ ), energy price( $p_{it}^E$ ), labor price( $p_t^L$ ), and price of homogenous final goods ( $p_t$ ) (capital is the final product) During any period, the profit of the firm is based on the optimal amount of energy( $E_{it}$ ) and labor( $L_{it}$ ) used so as to maximize production( $Y_{it}$ ) after deducting the costs associated with these two inputs. In addition, the firm pays a fee (H) based on the amount of capital in this period and in the future period, while firm-specific time-invariant fixed cost ( $c_{Fi}$ ) represents the company's fixed costs. As a result, it

<sup>&</sup>lt;sup>7</sup>For more detail see https://tariff.moe.gov.ir/

<sup>&</sup>lt;sup>8</sup>According to eia(https://www.eia.gov/consumption/manufacturing/data/2018/xls/Table7\_2.xlsx) in 2018, there exists a vast variation in price of energy (dollar for MBtu) between sectors and even different region in the US. For example, Printing and Related Support firms pay twice the food industry for the same amounts of energy. Moreover, even in the same region and industry these variations are not ignorable and standard errors of the prices are in the same degree of its average prices.

<sup>&</sup>lt;sup>9</sup>A similar pattern can be documented in the firm level, where firms face stochastics the energy prices over time.

is necessary to specify the production function itself as well as the costs related to the change in capital level in the following way:

The production function is:

$$Y_{it} = K_{it}^{\alpha_k} A_{it} \left( (1 - \alpha) L_{it}^{\rho} + \alpha \left( A_i^E E_{it} \right)^{\rho} \right)^{\frac{1}{\rho}}$$
(2)

Here,  $A_i^E$  is technology level, and we define the firm specific state variable as  $S_{it} = \{K_{it}, A_{it}, A_i^E, p_{it}^E, p_t^L, p_t\}$ .  $A_i^E$  will be exogenous assigned after entering. In this production function,  $\alpha_k$  is the elasticity of capital,  $\nu$  is the elasticity between static inputs (labor and energy) and dynamic inputs (capital),  $\rho$  is the elasticity of substitution between labor and energy, and  $\alpha$  is the energy-labor weights in production.H(K<sub>it</sub>, K<sub>it+1</sub>) represents the investment expenditure due to capital accumulation such as:

$$H(K_{it}, K_{it+1}) = (K_{it+1} - (1 - \delta)K_{it})p_t^k$$
(3)

Here,  $\delta$  is the depreciation rate,  $\xi$  is the coefficient for investment cost, and  $p_t^k$  is the capital relative price. Firms decide on their next period level of capital based on their value functions:

$$V^{inc}(S_{it}) = \max_{K_{i,t+1}} \pi^* \left( K_{i,t+1} | S_{it} \right) + \beta (1-\Delta) E_{A_{i,t+1}, p^E_{i,t+1} | A_{i,t}, p^E_{i,t}} V \left( S_{i,t+1} \right) - c_F \tag{4}$$

Here,  $c_F$  is the production fixed costs, $\beta$  is the discount factor, and  $\Delta$  is the exogenous exit rate. For the endogenous exit, at the end of each period, a firm decides to continue or to exit the market:

$$V(S_{it}) = \max\left\{V^{inc}(S_{it}), (1-\delta)K_i\right\}$$
(5)

There are unlimited potential entrants. An entrant pays the entrant costs ( $C_e$ ) and observes her specific energy price  $p_i^E$ . So, in a competitive market the value of entry on average is zero, so:

$$\int V^{ent}(0,0,p_i^E,0)d\Omega(p^E) \ge p_t C_e \tag{6}$$

Based on her specific energy price, she decides on the capital  $K_i$ .

$$V^{ent}(0,0,p_{i}^{E},0) = \max_{A_{i}^{E},K_{i,t+1}} \left\{ E_{p_{i,t+1}^{E},A_{i,t}^{L}p_{t+1}^{L},P_{t+1},A_{i}^{E}} V^{inc}(S_{i,t+1}|p_{i}^{E}) \right\}$$
(7)

 $c^{T}(A_{i}^{E})$  is the cost associated with the adapted technology. The Iranian manufacturing sector accounts for about one-seventh of the GDP.<sup>10</sup> The non-manufacturing sector use labor  $(L_{N})$  to produce:

$$Y_N = L_N \tag{8}$$

Household utility comes from consumption)  $C_t$  and leisure  $(l_t)$ . In equation 9, the household maximizes its utility based on these two components in an infinitely periodic manner.

<sup>&</sup>lt;sup>10</sup>See the Iranian national account from its statistical center: https://amar.org.ir/english/Statistics-by-Topic/Nationalaccounts

$$\sum_{t=0}^{\infty} \beta^t [\ln(C_t) - Aln(l_t)]$$
(9)

Equation 10 also shows the constraints of the household budget in each period in such a way that the household determines the amount of consumption expenditure in each period in such a way that it is less than its expenses (equal in equilibrium). Household incomes in each period include aggregate profit ( $\Pi_t$ ) they own, supply their labor( $L_t$ ) and pay the government tax ( $T_t$ ).

$$p_t C_t = L_t + \Pi_t + T_t \tag{10}$$

Equation 10 shows the consumption production function. Consumption good is a combination of manufacturing goods  $(c^M)$  and non-manufacturing outputs  $(c^N)$ .

$$C_t \le c_t^{N\alpha_c} c_t^M 1 - \alpha_c \tag{11}$$

In the government sector Energy belongs to the government and will export its endowment net domestic demand to the international market with the exogenous price  $(p_e^*)$ .

$$T = p_e^* \left( E_0 - \int E_f^d(S) d\mu(S) \right) + \int E_f^d(S) p_i^E d\mu(S)$$
(12)

Before solving the model numerically and estimating the optimal coefficients, it is necessary to stationary competitive equilibrium define it well: As this paper focuses on fuel subsidies and misallocation, we assume that all firms have the same final prices but heterogenous energy prices and productivity.

So, in equation 13 energy prices and productivity follow Markov processes. In the equilibrium,  $\mu(S)$  is the stationary equilibrium distribution and M is the mass of entrants,  $\Omega$  is the distribution of entrants:

$$\mu'(s') = \int [1 - X(S)] dF(s'|S) d\mu(S) + \int M \, dF(s'|0, 0, p_i^E, 0) d\Omega(p_i^E)$$
(13)

Moreover, in the equilibrium capital and labor clear markets.

$$C_t \le c_t^{N\alpha_c} c_t^M 1 - \alpha_c \tag{14}$$

$$L_{Mt} + L_{Nt} = L^D = L^S = P_t C_t A \tag{15}$$

As mentioned before, we need to add non-manufacturing in the general equilibrium with clearing conditions:

Relationship 16 shows the settlement of the final good market.

$$p_t C_t = p_t^N c_t^N + p_t c_t^M \tag{16}$$

Solving the non-manufacturing sector we have:

$$A_N P_t^N = 1 \tag{17}$$

By solving the consumption condition(eq. 14) and non-manufacturing sector problem we get equation 18 as follows:

$$c_t^N p_t^N = A_N L_t^N = \frac{\alpha_c}{1 - \alpha_c} c_t^M p_t = \frac{\alpha_c}{1 - \alpha_c} \left[ T + p_t \int Y_i(S) d\mu(S) \right]$$
(18)

#### 5. Estimation method and results

We estimate parameters in three steps: (1) estimation of the production function, (2) calibration of macro variables, and (3) running simulated method of the moment to estimate the structural parameters. Equation (2) describes a firm's production as a function of two static inputs (labor and energy) and a dynamic factor (capital). Olley and Pakes (1996) and Levinsohn and Petrin (2003) discuss that static inputs are a function of unobserved errors, i.e., productivity, so special consideration is necessary to capture this endogeneity.

They benefit from information embedded in other intermediaries, as a proxy, to extract unobserved information and then estimate the elasticities. The firm's production function includes two endogenous variables, labor, and energy that deviate from the standard approach and need additional proxies. Furthermore, like Linn (2006), the model assumes that technology, which is an unobservable to econometricians, is endogenously put in place by firms. To solve this estimation issue, following Blundell and Bond (1998), we benefit from time restrictions. We assume technology is chosen before the realization of productivity and is fixed through the life-cycle of firms. This assumption is consistent with the reality that technology amendments require massive investments; consequently, few firms make such a move after seeing a temporary shock.

As discussed by Ackerberg et al. (2015), this approach is identical to impose orthogonal moments and estimate parameters. Noticeably, knowing the parameters of the production function and the panel structure of data, we can drive both the productivity  $(A_{it})$  and the technology level  $(A_i^E)$  for each firm at each year. The appendix describes the method in detail, But briefly at this stage the goal is to estimating the production function in forms of:

$$Y_{it} = K_{it}^{\alpha_k} A_{it} \left( (1 - \alpha) L_{it}^{\rho} + (\alpha) \left( A_{it}^E E_{it} \right)^{\rho} \right)^{\overline{\rho}}$$

Because of bias arisen by correlation between unobservable productivity shocks and input levels, we use an extension of Levinsohn and Petrin (2003), Xi (2012) algorithm which intermediate inputs can also solve this simultaneity problem, Where rho is  $\rho = (\sigma - 1)/\sigma$  (The estimation steps which are similar to Levinsohn and Petrin (2003) are given in the appendix). Table 3 shows the results for our estimates of parameters in the first step.

Notice that shares in this three-input model is not comparable to the standard two input Cobb-Douglas framework. For example,  $\alpha_k = 0.07$  is much smaller than comparable estimates of capital shares. The main reason is that we have third input such as energy that accounts for 5.9% of the value-added in our data. The estimated parameters

Table 3. Parameters of production function.

Parameter	v	ρ	a <sub>k</sub>
Mean	0.61	0.68	0.07
STD	0.007	0.02	0.002

Note: production function estimated in a similar method to Levinsohn and Petrin (2003) see part V for the firms in Iran in 2011–2017 indicate that the elasticity of substitution between labor and energy is about  $\sigma_{lE} = \frac{1}{1+\rho} = .59$  and the *v* indicates the decreasing scale economies.

In the second step, we calibrate macro-parameters particularly those related to the non-tradable sector. In addition, knowing the production function, we can construct a series of stochastic variables like productivities to estimate their Markov processes. Table (A) in the Appendix shows estimates of these parameters.

In the third step, we estimate the five key structural parameters that determine the dynamics of the model. The entrant cost  $(C_e)$  balances the incentive of potential entrants, so they obtain an expected zero profits. The technology costs  $(C^T)$  determines the distribution of high technology, the fixed cost  $(c^F)$  cause endogenous exit of firms while exogenous exit is governed by destruction rate  $(\Delta)$ . All these parameters shape the firm distributions, which depends on counterpart information in data. Moreover, the adjustment cost  $(\xi)$  influences how fast the capital responds to shocks. Therefore, five moments of (1) the firm size, (2) the average technology, (3) the ratio of value-added to profit, (4) the number of firms, and (5) the ratio of value-added to investment are used to estimate the parameters. Table 4 reports the moments in data and our estimates using the structural models.

Table 4 shows a considerable distance between data and the model results, particularly for two moments: "average technology of + 50 firms" and "investment to the value-added ratio for + 50 firms". The gap is probably the result of inaccurate data measurement and missing observations. In our sample, 8% of non-entrant firms increase their capital stock by more than 20% in a consequent year. This skewed distribution shows inexact growth reports by respondents. Similarly, the information on the entry and exit of small firms could be more reliable if we had a census rather than a sample for firms with less than 50 employees. For example, we missed the first year of 30% of entrants in 2015 whom we observed their records in subsequent years.

Table 5 displays estimates of the structural parameters and their standard errors. It shows that the fixed cost parameters are about 80% of the entrant cost. Firms exit the market with an exogenous likelihood rate of 0.32, while their endogenous exit rate is about 10%. The exogenous destruction rate is high relative to other countries, but it has roots in volatile macroeconomic conditions. In the whole economy, the magnitude of the adjustment cost of investment to the capital depreciation parameter is about one-third of the fixed cost parameter.

Some parameters in Table 5 have high standard deviations almost as a degree of the estimation mean. Notably, their estimates are challenging in the literature, mainly because the technology is unobserved in our study. Ryan and Tucker (2012) estimate the fixed cost of adaptation of video calling technology using the realized usage

Moment	average size of + 50 firms	average technology of + 50 firms	relative profit to value- added ratio for + 50 firms	Number of + 50 firms	investment to value- added ratio for + 50 firms
Model	123	21.5	0.43	6350	0.18
(STD)	(19.1)	(.9)	(.1)	(1301)	(.13)
Data	104.5	15.9	0.38	5038	0.12

Table 4. Estimated moments in model and data, simulated method of moments.

Note: related moments are matched with the Iranian manufacturing establishments data(2011-2017).

Relative parameter	Entrant cost	Technology costs	Fixed cost	Destruction rate	Investment adjustment costs
mean	53.96	193.1	44.2	0.32	16.07
STD	27.3	198.5	38.14	0.26	17.38

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lable	5. Estimates	of S	structural	Parameters,	Simulated	Method of	f Moments.
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Note: Estimated parameters with "Table 4" moments. Parameters means and standard errors. All other parameters were estimated in earlier stages.

technology, but their model faces as low statistics as ours. This issue worsens in the presence of aggregate shocks and low-quality data, as is in our study. Further, the nature of the two-stage estimation deteriorates the significance; the noise in the first stage weakens the power of the second stage. However, the estimates are still jointly significant, and the alternative approaches provide the same results.<sup>11</sup>

Moreover, Table 6 shows the outcome of additional key moments out of the simulated method of the moment to provide external validation for the accuracy of the estimated parameters. The result shows that the estimated parameters offer a reasonable fit of the model to data. As we discussed above, the two important state variables are energy productivity and energy prices. Therefore, the distribution of resources, which is determined endogenously in a firm dynamic framework, examines the results. Table 6 shows that productive firms account for 84% of value-added in both model and data while accounting for just 26% of the labor. They also consume relatively the same share of energy as their value-added shares. About half of the firms face high energy prices and account for 26% of value-added and 26% of the energy consumed (in Btu). These firms are relatively smaller, and their total share of labor is 27%. Another robustness check of estimates is the sensitivity analyses of parameters. A 10% variation in parameters leads to

Moments	Data (Std)	Model (Std)
Share of firms with hig	h energy productivity in tot	al
Count		
Value added	0.82 (0.004)	0.74 (0.005)
Labor	0.56 (0.002)	0.73 (0.026)
Capital	0.82 (0.004)	0.93 (0.002)
Energy	0.83 (0.005)	0.84 (0.031)
Share of firms with hig	h energy prices in total	
Count	57 1	
Value added	0.26 (0.000)	0.33 (0.057)
Labor	0.27 (0.003)	0.42 (0.075)
Capital	0.20 (0.002)	0.36 (0.123)
Energy	0.26 (0.000)	0.44 (0.035)

 Table 6. External validation of estimates, additional moments in data and model.

Note: these are the chosen moments that have an impact on our counterfactual analysis. Value-added and capital are been cannot be seen without price in data so they become normal by dividing the average wage. For more information about the data see the data section.

<sup>&</sup>lt;sup>11</sup>A detailed discussion of these factors and others which contributed to the gap between data and model and increased standard deviation, as well as why the results remain valid despite such flaws in the data and model, is presented in the Online Appendix on authors' websites.

about a 1% deviation in aggregate outcomes such as numbers of firms, total value-added, capital and labor, and their associated distributions.<sup>12</sup>

#### 6. Counterfactual results

We introduce four channels that energy subsidy may reduce efficiency and production: (1) distortion in extensive margins like suboptimal entry and exit, (2) intensive margin distortions like over-sized firms due to undercutting prices, (3) technology channel in which firms adopt low-efficiency machinery (4) resource allocation channel, on how the government distributes the revenue of reforms among firms and households. There are two distinct policies that can mitigate subsidy: (1) increase in the average price of energy by 1% kept the price distribution as before (2) reduction in the standard deviation of price distribution by 1% kept the average price level unchanged. We call the former the "Average" policy, and the latter the "Distributional" policy. Policymakers often mean by "subsidy reform" as the Average policy, but we will show that the Distributional policy is as important as the former. Table 7 shows the counterfactual results of these two policies at the firm level, industry aggregate, and the whole economy.

The impact of cutting subsidies on the intensive margin of individual firms is well documented in the literature. Uniform increase in energy prices (as the implementation of the Average policy) leads to less use of energy, alongside with fewer production. In our counterfactual, if energy prices increase by 1%, the average energy consumption (MBtu) declines by 3.98% in the firms with more than 50 employees, and by 2.34% in the whole industry. The real capital stock increases by 0.52% in large firms indicating a strong substitution between energy and capital. Interestingly, the labor in large firms declines due to energy subsidy cuts because of less production, while the industry faces an increase in the labor force. This only can be explained by firm counts and their dynamics.

Energy subsidy removal affects the entry and exit in two ways. First, the higher the average energy prices, the lower rents to produce, which makes the fixed entry cost relatively sizable. This will reduce the flow of firms. On the other hand, keeping the prereform Markov process unchanged, the Average policy makes the uncertainty in energy prices more costly. In this regard, this policy generates higher rates of entry and exit. Therefore, it is unclear how an increase in energy prices affects several firms. Uncertainty in future energy prices plays a significant role in this tradeoff. In our exercise, the former dominates, so the Average policy furthers the firm entry and exit, as well as the number of firms.

Alternatively, dispersion in energy prices could cause the misallocation of inputs. We call this reform the Distributional policy when the average stationary energy prices remain unchanged. That is, the policy works in a way to increase energy prices for heavily subsidized plants, and redistribute the rent to the other tail. Importantly, this policy acts very similarly to the Average policy. A 1% decline in the standard error of energy prices reduces energy consumption by 2.74% in large firms and by 0.35% in the industry. We name these "Dispersion Elasticity".

<sup>&</sup>lt;sup>12</sup>The robustness check tables are provided by request to the corresponding author.

	Simulation benchmark	Average Price Increase by 1%	Price Dispersion Decline by						
	(1)	(2)	(3)						
Panel A: Firm level statistics- average of	Panel A: Firm level statistics- average of firms with more than 50 labor								
No firms + 50 labor	14815	2.06%	1.51%						
Labor in + 50 firms	109.5	-0.57%	-0.53%						
Energy in + 50 firm	54.8	-3.98%	-2.74%						
Capital to annual wage in + 50 firms	38.6	0.52%	0.21%						
Value-added(to real wage)in +50 firms	4205.7	-1.63%	-1.10%						
Panel B: Manufacturing industry- all fire	ms, simulation								
Labor (Million)	1.83	1.56%	1.05%						
Energy (BBTU)	820	-2.34%	-1.43%						
Value-added(B\$)	185.3	0.77%	0.54%						
Aggregate productivity	27	0.09%	0.12%						
energy productivity	67.8	2.96%	1.89%						
capital productivity	1302	-1.93%	-1.61%						
labor productivity	20	-1.71%	-0.88%						
Panel C: Non-Manufacturing sector									
Labor (Million)	21.35	1.30%	2.33%						
Value-added(to real wage)	626	1.52%	0.68%						
Panel D: Economy									
labor(Million)	23.18	1.40%	2.20%						
Total Welfare	1000	0.07%	0.03%						

#### Table 7. Counterfactual analysis of average and dispersion policy.

Energy productivity is computed as value-added to the summation of heat equivalent of each energy source ratio capital productivity and labor productivity are computed in the same way. aggregate productivity is the average value-added residual in the productivity function. The dollar is in the year 2017 Energy consumption dispersion is a simple standard error.

These policies affect productivity as well. Drop-in energy utilization is deeper than the fall in production. Therefore, energy productivity improves due to the reforms, or energy intensity declines. However, as a result of input substitution, the productivity in capital worsens because of a drop in production. Interestingly, firm-specific change in labor productivity is positive, while various aggregates in labor efficiency are negative due to the entry of small firms. Nevertheless, the aggregate productivity depends on the sum of these input productivity, and it slightly improves. Significantly, the source of productivity gains is different in the two policies. Under the Average policy, all firms proportionally experience subsidy cuts, so all channels are working in the same direction. Nevertheless, in the Distributional policy, some firms face a cut in subsidy while others provide larger subsidies. Therefore, the productivity measure in the latter is just the result of reallocation.

Less energy consumption by the industrial sector allows the government to export excess resources and leads to greater transfer to households. Therefore, the demand rises including the demand for non-manufacturing sectors. In our benchmark estimates, the Average and Distributional policies increase the non-manufacturing production by 1.52 and 0.68%, respectively. The production function in this sector is linear to labor, so the aggregate labor will also increase accordingly. These results stem from the greater resources in the country due to exporting energy with more value than domestic production. Consequently, total labor and welfare both increase.

The results confirm that a policy of reducing subsidies shall ameliorate welfare. So, why do policymakers still promote and continue subsidization? This study highlights that

many firms exit the competition due to cutting energy subsidies because of heterogeneity in the production function. We consider a representative agent household in which the benefit of reform redistributes without any cost; however, the massive wave of layout may produce socio-economic considerations. Therefore, in actual practice, the social considerations may justify why the government supports unproductive firms by lingering reforms to avoid unemployment, which weighs highly in decision-making.

This study provides evidence that both policies increased the value added by a small amount. Additionally, higher prices contribute to the substitution of labor for energy in the production process and the entry of more productive firms that increase aggregate productivity. However, this increase has been realized at the cost of a 1.6% decrease in production due to a reduction in energy subsidies and 1.1% due to uniformization. According to this article, reducing price heterogeneity would have a lesser effect but would be equally crucial for increasing welfare and employment as reducing subsidies. Consequently, this tool can be used as an alternative to first-best non-intervention to reduce the destructive effects of energy subsidies on the economy if the first-best policy cannot be achieved.

We next address separately the channels that are in place in our exercise of the Average policy for the aggregate industry, i.e., column (4) Panel (B) in Table 7. It is not trivial how to decompose channels in a dynamic general equilibrium model. We define the effect of a channel if a reform only works through this channel and other aspects of the counterfactual remain silent.<sup>13</sup> Table 8 shows that intensive margin is the dominant determinant of energy consumption. This coincides with a general sense that only higher energy prices improve energy intensity. In contrast, the extensive margin is the main driver of the labor aggregate, and the dynamic environment of more labor-intensive small firms causes more labor demands. It is important to highlight that the resource channel does not affect the labor of the manufacturing sector, but has a major impact on the labor demand of the non-manufacturing sector. The technology adaptation channel appears to affect labor

Table of Decom	able of Decomposition of chamles, an manufacturing mins.							
	All Channels	Pure Intensive Margin	Pure Extensive Margin	Pure Technology Adaptation	Recourse Channel			
	(1)	(2)	(3)	(4)	(5)			
Labor (Million)	1.56%	-0.71%	0.55%	-0.07%	-0.07%			
Energy (BBTU)	-2.34%	-4.20%	0.53%	-0.06%	-0.06%			
Capital (real to wage)	2.64%	0.89%	1.36%	0.89%	0.89%			
For data	0.77%	-1.41%	1.04%	0.43%	1.04%			

Table 8. Decomposition of channels, all manufacturing firms.

Note: in intensive margin, we just let input and product price adjust, in extensive margin we just let entry and exit move, in technology adoption, we free the transfer and technology and initial capital, and in the last column just transfer adjust by reform.

<sup>13</sup>We define pure extensive margin when labor, capital, energy policy functions, final good pricing, and corresponding value functions are updated based on new pricing reforms. Other policy functions remain unchanged and are drawn from the former price process. Similarly, pure extensive margin channels operate through entry and exit. The third is the technology channel that is a technology choice and capital decision of entrants. Finally, the resource channel is the function determines amounts of government transfers.

and energy and has a meaningful effect on capital accumulation. Significantly, the intensive margin reduces total value-added, but because of the positive effect of other channels, the total production increases. This indicates that accounting for all channels is necessary to study the impact of energy reform.

It is important to highlight that the resource channel does not affect the labor of the manufacturing sector, but has a major impact on the labor demand of the non-manufacturing sector. The technology adaptation channel appears not to affect labor and energy and has meaningful effects on capital accumulation. Significantly, the intensive margin reduces total value-added, but because of the positive effect of other channels, the total production increases. This indicates that accounting for all channels is necessary to study the impact of energy reform.

So far, we assumed a special resource reallocation with uniform flat redistribution of energy resources to the household. Noticeably, this policy makes substantial demand, so all firms responded with higher production by all means. Countries often deviate from this policy and compensate firms with various approaches. We consider alternative redistributional policies in Table 9. Column (1) is our previous benchmark counterfactual with flat transfer to households. Column (2) assumes the governments pay technology expenses and make  $C^T$  as half. Column (3) pays for all active firms by reducing their fixed cost ( $c_F$ ) to half. Finally, Column (4) makes  $c_F$  to half for only large firms. This exercise addresses the government's decision to reimburse firms with influential political power.

Significantly, the distribution of revenue to households increases demand and total production; so it prevents a plunge in energy consumption and firm activities. In contrast, any transfer to firms, with the target to compensate their costs, provides no incentive for additional production. As a result, these alternative policies reduce aggregate productivity, without any improvement in energy intensity. This result suggests, that unless other aspects like political reasons and R&D are in place, the best redistribution policy is to compensate households in a flat lump-sum transfer. Furthermore, our framework lacks any study on the exchange rate and the possibility of exports by firms. Other channels are working in response to energy reform, and this is beyond the scope of this paper.

	Flat transfer to HH	Reduce technology costs	Flat transfer to firms	Size-dependent transfer to firms
	(1)	(2)	(3)	(4)
Labor (Million)	1.56%	-0.11%	-1.98%	-0.12%
Energy (BBTU)	-2.34%	-3.74%	-5.58%	-3.75%
Capital (to real wage)	2.64%	0.88%	1.36%	0.88%
Manufacturing Value-added(to real wage)	0.77%	-0.87%	-3.03%	-0.89%
Aggregate productivity	-0.02%	-0.10%	-0.10%	-0.10%
energy productivity	2.96%	2.96%	3.86%	2.96%
capital productivity	-1.89%	-1.88%	-3.29%	-1.88%
labor productivity	-1.20%	-1.23%	-0.90%	-1.23%

Table 9. Effect oF redistribution policy on energy reform benefit, all manufacturing firms.

Note: This table compares the three policies of transfer of income from rising energy prices with the policy of direct payment to households. The first column gives the same results as Tables 7 and 8. The second column of higher energy sales revenue is technology costs reduced by 10%. In the third column of this revenue, the fixed cost is reduced by 10%. The fourth pillar is similar to the third column, except that it has only happened in companies with more than 50 people.

#### 7. Conclusion and policy implications

The impact of energy price policy on welfare and aggregate productivity in a closed economy is explored in this study through four channels. As part of the two-stage structural estimation approach, stochastic processes are identified first, and deep parameters are estimated using simulated methods of moments in the second stage. We compare two distinct energy reform policies in the counterfactual exercise. Besides the standard diminishing subsidies, we also examine a new policy of uniforming the price, the distributional energy policy.

We find that the dispersion elasticity is about twice in large firms in contrast to the manufacturing sector, suggesting strong support for the distributional policy as an energy reform.

Finally, the influence of heterogeneous fuel pricing on industry efficiency has often been overshadowed by discussions around fuel subsidies. However, our study's findings indicate that the impact of such pricing mechanisms on total productivity is comparable to that of fuel subsidies. Therefore, any tariff preference should be meticulously evaluated for its potential effects on both equilibrium firm distributions and total productivity.

#### **Disclosure statement**

No potential conflict of interest was reported by the author(s).

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