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How manufacturing firms respond to energy subsidy reforms? An impact assessment of the Iranian Energy Subsidy Reform

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Abstract

Energy prices increased several folds due to the 2010 Iranian Energy Subsidy Reform. This study assesses the impact of the reform on the performance of manufacturing firms using a detailed micro-panel dataset at the 4-digit ISIC level for the period 2009 to 2013. Since the reform universally affected all firms, the analysis relies on a quasi-experimental framework implementing first an explorative before-after design with structural fixed-effects and second a difference-in-difference analysis exploiting energy-sensitivity. The subsidy removal caused a shrinkage in output and manufacturing value-added of at least 3 and 7%, respectively. This results in a deterioration of profits by nearly 9%. Manufacturing firms have been affected through three channels: increasing costs of direct energy inputs, pass-through costs for inputs from upstream firms and an energy-price-induced demand contraction. To successfully implement an energy subsidy reform while maintaining growth in the manufacturing sector, not only the direct but also the indirect, pass-through effects have to be considered since capital or technology-led responses to mitigate negative repercussions in the short-run are unlikely at large scale. The results can inform price reforms that aim to mitigate climate change.

JEL: L60, O12, Q48

Keywords

Manufacturing firms, Iran, energy subsidy reform, energy price, performance loss.

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Acronyms

GDP	Gross Domestic Product
IR	Iranian Rial
ISIC	International Standard Industrial Classification
Koe	Kilo of oil equivalent
N.e.c	Not elsewhere classified
OECD	Organization for Economic Co-operation and Development
SCI	Statistical Centre of Iran
SRCT	Subsidy Removal and Cash Transfer
Toe	Tone of oil equivalent

How manufacturing firms respond to energy subsidy reforms? An impact assessment of the Iranian energy subsidy reform[1] [2]

1 Introduction

Subsidies for energy carriers, such as fuels and electricity, affect not only consumers but also producers, in particular the manufacturing sector. In December 2010, the Iranian government implemented a large-scale energy subsidy reform (SRCT) to remove energy subsidies and adjust the local price of energy including fuels, natural gas and electricity to global prices. The local authorities called the reform 'the largest economic surgery in the history of Iran'[3] affecting all economic sectors and importantly the manufacturing sector was not exempt from the subsidy cuts but fully and entirely affected.

Overnight, the energy prices for manufacturing firms increased several fold, i.e., a six-fold increase in the price of kerosene, a roughly four-fold price increase for natural gas and almost a doubling in the price of gasoline and electricity.[4] Such huge increases in energy prices do not go unnoticed and are likely to have non-negligible implications for an economy in which the manufacturing sector forms an important part. In the 2000s the manufacturing sector of Iran produced on average about 1,000 trillion Iranian Rials in real value-added (2011=100) per year. This constitutes about 17% of overall GDP and 24% of GDP if oil revenues are excluded from national output over the 20-year period from 1994 to 2013 (Figure 1). Moreover, approximately 31% of the country's employment relies on the manufacturing sector (National accounts: Published by the Statistical Center of Iran (SCI)). The prominent role of the manufacturing sector for the Iranian economy is reinforced by the growth of the sector. Manufacturing value-added has seen a steep upward trend from roughly more than 400 trillion Iranian Rial in 1994 to almost 1,400 trillion Iranian Rial in 2010 (Figure 1). However, with the introduction of the energy subsidy reform manufacturing value-added fell by 27%. This shrinkage in the manufacturing sector is not only unprecedented in the last two decades but also represents the largest sectoral shrinkage compared to all other sectors in that same year.

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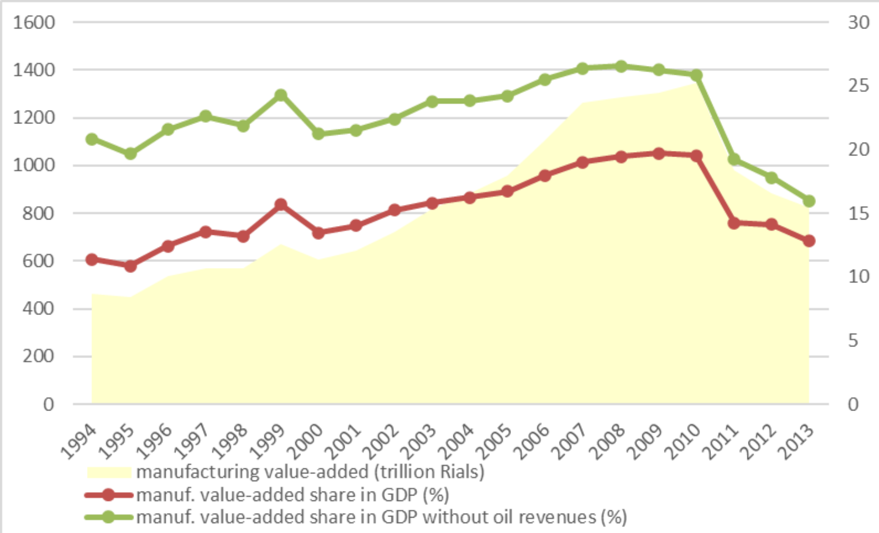
1 An article based on this paper, co-authored by Natascha Wagner has been submitted for peer-review.

2 I thank (Parissa) Nahid Parvizi for kind support in purchasing data from SCI and also for converting data to the right format.

3 A phrase initially used by the then President- Ahmadinejad (13 May 2010) to describe the subsidy reform.
< https://www.bbc.com/persian/business/2010/04/100419_timeline_subsidy> accessed on 20-08-2021.

4 Detailed price information is provided in Appendix 2.

Figure 1
Manufacturing sector's role in the economy



Note: Manufacturing value-added is denoted in real terms (2011=100) and in trillion Iranian Rials, based on national accounts data published by the Statistical Center of Iran (SCI).

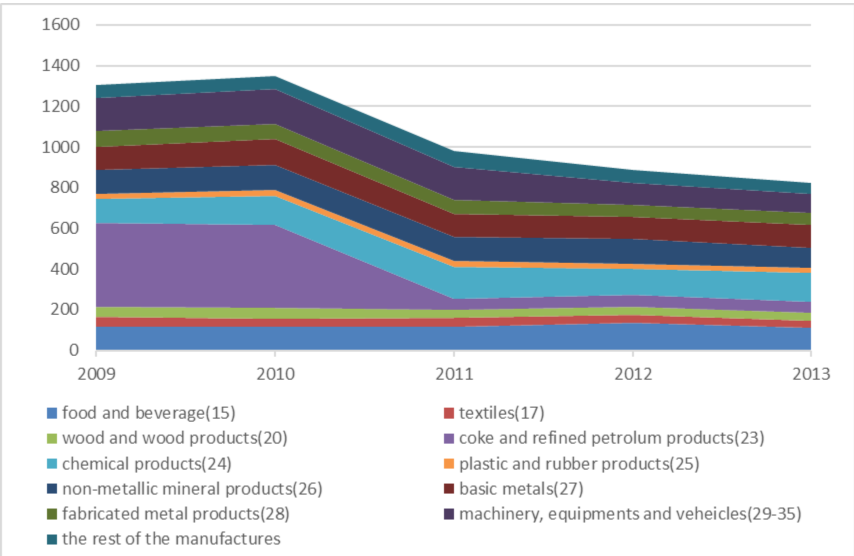
The composition of the Iranian manufacturing sector makes it susceptible to changes in energy prices. In Figure 2 we present the major contributors to the manufacturing value-added. These are food and beverage products (ISIC15), petroleum coke and refined petroleum products (ISIC23), chemical products (ISIC24), non-metallic mineral products (ISIC26), basic metals (ISIC27), fabricated metal products (ISIC28), and machinery, equipment, and vehicles (ISIC29-35). These aforementioned industries constitute approximately 85% of the total manufacturing value-added (Figure 2). Manufacturers of petroleum coke and refined petroleum (ISIC23) form the industry group that contributed most to the manufacturing value-added prior to the reform and deteriorated the most in response (Figure 2). This industry is a top energy consumer even among the high energy-intensive industries.

Geographically speaking, Iran's manufacturing sector is regionally concentrated. Tehran province alone accounts for 21% of the produced value-added. The provinces Esfahan and Khuzestan account for 15 and 12%, respectively, which makes them the second and third largest contributors to the manufacturing value-added of the economy implying that almost 50% of the manufacturing firms are located in only three out of 31 provinces (a detailed graphical representation is provided in Appendix 1).

Considering the importance of the manufacturing sector for the Iranian economy in terms of contribution to GDP as well as employment provision, this research analyses the impact of the 2010 energy subsidy reform on the performance of manufacturing firms. Moreover, studies on the impact of the energy subsidy reforms on manufacturing firms are rare (Rentschler et al., 2017).

The research relies on a micro-panel dataset for the period 2009 to 2013. Since the reform under study is a universal reform, the analysis relies on a quasi-experimental approach to establish a potentially causal relationship between the energy subsidy reform, i.e., the increase in energy prices, and the responses of manufacturing firms. First, we employ an exploratory before-after comparison with firm group level fixed-effects to account for structural differences. Second, we identify the differential impact the reform may have had on the manufacturing firms by constructing a counterfactual that consists of firms that are less sensitive to energy price. We identify that the energy subsidy reform considerably affected the performance of the manufacturing firms since this sector is likely to be most affected by the price increases due to the energy dependence of the manufacturing firms. We observe that the increase in energy prices did not reduce energy consumption highlighting the energy dependence of the firms. In turn, output, value-added and operating-surplus (a proxy for profit) declined by at least 3, 7, and 9%, respectively. Conducting further exploratory analyses we find evidence that the increase in energy prices affected firms through three channels: (i) increase in the costs of direct energy inputs, (ii) increase in pass-through costs for inputs from upstream firms and (iii) the energy-price-induced contraction on the demand side (Zarepour and Wagner, 2021). Impacts are heterogeneous, and the magnitude of the impact depends on the intensity of energy consumption, the location of the industry in the production chain as well as its capital base and level of technology use. While we show that capital and technology can mitigate the negative repercussions, the share of firms in our dataset with a large capital base and those employing advanced technologies is 23% and 27%, respectively, making it unlikely that capital or technology-led responses can be used at large scale in the short-run. While a priori the results present an ex-post evaluation of a large-scale energy reform, they can be used to inform energy policies that are concerned with energy price increase. The study at hand can give an indication of possible effects as well as mitigating and reinforcing firm characteristics.

Figure 2
Manufacturing value-added across ISIC codes (2009-2013)



Note: Manufacturing value-added is denoted in real terms (2011=100) and in trillion Iranian Rials, based on national accounts data published by SCI.

The remainder of the paper is structured as follows: Section 2 provides background information about energy consumption of the manufacturing sector in Iran. Section 3 presents a theoretical framework and existing empirical evidence discussing the channels through which energy prices affect the manufacturing sector. The research design and empirical identification strategy are introduced in Section 4. Sections 5 and 6, respectively, present the data and discuss the results. Section 7 concludes.

2 Energy consumption and intensity of the manufacturing sector

Data on energy consumption in the manufacturing sector may be obtained from the supply side or from the demand side. On the supply side, data may be accessed from the Iranian Ministry of Energy which provides energy balance sheets. On the demand side, data is available from the Statistical Center of Iran (SCI), that is, from firm level surveys of manufacturing firms with 10 or more workers. Each of these references has their own advantage and pitfalls. Data from the Ministry of Energy includes all manufacturing firms regardless of their size, but it does not include firms that are not registered and operate informally. In turn, the available firm-level data includes informal firms but only represents those firms with 10 workers or more.

The energy consumption of the manufacturing sector according to both sources is presented in Table 1. Both sources show that on average manufacturing firms use 42 million tons of crude oil of energy (Toe) over the period 2009 to 2013. The Ministry of Energy statistics show an increasing trend in energy consumption in the manufacturing sector. It starts before the reform and continues afterward. In turn, the survey data suggest fluctuations in energy consumption across the years with 2009 reporting the highest energy consumption and 2010 the lowest. There is no indication that energy consumption reduced in response to the subsidy reform. The data suggest demand inelasticity with respect to energy consumption. Despite the sharp increase in the energy price in late 2010 there seems to have been no decline in energy consumption. As the reform was implemented in December 2010, we would expect to observe immediate reductions in energy consumption in 2011. However, according to both datasets, consumption in 2011 consumption is larger than consumption in 2010. In short, an important take away from these figures is that there is no reduction in energy consumption, highlighting the energy dependence of the manufacturing sector.

Table 1
Manufacturing energy consumption (million Toe)

	2009	2010	2011	2012	2013
Industry sector consumption, from Ministry of energy	37.73	41.16	42.46	44.52	45.27
Manufacturing firms with 10 and more workers, from SCI	43.42	39.98	42.08	40.57	42.07

Note: Toe abbreviates tone of crude oil equivalent.

The total energy consumption by the manufacturing sector as well as average firm level use only provides limited information since it disguises industry-specific energy dependence. We capture energy dependence using the energy intensity of the industries. Energy intensity is measured by comparing the consumed energy with the value-added (Upadhyaya, 2010). More precisely, the intensity measure is the ratio of consumed energy measured in tons of crude oil equivalent (Toe) per each real billion Iranian Rial value-added (2011=100). To calculate the total energy consumption, the quantities of all types of energy, including kerosene, gas oil, natural gas, liquid gas, gasoline, mazut (fuel oil), coal, charcoal and electricity are converted to Toe using the guidelines published by the Iranian Ministry of Energy. Thereafter, the energy intensity measure is calculated at the 2-digit level ISIC code using the survey data of manufacturing firms with 10 or more workers for the years 2009 and 2010, i.e., before the introduction of the energy subsidy reform. The average consumption over that period is used. The resulting energy intensity measures are presented in Table 2.

The classification of industries into three energy categories is adopted from Upadhyaya (2010): Category I represents industries with more than average energy consumption intensity, i.e., 55.27 Toe and more. They are ranked as high consumers. Five ISIC codes are in that category including among others: manufacturers of chemicals, metal and refined energy products. Industries with less than the average consumption but more than the median energy consumption, i.e., between 12.07 and 55.27 Toe, are denoted as moderately energy-intensive. Seven ISIC codes are in this group. Industries with below median energy intensity, i.e., below 12.07 Toe, are classified as low-energy intensive. This category comprises eleven ISIC codes.

On average, manufactures use 55.3 Toe to produce a billion Rial value-added (2009-2010). This is equivalent to 328.3 Toe per each million US dollar value-added (using the PPP conversion factor). Manufacturers of petroleum coke and refined petroleum products (ISIC23) represent the top energy consumers driving the average energy consumption across manufacturers considerably upward. The average energy consumption without ISIC23 falls to less than half, namely 25.7 Toe to produce one real billion Iranian Rial in terms of value-added. This is equivalent to 151.9 Toe per million US dollar (using the PPP conversion factor).

The availability of rich energy resources has had a great influence on the shape of the manufacturing sector. As such, the manufacturers of petroleum, coke and refined petroleum products contributed nearly one third of the total value-added in 2009. After the introduction of the energy subsidy reform, the value-added of this industry declined by 86% (Figure 2). However, even after the energy reform, nearly half of the manufacturing value-added is produced in high energy-intensive industries showing their importance for the Iranian economy and hinting at the fact that the energy subsidy reform had a major impact on firms (Figure 3).

Table 2
Classification of manufactures based on energy intensity (2009-2010)

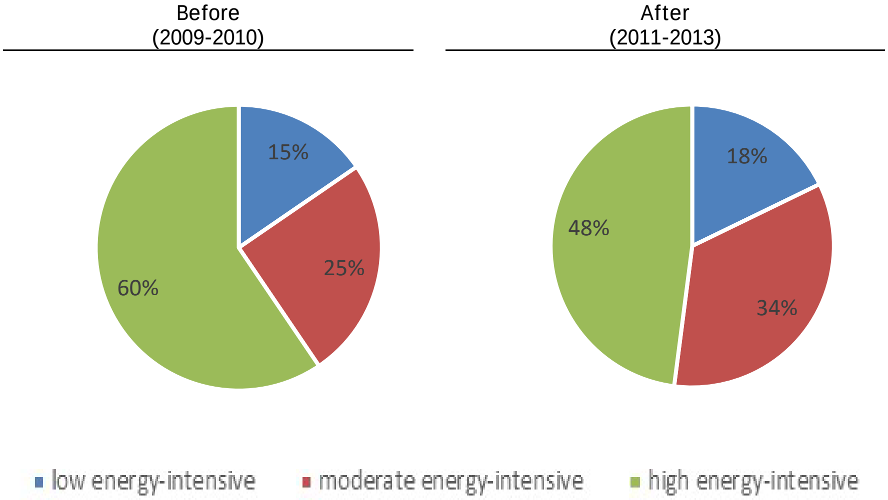
ISIC	Industry code	Energy intensity•	Energy intensity classification◦
Manufacture of food products and beverages	15	30.21	moderate
Manufacture of tobacco products	16	1.89	low
Manufacture of textiles	17	26.38	moderate
Manufacture of wearing apparel, dressing and dyeing	18	9.53	low
Manufacture of leather products	19	11.62	low
Manufacture of wood and wood	20	27.72	moderate
Manufacture of paper and paper products	21	64.78	high
Publishing, printing and reproduction of recorded media	22	9.82	low
Manufacture of coke, refined petroleum products	23	145.91	high
Manufacture of chemicals and chemical products	24	56.53	high
Manufacture of rubber and plastics products	25	19.15	moderate
Manufacture of other non-metallic mineral products	26	117.47	high
Manufacture of basic metals	27	83.3	high
Forging, pressing, stamping and roll-forming of metal	28	12.07	moderate
Manufacture of machinery and equipment n.e.c.	29	10.13	low
Manufacture of office and computing machinery	30	2.61	low
Manufacture of electrical machinery and apparatus n.e.c.	31	6.82	low
Manufacture of radio, TV and communication equipment	32	4.66	low
Manufacture of medical, precision and optical instruments	33	5.97	low
Manufacture of motor vehicles, trailers and semi-trailers	34	3.97	low
Manufacture of other transport equipment	35	5.13	low
Manufacture of furniture; manufacturing n.e.c.	36	14.72	moderate
Recycling	37	42.37	moderate
Average without ISIC code 23		25.76	
Average		55.27	

Note: Energy intensity is classified in three categories: (1) low, (2) moderate, and (3) high.

•Energy intensity is measured as energy consumption (Toe) per billion Iranian Rial value-added before the introduction of the subsidy reform, i.e., for the years 2009-2010.

◦ Ranking of the industry codes based on the energy intensity measure reported in the previous column. Industry codes with more than the average energy consumption intensity, i.e. 55.27 Toe, are ranked as high consumers; industries with less than the average but not less than the median energy consumption, i.e. between 55.27 and 12.07 Toe, are considered moderate energy-intensive; industries with below median energy intensity, i.e. below 12.07 Toe, are classified as low-energy intensive.

Figure 3
Manufacturing value-added based on energy intensity



Note: High energy-intensive are manufactures that consume above average energy (Toe) per value-added. Moderate energy-intensive are manufactures that consume less than the average Toe per value-added but more than the median. Manufacturers with below median energy consumption (Toe per value-added) are considered low energy-intensive.

3 From theory to practice: How energy prices affect firms

Before empirically assessing the impact of the energy subsidy reform on the manufacturing sector, we will conceptually place the analysis within economic theory and theoretically identify the channels through which the reform, i.e., the increase in energy prices, may affect manufacturing firms. Energy is an input into all production processes be it direct or indirect. Energy costs are typically considered a variable cost as they are linked to the level of production implying that their increase shifts the marginal costs upward. Theoretically speaking, the part of the marginal cost curve above the average variable cost is the supply curve. Therefore, the shift of the marginal cost curve is a backward shift of firm supply implying a lower level of production. The magnitude and the persistence of the effect over time depends on the production function and the existence of a substitute good for energy (Hope and Singh, 1999). Bohi (1991) developed a model that illustrates how energy prices influence output through price and substitution effects. In this model output is a function of capital, labour and energy inputs. The price effect is negative resulting in an output decline in response to the increasing costs of energy. Along with the price effect, there are two substitution effects: Substitution of energy with labour and energy with capital. These two impacts are assumed to be positive and curb the negative impact of the price effect. Yet, there are circumstances under which this assumption does not hold, for instance, in the case of wage inflexibility. When real wages are sticky the substitution effect between energy and labour is negative and exacerbates the price effect of the energy price increase on output. Such negative effects can further be exacerbated if an abrupt, sharp increase in energy price renders some part of the capital obsolete. In such a situation, the increase in energy costs interrupts the flow of capital services to production and further adds to the negative price effect (Bohi, 1991). Even when input ratios are interchangeable, in response to rising energy prices, firms have to move to a higher capital-to-output and/or labour-to-output ratio. These adjustments often imply productivity improvements, i.e., the employment of more (energy) efficient technologies.

Empirically, using data from 1,735 Chinese firms for the period 2003-2006, Kong, Yang and Xu (2020) studied whether energy price increases induced innovation. They find evidence that firms innovated more as measured by patent applications. Similarly, Golder (2011) associated increases in the productivity of energy inputs in the manufacturing sector of India between 1992-2008 with increases in energy prices and related technological improvements. However, substitution effects as well as technology-led adjustments tend to be slow and therefore the impacts of increased energy prices can be sizable in the short-run even if they can be mitigated in the long-run (Atkeson and Kehoe, 1999). Thus, an often-used short-term approach to mitigate the negative impacts of increased energy prices is absorption. If profit margins are large, a firm can temporarily absorb the increased costs (Rentschler et al., 2017). This stage is essential for securing the short-term survival of the firm, particularly, in the case of a subsidy reform like the one under study that results in a sharp increase in the energy price. It is possible that firms with small profit margins may not be able to survive this stage.

3.1 Relationship between capital and energy inputs – A more detailed discussion of existing findings

There is a long-standing debate in the empirical literature on whether inputs such as capital and energy are substitutes or complements. Bardazzi et. al. (2015) using 2000-2005 data from Italian manufacturing firms identified energy as the most elastic input. They show that capital and energy tend to be substitutes in low technology sectors and weak complements in other sectors. Based on a micro-panel dataset of manufacturing firms in Denmark, Arnberg and Bjorner (2007) found that both electricity and other fuels are complementary to capital inputs. Deininger, Mohler and Mueller (2018) investigated the substitutability between the input factors capital, labour, energy and material with respect to the energy-intensity degree (low, medium and high) of manufacturing firms in Switzerland using micro-panel data from 1997 to 2008. They found substitutability among all production factors except between capital and energy in energy-intensive manufacturing. In such firms, energy and capital was complementary - a 10% increase in the energy price reduced capital use by nearly 1%. Thus, overall, the existing literature provides context-specific conclusions which do not lead to straightforward generalizations.

For the case of Iran, Samadi et al. (2009) estimated energy demand functions for the basic metals industry and found that capital and electricity are complementary inputs but there is a substitutional relationship between other energy carriers such as fuels and capital. Sharifi and Shakeri (2011), using a translog functional form, similarly showed that substitution among production inputs namely labour, capital, electricity, and fuel is relatively limited. Moreover, the capital stock adjustment in response to changes in energy prices is very slow. Thus, for Iran, results point to capital and energy being complements.

Koetse et al. (2006) attribute the different outcomes of the studies to differences in the underlying assumption. The authors compiled and synthesized the heterogenous empirical studies on the substitution between energy and capital in a meta-analysis framework and show that assumptions related to return to scale, separability and technological change alter the result. They differentiated between the use of Morishima substitution elasticities that merely represent the technical substitution possibilities and cross-price elasticities that include income effects and represent economic substitutes. The technical elasticities are substantially higher than price-cross elasticities revealing that sizable technical possibilities for capital-energy substitution are outweighed by negative income-effects resulting from an increase of energy prices. What can be concluded is that the short- and mid-term price elasticities are not different from zero and only long-term capital formation may change in response to increases in energy prices (Koetse et al., 2006). Likewise, Haller and Hyland (2014) show that with the same dataset opposing results can be drawn due to differences in model specification and differences in the aggregation of energy inputs.

3.2 Indirect channels for energy prices to affect firm performance

Next, we turn to indirect channels through which energy prices are likely to affect firm performance. A first indirect channel that connects the impact of energy prices to the performance of a firm is with respect to the firm's placement in the production chain. If a firm is located in the mid- or down-stream the increase in energy prices does not only affect the firm directly but also indirectly through increases in the prices of intermediate goods. In this case upstream industries pass-through the energy price increase to other firms. Thus, energy price shocks can have a snowball effect along the production chain. Firms that employ a considerable share of intermediate inputs that contain high embodied energy content can be affected severely by an energy subsidy reform even if the effects are only indirect. We theoretically motivate this snowball effect in Appendix 6 showing that downstream firms can be severely affected by passthrough of price increase of an input of upstream firms. In the real world, the extent and timing of the impact depends on the significance of the linkage to other industries and also on the degree and speed with which other industries can pass-through the energy price (Rentschler et al., 2017). The existing empirical literature supports the pass-through argument: Pass-through of increased energy costs has been documented by Kim, Chattopadhyay and Park (2010), Sijm, Neuhoff and Chen (2006), and Fabra and Reguant (2014) among many others.

A second indirect channel through which energy prices affect manufacturing firms is an energy-induced shift in demand. An increase in energy prices tends to result in a decline in aggregate demand since it affects consumer budgets and it particularly decreases the demand for energy-intensive products (Bohi, 1991; Kilian, 2008; Rentschler et al., 2017; Rentschler and Kornejew, 2017). Sadath and Acharya (2015) analysed the effect of rising energy prices on investment of manufacturing firms in India using a panel dataset for the period 1993-2013. They show that the negative effect of the increase in the energy price manifested itself on investment transmitted through both channels, i.e., the demand and the supply side. Similarly, Ayakwah and Jamal (2014) emphasized the negative impact of increases in energy prices transmitted through the demand side for the case of Ghana.

These indirect effects are particularly important in the context of energy inputs. Since energy costs tend to be considerably smaller compared to the costs of intermediate inputs and are contingent on the context, it is possible that the indirect impact of an energy subsidy reform on firms is equal or exceeds the direct impact (Rentschler et al., 2017; Ayakwah and Mohammed, 2014). To further evaluate the empirical aspects of the theoretical links that have been discussed, we assessed data-driven studies about energy subsidy reforms.

3.3 Empirical studies on the effect of energy subsidy reforms on manufacturing firms

There are a limited number of studies which have addressed the impact of energy subsidy reforms on manufacturing firms (Rentschler et al., 2017). For the case of Ghana, Ayakwah and Jamal (2014) studied the impact of the 'Fuel Price Adjustment' policy on small and medium businesses (SMEs) by combining quantitative and qualitative surveys. They found a negative impact of the price adjustment on the growth of SMEs due to increases in the costs of transportation, raw materials, capital and also through the demand channel since the real income of consumers fell resulting in diminished aggregate demand. For the case of Nigeria, Bazilian and Onyeji (2012) identified that the 2012 subsidy removal had an adverse effect on power supply which pressed hard on businesses that depend on stable power supply. The authors criticized the fact that the subsidy removal plan was drawn and implemented without reflecting on the complex interrelationships in the economy. For the case of Indonesia, Rentschler and Kornejew (2017) employed cross-sectional micro-level firm data for the year 2013 and demonstrated that the energy subsidy removal had a small but significant long-run negative impact on the profitability of the manufacturing and mining sectors. The study showed that firms responded to variations in energy prices by adjusting the energy mix, increasing energy productivity and passing the costs through to the end-users.

Few researchers have addressed the impact of the Iranian energy subsidy reform on manufacturing firms. Rahmati and Pilehvari (2018) used data from manufacturing firms (at the 2-digit ISIC level) for the period 2005-2011 and applied a log-linear production function to estimate the productivity of the manufacturing firms. The authors showed that the energy subsidy reform led to a 3% decline in firm productivity one year after the reform. Ranjbar Fallah (2001) estimated energy demand functions suggesting that the increase in the energy price did not curb energy consumption due to the technological inflexibility of the Iranian manufacturing sector. Barkhordar et al. (2018) scrutinized the potential opportunities for increasing energy efficiency in the manufacture of some energy-intensive products namely pulp and paper, steel, cement, brick, glass and aluminium. The authors suggest that there is an energy saving potential equivalent to 80 petajoule (or 1.9 million Toe) in e manufacturing processes. However, this potential has not been realized after the energy subsidy reform due to non-price barriers. The challenge with the existing studies about the Iranian energy subsidy reform is that they work with fairly aggregated data, focus on the computation of macro models, and fail to establish a causal relationship. This is the gap that the study at hand tries to fill.

4 Research design and identification strategy

We seek to estimate the causal effect of the increase in energy prices due to the energy subsidy reform (SRCT) on manufacturing firms. The approach is motivated by impact evaluations of one of the most recent energy policies in the European Union, namely the introduction of a carbon tax in the European Emission Trading System (EU ETS) in 2005. To investigate the impact of this universal policy on the performance of the European manufacturing firms several evaluations have been conducted (Commins et al., 2011; Arlinghaus, 2015; Anger and Oberndorfer, 2008; Abrell et al., 2011; Petrick and Wagner, 2014). Inspired by these evaluations of a similar universal reform that directly affected energy prices, we set up a series of empirical models. As a first step, we use the most common approach, that is a before-after analysis combined with firm-group fixed-effects (please see section 5 for an explanation of the term firm-group). The empirical model is laid out as follows:

$$y_{ipt} = \gamma F'_{ipt} + \xi G'_{ip} + \eta T'_{t} + \pi SRCT_t + \varepsilon_{ipt} \quad \text{(Eq. 1)}$$

where y_{ipt} is the output indicator for all firms with ISIC code i in province p at time t; we measure output using three indicators that represent the performance of manufacturing firms: (i) output (including produced goods and manufacturing services), (ii) manufacturing value-added (output minus input) and (iii) manufacturing value-added inclusive of the operating-surplus (manufacturing value-added minus compensations plus net non-manufacturing service account). The latter is meant to proxy manufacturing profit. F_{ipt} contains the matrix of main inputs, compensations, and capital formation to account for firm-group specific, variable factors that are likely to affect performance. G_{ip} is the matrix of structural effects including the combined regional and firm-group specific effects, i.e., we employ firm-specific effects. T_t captures the time trend and a proxy for the onset of international sanctions. We use Iran's oil exports (in barrels) as a proxy to control for the effect of the sanctions. $SRCT_t$ is the treatment variable, which is a dummy that takes on the value 1 for observations collected after the implementation of the energy subsidy reform and 0 otherwise; π is the parameter of interest. A similar model has been used by Commins et al. (2011) to capture the impact of the European carbon tax on firm productivity. Similarly, Petrick and Wagner (2014) applied fixed-effects models combined with propensity score matching to establish a causal relationship between the

European carbon tax and emission reductions using German manufacturing data.

In addition to estimating Eq.1, acknowledging the limits of a before-after analysis, we also attempt to create a counterfactual. To form this counterfactual, we identify less energy-*intensive* industries and compare the outcomes for such firms with firms that are more energy intensive. The review of the channels through which energy prices can be transmitted to manufacturing firms, a s presented above, provides the basis for classifiying firms according to energy-intensity. The first channel we consider is the direct one, namely increases in energy costs. The less energy-intensive a manufacturing firm is the less of an effect of this channel it will experience. Hence, low energy-intensive industries lend themselves as potential candidates to create a control group. However, it also has to be considered that there are indirect transmission channels. The supply-side indirect channel is contingent on the placement of the industry in the production chain and how intensely high-energy-embodied intermediate goods such as petroleum products, cement and metals are used. Inspecting the major inputs of the low energy-intensity group reveals that machinery and motor vehicles (ISIC29 and 34) rely intensively on metals such as iron and steel as intermediate input and are therefore sensitive to indirect price transmissions. Moreover, the two industries are downstream industries to basic metals and fabricated metals industries (ISIC27 and 28). Considering these channels, we take the group of low energy-intensive industries excluding machinery and motor vehicles (ISIC29 and 34) as control group to identify the impact of the subsidy reform on the other firms. Thus, our control group consists of industries that are less-*sensitive* to an increase in energy prices from either the direct or indirect channel. This does not imply that the control group is non-sensitive to energy price increases. Hence, the outcome of our control-treatment comparison represents a conservative measure of the impact of the subsidy reform. The resulting empirical model looks as follows:

$$y_{ipt} = \alpha F'_{ipt} + \beta G'_{ip} + \vartheta T'_{t} + \delta C'_{ip} + \psi SRCT_{t} * C_{ip} + \epsilon_{ipt} \quad \text{(Eq. 2)}$$

where C_{ip} takes on the value of 1 for industries that constitute the treatment group and 0 otherwise and the interaction term $SRCT_t * C_{ip}$ accounts for treatment. ψ represents the average treatment effect (subsidy reform) on the treated (all energy intensive industries). The time effect T'_t controls for temporal changes affecting both groups. The remaining variables are as in Eq. 1. Across models, standard errors are clustered at the regional 4-digit ISIC code level. By comparing results from the two models and incorporating further robustness analysis we attempt to identify the impact of the energy subsidy reform on the performance of manufacturing firms.

5 Data

Five rounds of the annual survey of manufacturing firms with 10 or more workers are employed. These data are collected from the Statistical Center of Iran (SCI). The study period covers the timespan 2009 to 2013. The survey is carried out countrywide every year from July to September. Firms with 10 to 49 workers are sampled from the list of all firms of that size and all firms with 50 workers and more are included in the survey. The unit of data collection is the individual manufacturing firm; however, the Statistical Center of Iran does not publish data at the firm level. The available data is aggregated to the 4-digit ISIC code for each province. The classification of the manufacturing firms follows the International Standard Industrial Classification of all economic activities ISIC Rev.3.1 updated by the United Nations Statistical Division (UNSD) in 2002. The manufacturing firms are classified in section D, manufacturing.

Each observation in the dataset is a 4-digit ISIC code which we refer to as a 'firm-group'. For example, ISIC2699, which codes for manufacture of other non-metallic mineral products n.e.c.,[5] contains 26 firms with 882 workers in Mazandaran province in 2009. The real total input of this firm group is 770,426.4 million Iranian Rials (RI) and the real value of total output is 1,309,898 million IR.

Furthermore, some observations in 2009 and 2010 only contain 1 or 2 firms. However, since 2011, the Statistical Center of Iran does not publish the ISIC-codes that comprise less than 3 firms to protect the anonymity of the respondent firms. To make the data comparable over time we apply the same rule for the years 2009 and 2010 and include only observations that contain more than 2 firms. Table 4 shows the structure of the panel data for the timeframe of the analysis indicating that across years the sample is well-balanced and for every individual year there are at least 1,000 observations.

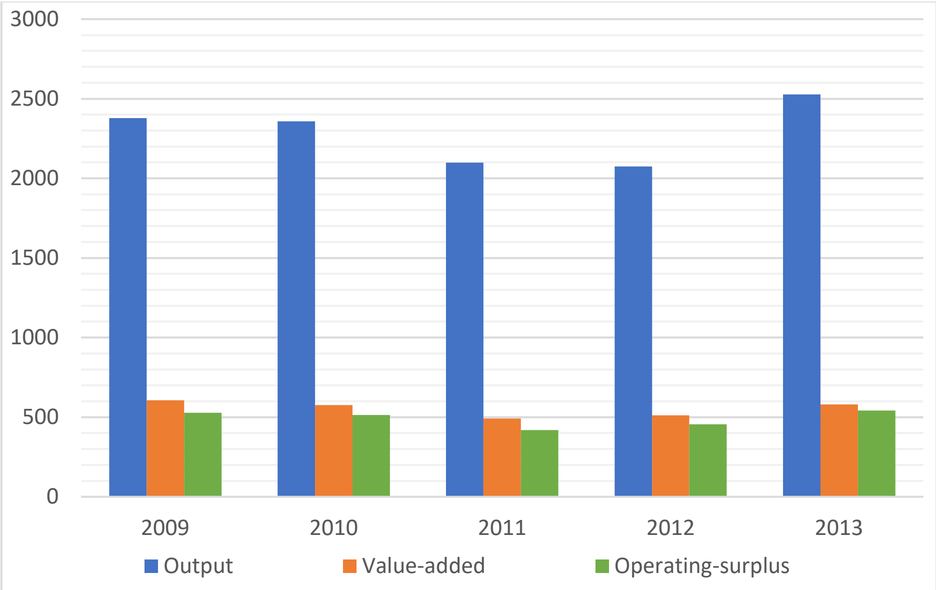
Table 3
Shape of the panel data

Year	No. of 4-digit ISIC (firm groups)	Percentage of the sample
2009	1,149	20.39
2010	1,118	19.87
2011	1,117	19.82
2012	1,118	19.84
2013	1,134	20.12
Total	5,636	100

Source: Survey of manufacturing firms with 10 and more workers, 4-digit level ISIC data

[5] Not Elsewhere Classified.

Figure 4
Overview of manufacturing indicators over time (in Billion Iranian Rial)

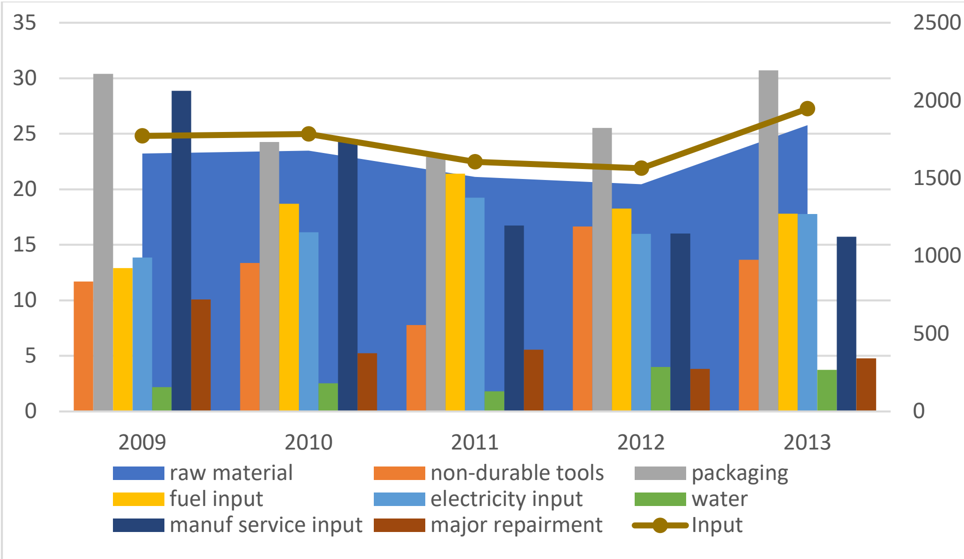


Source: Survey of manufacturing firms with 10 and more workers, 4-digit level ISIC data

An overview of the major firm group indicators for each year in the period 2009-2013 is presented in Figure 4. We present the three outcome indicators under study: (i) output, (ii) manufacturing value-added and (iii) manufacturing value-added inclusive operating-surplus. Not a single indicator shows a substantial change between the year 2009 and 2010. After the introduction of the energy subsidy reform, that is, at the end of 2010, a contraction in all performance indicators is visible for the years 2011 and 2012 relative to the earlier years. In 2013, the trend reverses. If we take 2010 as a reference point, the indicators revert to that level or even above.

To place the performance dynamics presented in Figure 4 in perspective, Figure 5 presents the composition of the major manufacturing inputs over time. Raw materials comprise more than 90% of all inputs. To avoid that raw materials, mask the rest of the input composition, Figure 5 has two vertical axes. The secondary axis measures the total value of the raw materials (illustrated by the blue area) and the total value of all inputs (illustrated by the brown line) and is presented at the right side. The primary axis measures the remaining inputs and is presented at the left axis. As can be seen from the graph, the amount spent on fuel (yellow bar) and electricity (light blue bar) increases in 2011 which is indicative of a direct effect of the subsidy reform. However, in 2012 and 2013 they revert to lower levels. Overall, the graph reveals that apart from payments for manufacturing services (dark blue bar), which have a decreasing trend over time, the composition of the inputs has not changed prominently between 2009 and 2013 suggesting that no other large structural shifts affected manufacturing firms.

Figure 5
Composition of the major input of manufacturing firms (in billion Iranian Rial)

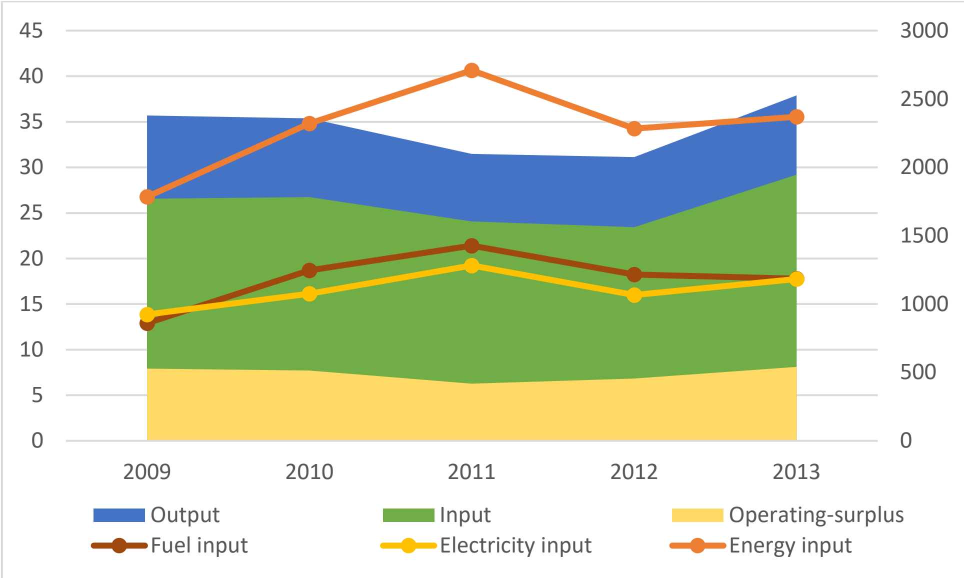


Source: Survey of manufacturing firms with 10 and more workers, 4-digit level ISIC data

To further disentangle the increase in energy spending observed in Figure 5 we also present the temporal relationship between output, inputs and operating-surplus vis-à-vis the energy inputs (Figure 6). The development of output, input and operating-surplus are measured on the right-hand side of the secondary axis. They show synchronized movement over time. Although, the fluctuation in operating-surplus is smaller than that of output and value-added suggesting that under unstable circumstances firms try to smoothen out fluctuations in operating-surplus. On the left axis the energy input is presented (orange line). An inverse relationship can be observed between value-added (blue area) and energy inputs (orange line) for the years 2009-2011. In 2011, the initiation of the energy subsidy reform, the cost of energy inputs reaches its maximum and output shrinks. Yet, this inverse relationship does not hold in the years 2012 and 2013. In 2012, energy input and output both dwindle and in 2013 both increase. Hence, the inverse relationship between energy inputs and output does not hold anymore after the subsidy reform. This basic relationship presents an indication why parametric models that use ex-ante parameters to forecast the impact of a subsidy reform are unlikely to be accurate.

Further note that electricity and fuels have equal shares in the energy consumption of manufacturing firms (Figure 6). The share of energy in total output before the reform is 1.6% and in 2011 with the introduction of the reform it reaches approximately 2.1%.

Figure 6
Temporal relationship between output, input and operating-surplus vis-à-vis the energy inputs (in billion Iranian Rial)



Source: Survey of manufacturing firms with 10 and more workers, 4-digit level ISIC data

Next, we turn to additional firm-group level characteristics that affect performance. We focus mainly on inputs. Table 4 summarizes some key characteristics of the firm groups before and after the subsidy reform of December 2010.

After the reform, total output decreased slightly. However, the reduction is not statistically significant (*p*-value=0.736). Raw materials that constitute the major input factor in the production process exhibit a similarly insignificant reduction. As expected, the costs of some inputs such as fuel, electricity and water do increase after the reform. However, even for these inputs, the simple comparison of means does not identify any statistically significant difference which may be an indication of stagnation of manufacturing sector after SRCT.

The number of workers does not show a significant change over time either, although their real compensation declines substantially (nearly 30 percent). A decline in the real minimum wage has contributed to this substantial decrease in compensation. The real minimum wage decreased nearly 20% after the reform, from 3.8 million IR per month in 2009-2010 to 3.1 million IR in 2011-2013. These are early indications that workers were forced to *absorb* the energy price shock. For manufacturing firms, the ratio of compensation to input declined from nearly 37% before SRCT to 29% after SRCT.

Table 4
Selected statistics of panel data

Variables	Before the reform		After the reform		Diff in mean
	Mean	Std. Dev.	Mean	Std. Dev.	*p*-value
Manufacturing output⁰	2368988.8	15343393	2234729.8	14227129	0.736
Manufacturing input	1777633.9	12684549	1706622	12383348	0.834
Raw material	1667868.4	12304121	1604727.8	12123958	0.848
Non-durable tools and equipment	12531.475	78207.365	12707.248	134614.8	0.955
Packaging material	27366.107	111815.07	26415.934	104075.32	0.744
Energy	30742.73	174670	36818.73	203177	0.245
Fuel	15762.737	122063.82	19149.005	114670.72	0.289
Electricity	14979.99	87011.702	17669.724	108689.8	0.324
Water	2365.64	26455.491	3189.91	47759.205	0.454
Payments for manuf. services	26736.634	322794.05	16152.783	155670.49	0.101
Major repairment	7694.947	145471.65	4732.597	54510.038	0.282
Number of workers	981.479	2442.76	985.184	2459.534	0.955
Wage and non-wage compensation	144282.75	624342.63	103522.96	461777.36	0.005***
Average compensation per worker	109.260	45.027	77.172	64.827	0.000***
Firm number	12.793	21.381	12.116	18.695	0.208
Capital formation	150616.75	1057782.9	123216.02	1382676.3	0.424
Fixed capital formation	97809.056	847173.37	53948.364	388649.99	0.009***
Inventory change	52807.699	481732.4	69267.655	1296448.3	0.563
Net non-manufacturing services ⁺	-63696	485788	-38402	254008	0.011**
Payments for non-manuf. services	68667.078	511123.58	43012.854	269683.21	0.014**
Receipts for non-manuf. services	4970.839	51881.126	4610.466	76032.025	0.844
Manufacturing value-added*	591354.95	3285369.1	528107.84	2628897.2	0.424
Inclusive operating-surplus ▫	520710.11	3219039.2	472208.2	2544398	0.000***

Note: The before reform sub-sample consists of 2,267 observations and the after-reform sub-sample of 3,369 observations. Each observation in this sample is a 4-digit ISIC code that contains 2 and more manufacturing firms; All monetary items are presented in real terms (2011=100) and in million Iranian Rials (IR); * p<0.10, ** p<0.05, *** p<0.01; ⁰Manufacturing output comprises the following items: the total value of produced goods, receipts for manufacturing services, changes in the value of inventory of goods that are in the production process, difference between the sale and purchase value of goods that have been sold without any transformation and production of capital goods; ɨ Fixed capital formation refers to net capital (goods, equipment and assets) accumulation within the accounting period; ⁺ Non-manufacturing service account refers to the receipts and payments for non-manufacturing services such as rent for buildings or equipment/machinery, communication, transportation, auditing services, research and labouratory activities, training and commissions. * Manufacturing value-added is the difference between total output and total input; ▫ inclusive operating-surplus is obtained after the deduction of (wage and non-wage) compensations from value-added and including the net value of non-manufacturing service account.

This is Firm capital has two elements: fixed capital and inventory change. Although overall capital formation shows no significant change after the reform, fixed capital formation declines considerably. Moreover, we observe a significant decrease in non-manufacturing services after the introduction of the energy subsidy reform. This is likely due to the increase in transportation costs which are part of non-manufacturing services and responded considerably to the energy subsidy reform. Moreover, there is a sizable reduction in value-added and operating-surplus (approximately 10 percent). However, only the reduction in operating-surplus is statistically significant. In the next section, we account for industry specific effects to further disentangle whether the overall observed increase in spending on energy manifests itself in performance losses.[6]

6 Results

To go beyond differences in averages before and after the reform, we proceed with the multivariate analysis accounting for regional firm-group specific effects. First, we present the main results following the empirical models specified above. The second and third part introduce the supplementary and robustness analyses and the fourth part elaborates on the heterogeneity of the results as well as mitigating and reinforcing firm level characteristics. We use *output*, manufacturing *value-added* and *operating-surplus* as performance indicators. The outcome indicators are employed in logarithmic form. Thus, the coefficient estimates do not display the precise marginal effects and the marginal effects are obtained by exponentiating the original coefficients: (exp(coefficient)-1)*100. While all models include firm-level confounding factors (Table 5), control for a time trend, international sanctions and regional firm group specific effects, for the sake of brevity we only present the coefficient associated with the energy subsidy reform.

6.1 Main results

The main results are presented in Table 5. Panel A and B report the empirical results of estimating Eq. 1 that is the before-after analysis employing the regional firm group specific effects for different timeframes. Panel A includes all manufacturing firms and the complete period of available data from 2009 to 2013 allowing us to gauge mid-term effects. Panel B focuses on the immediate effects and includes only one post reform year, namely 2011. The reform was initiated in December 2010. Given that the manufacturing firms are surveyed during the summer of each year, the 2011 survey is done roughly 6 to 9 months after the introduction of the reform.

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[6] Appendix 3 shows the same summary statistics for the treatment and control group, before and after the reform. The temporal dynamics of the treatment group are not different from the above discussed relationships. However, for the control group, the difference in manufacturing output before and after the reform is statistically significant. Importantly, since the treatment and control group come from different sectors they differ in their composition and thus in their average characteristics. For that reason, we control for the time-varying firm characteristics in the analysis on top of the firm-group-specific effects.

Table 5
Impact of the energy subsidy reform on manufacturing firms

		Output	Value-added	Operating-surplus
Panel A	Mid-term impact (2009-2013)			
	SRCT	-0.065***	-0.125***	-0.148***
		(0.019)	(0.030)	(0.055)
	Impact	-6.3%	-11.8%	-13.8%
		4,861	4,848	4,693
Panel B	Short-term impact (2009-2011)			
	SRCT	-0.082***	-0.144***	-0.206***
		(0.020)	(0.031)	(0.062)
	Impact	-7.9%	-13.4%	-18.6%
	N	2,905	2,897	2,804
Panel C	Difference in Difference			
	SRCT*treatment	-0.034**	-0.076***	-0.096*
		(0.017)	(0.029)	(0.051)
	Impact	-3.3%	-7.3%	-9.2%
	N	4,861	4,848	4,693

Note: Panel A and Panel B report the impact of the subsidy reform on manufacturing firms with 10 and more workers for the period 2009-2013 and 2009-2011, respectively. Panel C shows the impact of the subsidy reform employing a difference-in-difference model with the lower energy intensive firms forming the counterfactual. All models use fixed effects at the regional 4-digit ISIC level. Standard errors clustered at the individual firm group level are presented in parentheses; * p<0.10, ** p<0.05, *** p<0.01; N is the number of observations. The dependent variables (outcome indicators) are in logarithmic form. All models include the following set of control variables: raw material (log), non-durable tools and equipment (log), packaging material (log), energy input (log), water input (log), payments for manufacturing services (log), worker's compensation (log), capital formation (log), number of firms in the firm group(log), a proxy for international sanctions, i.e. Iran's oil exports (in barrels) and a time trend.

The control group consists of industries that are less-sensitive to an increase in energy prices i.e. low energy-intensive industries excluding machinery and motor vehicles (ISIC 29 and 34). The following groups are in the control group: tobacco products (ISIC16), wearing apparel, dressing and dyeing (ISIC18), manufacture of leather products (ISIC19), printing and publishing (ISIC22), office, accounting and computing machinery (ISIC30), electrical machinery and apparatus n.e.c (ISIC31), radio, tv and communication equipment (ISIC32), medical, precision and optical instruments (ISIC33), other transport equipment (ISIC35).

We observe a contraction in all three performance indicators that is less pronounced in the mid-term (Panel A). The effect is practically meaningful and statistically significant. Output declined by nearly 6% due to SRCT, value-added and operating-surplus measures shrunk by approximately 12 and 14%, respectively. The immediate effects reported in Panel B tend to be 2 percentage points larger in absolute terms indicating that firms were not able to change their mode of production and smooth out the increased energy costs directly after the reform. Thus, production processes are inelastic in the short-term. Particularly, the short-term reduction in operating-surplus is large (almost 19%). This can be considered as evidence of *absorption*. In the short-run, firms seem to opt for taking in the energy price by compromising their profit margin (Rentschler et al., 2017; Rentschler and Kornejew, 2017). It is noteworthy that the reduction in profit could have been larger if the compensation of workers was not reduced.

Panel C of Table 5 reports the outcome of the difference-in-difference model (Eq. 2) with the less-energy-sensitive firms forming the counterfactual.

To be precise, the control group consists of industries that are less-sensitive to changes in the energy price, i.e., industries that are low energy-intensive and/or do not extensively use high energy-embodied intermediate goods such as metals. The results of the difference-in-difference estimation show that due to the energy subsidy reform energy-price-sensitive firms (treatment group) experienced a decline in output of about 3% and a decline of value-added and operating-surplus of about 7 and 9%, respectively, compared to the less energy-sensitive firms that constitute the control group. All the estimates are economically and statistically significant. Since the control group in the difference-in-difference framework are industries that are less energy-sensitive and thus are likely to react less to an increase in the energy price, it comes as no surprise that the difference-in-difference estimates are smaller in absolute magnitude compared to the before-after estimates. The former helps us to gauge the validity of the before-after results, which are likely to be upper bounds since we cannot completely rule out all other possible events that affect firm performance despite accounting for regional firm-group specific effects, inputs, the temporal trend and the international sanctions in the form of Iran's oil exports. we therefore consider the difference-in-difference results as conservative or lower bound estimates of the impact of the energy subsidy reform.

While not shown, we note that our findings are not driven by the impact of the international sanctions. Across specifications we control for the international sanctions and identify sizeable negative repercussions that are above and beyond the impact of the energy subsidy reform. Put differently, the presented results about the impact of the energy subsidy reform are purged from the impacts of the international sanctions.

6.2 Supplementary analysis: Relationship between firm performance and the energy price

As a supplementary analysis and to gauge the validity of the results against alternative measures, we use the development of the energy price instead of a simple reform dummy. Thus, in this specification we explore how the studied outcome indicators react to the increase in energy prices. Since manufacturing firms use a range of fuels and electricity, all the prices of the energy carriers are converted to a uniform unit which is Iranian Rial per Toe (ton of equivalent crude oil) using the unit converter guidelines published by the Iranian Ministry of Energy. In the empirical specification we employ the average of the converted price of fuels and electricity (in logarithmic form).

Table 6 presents the results. For the full dataset and timeframe, we show that a doubling of the energy price diminishes output by 7%. Similarly, value-added and operating-surplus decline by nearly 13 and 14%, respectively. These results are congruent with the before-after results presented in Table 5, Panel A.

Panel B presents the results from splitting the sample into the less energy-sensitive firms, our control group, and the energy-sensitive firms. As expected, the less energy-intensive firms do not show any practically or statistically significant response to the increase in the energy price. In turn, the energy-sensitive industries do, and the response is as large as for the full sample.

Moreover, the difference between the two groups is significant. This analysis further supports our choice of control group in the difference-in-difference analysis. Alternatively, we also employed a specification with the real energy price (Appendix 4). The upshot of these specifications does not suggest any different conclusion: In fact, the magnitude of the impact is even larger when relying on the real energy price for the analysis.

Table 6
Effect of the energy price on the performance of manufacturing firms

		Output	Value-added	Operating-surplus
Panel A	Overall			
		-0.072***	-0.127***	-0.140***
		(0.017)	(0.027)	(0.050)
	N	4,861	4,848	4,693
Panel B	Control group			
	(Less energy-sensitive industries)	-0.009	-0.045	-0.019
		(0.040)	(0.078)	(0.130)
	N	566	566	546
	Treatment group			
	(Energy-sensitive industries)	-0.078***	-0.135***	-0.153***
		(0.018)	(0.029)	(0.054)
	N	4,295	4,282	4,147

Note: Impact of the energy price on the performance of manufacturing firms with 10 and more workers for the period 2009-2011 using fixed-effect models. All models employ firm-group fixed-effects. Standard errors clustered at the individual firm group level are presented in parentheses; * p<0.10, ** p<0.05, *** p<0.01; N is the number of observations. Both dependent and independent variables are in logarithmic form.

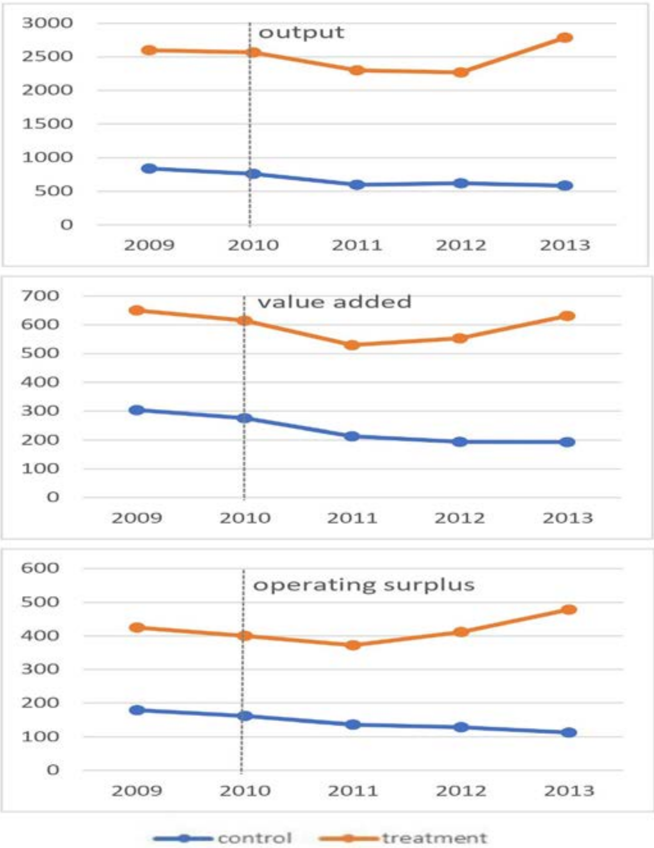
Details about the confounding factors included in the models and the construction of the control group can be found in the note to Table 5.

6.3 Robustness checks

The pre-subsidy reform trend

Our difference-in-difference identification strategy rests on the assumption that in the absence of the energy reform the differences between the control and treatment group are constant over time. This assumption is not testable. Yet, having two time periods before the introduction of the energy subsidy reform allows us to observe the pre-treatment trends. Figure 7 shows that the pre-subsidy reform trends are parallel. After the reform the energy-sensitive industries first experience a larger negative impact compared to the less energy-sensitive industries but then also experience a larger gain starting in 2012 which is reinforced in 2012. In turn, the less energy-intensive firms only see a small performance impact and then a steady performance. These differences highlight the need to account for firm-group specific effects. We also observe the already discussed difference in levels in the outcome indicators. The control group of less energy-sensitive firms has a lower performance, on average, compared to the treatment group. As explained above, we control for these differences by including the inputs used and by employing regional firm-group specific fixed effects. We take the visual presentation of the trends in Figure 7 as indication that the identified impact estimates are unlikely to be driven by differences in the pre-treatment trend.

Figure 7
Pre-subsidy reform trends



Note: All performance indicators are presented in billion Iranian Rials

Balanced sample

Our study sample is unbalanced. Over the years more and more 4-digit ISIC codes (firm groups) have been added to the sample. Theoretically, if the decision to add new firm groups to the sample is not correlated with the firms' performance, fixed-effect models should yield consistent estimates. If not, the error term will no longer be random. It is unlikely that adding more ISIC codes to the sample is correlated with the firms' performance. Rather it is due to the progress made by the statistical office that more inclusive datasets have been achieved over the years. Moreover, only about 12% of our observations are unbalanced. The majority of the firm groups, nearly 88% of the observations, are present in all five survey rounds. Yet, to rule out any effects stemming from the unbalanced sample we re-estimated the before-after and the difference-in-difference model for the balanced panel. The detailed results are summarized in

Appendix 5. The findings are akin to those from the models estimated with the full sample (Table 5). The variation in the estimated impacts is less than 1 percentage point and all estimates are statistically significant.

6.4 Heterogeneity analysis and impact channels

The discussion so far was focused on the average impact of the energy subsidy reform on manufacturing firms. To go beyond the average impact, we also inspected the heterogeneity of the impact and firm characteristics that reinforce or mitigate the impact.

Table 7, Panel A compares the impact of the reform on low, moderate and high energy-intensive industries as classified in Table 2. As expected, the impact on the low energy-intensive firms is less than the average impact and statistically insignificant. An obvious immediate conclusion would be that high energy-intensive industries are the ones that are affected the most by the energy reform. But, in fact, the data show that the moderate energy-intensive industries experienced the largest impact, nearly 2 percentage points higher as compared to the high energy-intensive group. Looking into the composition of the high energy-intensive group reveals that 4 out of 5 high energy-intensive industries in the sample are upstream industries, namely (i) coke and refined petroleum products, (ii) chemical products, (iii) non-metallic mineral products and (iv) manufacture of basic metals. Upstream industries refer to industries that operate in the early stages of the production chain. Almost all downstream industries are linked to them together with other end-users such as households. For example, the petroleum industry is an upstream industry as its production is used in the rest of the production chain and particularly in moderately energy-intensive industries such as the rubber and plastic industry, fabricated metal products or food and beverage industry. For upstream industries, the transmission channel for increased energy prices is mainly the direct one, namely in the form of increased energy costs. But since these industries are at the beginning of the production chain, they can pass-through a large portion of the energy cost increase to downstream industries or consumers. In turn, the moderately energy-intensive firms experience a snowball effect along the production chain due to the pass-through mechanism. We show with a simple example that the incorporation of one intermediate good for which the price increase is fully passed though results in more than a doubling of the price increase imposed on the final product if the final product is subject to both a direct and an indirect effect (Appendix 6). This snowball effect is strongest for the downstream industries that are located at the end of the production chain or those who have multiple linkages to other high or moderate energy-intensive industries. These industries experience the impact of the subsidy reform from all three channels: directly through increases in energy costs, indirectly through increases in the costs of raw materials which constitute on average around 90% of the manufacturing input, and through decreasing demand. For all these reasons we identified an 8, 13, and 16% decrease in output, value added and operating-surplus, respectively, for the moderate energy-intensive firms highlighting that the negative repercussions of the energy reform are particularly large for moderate energy-intensive firms.

Table 7
Heterogeneity analysis

		Output	Value-added	Operating-surplus
Panel A	Energy-intensity			
	Low energy-intensity+			
		-0.026	-0.066	-0.098
		(0.032)	(0.067)	(0.120)
	Impact	-2.6%	-6.4%	-9.3%
	N	1,076	1,075	1,039
	Moderate energy-intensity+			
		-0.083***	-0.140***	-0.180**
		(0.027)	(0.046)	(0.088)
	Impact	-8%	-13.1%	-16.5%
	N	2,133	2,122	2,061
	High energy-intensity+			
		-0.068	-0.132**	-0.126
		(0.041)	(0.054)	(0.089)
	Impact	-6.6%	-12.4%	-11.8%
	N	1,652	1,651	1,593
Panel B	Technology-intensity			
	Low and medium-low technology†			
		-0.078***	-0.142***	-0.161**
		(0.023)	(0.036)	(0.066)
	Impact	-7.5%	-13.2%	-14.9%
	N	3,541	3,529	3,415
	Medium-high and high technology †			
		-0.026	-0.078	-0.134
		(0.027)	(0.057)	(0.103)
	Impact	-2.6%	-7.5%	-12.5%
	N	1,320	1,319	1,278

Note: Impact heterogeneity of the subsidy reform on manufacturing firms with 10 and more workers for the period 2009-2013 using fixed-effect estimates. Details about the confounding factors included in the models can be found in the note to Table 5. * p<0.10, ** p<0.05, *** p<0.01.

+Manufacturing firms are divided into three categories based on the level of energy-intensity. Energy intensity is defined as energy consumption (Toe) per value-added. For details compare the footnote to Table 2.

† The classification of industries is adopted form OECD (2011). High and medium-high technology intensity industries are chemical products (24), machinery and equipment, n.e.c. (29), office, accounting and computing machinery (30), electrical machinery and apparatus n.e.c (31), radio, tv and communication equipment (32), medical, precision and optical instruments (33), motor vehicles, trailers and semi-trailers (34), other transport equipment (35) excluding building and repairing ships and boats (35). The remaining codes are low and medium-low technology-intensive manufacturing firms.

Furthermore, the literature suggests that *technology* is another transmission mechanism: high-tech firms are affected less by energy prices compared to low-tech firms (Popp, 2001; Golder, 2011; Rentschler, 2016). This is what we investigated as well. Adopting the classifications of technology-intensive industries by the OECD (2011), we assess whether the energy reform hit low-tech firms more. Results are in Panel B of Table 7. The findings support the aforementioned literature, i.e., the impact of SRCT on low and medium-low technology-intensive industries is substantially larger (8, 13, an 14% reduction in output, value added and operating-surplus, respectively) compared to the medium-high and high technology-intensive industries. In fact, the latter do not experience any significant negative performance impacts.

Last but not least, Table 8 explores other firm characteristics which reinforce or mitigate the impact of the energy reform. The existing literature points to a negative association between firm size and energy intensity due to economies of scale (Golder, 2011). This implies that larger firms would be less affected by increases in the price of energy. Panel A of Table 8 shows that, on the contrary, large firms (firm groups where more than half of the firms have more than 100 workers) lost about 5 to 6 percentage points more than the average firm in terms of value-added and operating-surplus, respectively. This is likely to reflect the fact that the large firms under study here tend not to be the most dynamic ones. Far from it, they tend to have less flexibility in responding to external shocks because of their large scale of operation. Thus, they mitigate the price shock by reducing their profit margin.

Table 8
Mitigating and reinforcing firm characteristics

		Output	Value-added	Operating-surplus
Panel A	Large firms◦			
		-0.076**	-0.189**	-0.250
		(0.033)	(0.083)	(0.171)
	Impact	-7.3%	-17.2%	-22.1%
	N	532	532	516
Panel B	Large fixed-capital▫			
		-0.044	-0.103	-0.112
		(0.055)	(0.099)	(0.217)
	Impact	-4.3%	-9.8%	-10.6%
	N	1,133	1,126	1,081
Panel C	Food and beverages industry			
		-0.128***	-0.210***	-0.314***
		(0.039)	(0.069)	(0.118)
	Impact	-12%	-18.9%	-26.9%
	N	1,129	1,118	1,086
Panel D	Located in provinces with low GDP‡			
		-0.077	-0.137	-0.120
		(0.056)	(0.089)	(0.190)
	Impact	-7.4%	-12.8%	-11.3%
	N	636	630	597

Note: Impact heterogeneity of the subsidy reform on manufacturing firms with 10 and more workers within 2009-2013 using fixed-effect estimates. Details about the confounding factors included in the models can be found in the note to Table 5. * p<0.10, ** p<0.05, *** p<0.01.

◦ Large firms refer to the firm groups that more than half of the manufacturing firms have 100 workers and more.

▫ Large fixed-capital refers to firm groups that the ratio of capital formation to output is more than average.

‡ The eight provinces with the lowest GDP per capita are: West Azarbaijan, Sistan & Balouchestan, Kurdestan, Golestan, North Khorasan, South Khorasan, Chahar-Mahal & Bakhtiari and Lorestan.

Next, we turn to the role of fixed-capital in mitigating the price shock. Panel B presents results for firms with a large fixed-capital formation meaning that the ratio of capital formation to output is more than average. Manufacturing firms with large fixed-capital are less affected by the energy subsidy reform suggesting that there might be some substitution between energy and capital to alleviate the negative impact of SRCT for these firms. In Panel C, we turn to the food and beverage industry because it is the most prevalent industry in the manufacturing sector. Roughly a quarter of the manufacturing firms in the dataset at hand are active in this industry. This industry has been affected more than the average firm by the energy reform which is not unexpected since food production is moderately energy intensive. Moreover, it is a downstream industry not only in the manufacturing sector but also in the agricultural sector. Consequently, this industry experiences the pass-through of several other sectors. Another channel that adversely affects the food and beverage industry is found on the demand side. Zarepour and Wagner (2021) identified a significant negative decline in households' food expenditure due to SRCT. Finally, we examine whether being located in the eight provinces with the lowest level of GDP has an implication on the impact of the subsidy reform. The results are mixed. The decreasing effect on output and value-added is larger compared to the average impact, but for the operating-surplus it is less. Besides, the estimates are not statistically significant at conventional levels.

In short, the findings about impact heterogeneity as well as mitigating and reinforcing firm characteristics indicate that the magnitude of the impact of the subsidy reform hinges on the intensity of energy consumption and the location of the industry in the production chain. The heterogeneity analysis once more reinforces the role of indirect transmission channels of the increase in the energy price to manufacturing firms. Both high and moderate energy-intensive industries are considerably affected by the subsidy reform. While technological advancement and a solid capital base have shown to lessen the negative repercussions of the Iranian energy subsidy reform.

7 Conclusion and policy implications

Due to the Iranian energy subsidy reform (SRCT) in December 2010 the energy prices for all economic sectors including manufacturing firms hiked up severalfold. This research presents, to the best of our knowledge, the first attempt to disentangle the micro-economic impacts of the reform on firm performance. The literature on energy prices and manufacturing firms points to three main channels through which an increase in the energy price may be transmitted to firms. The first one is a direct channel and manifests itself in an increase in energy price and related increases in energy costs for manufacturers. Second, the increase in the energy price leads to an increase in the price of materials that intensively embody energy and are inputs to other firms. Hence the subsidy reform increases the price of other inputs apart from energy as well. The location of the industry in the production chain, the magnitude of high-energy-embodied materials (such as petroleum products, bricks, cements, steel and iron) that firms use and the degree that upstream firms can pass-through the costs determine the significance of transmission from this channel. These two channels are associated with the supply side. In turn, the third channel presents the demand side effect. Increases in energy prices have a direct impact on the real budget of households and lead to a contraction in aggregate demand. Such reduction in consumer demand can transmit from down-stream industries all the way up (Zarepour and Wagner, 2021).

In order to empirically identify the impact of the reform on manufacturing firms and to assess the possible role of the different channels, we employed impact analysis techniques. We used a micro panel dataset of manufacturing firms with 10 workers or more (at the 4-digit ISIC level) for the period 2009 to 2013 to study three outcomes: (i) output, (ii) value-added, and (iii) operating-surplus proxying for profits. Since the reform universally affected all manufacturing firms without any exceptions, we started the analysis with a simple before-after comparison which accounted for regional firm-specific effects. Next, we employed a difference-in-difference framework. We constructed a control group that consists of industries that are less-sensitive to the increase in the price of energy. Across specifications, the results show that the energy subsidy reform had a significant negative impact on all three firm performance indicators. This impact is larger in the short-term, i.e., one year after the reform, compared to the mid-term, i.e., 3 years after the reform. Firms responded to the increase in energy prices with two mechanisms: (i) absorption, meaning that they swallow the increased costs by reducing the compensations (forced absorption by workers) and/or accepting lower profits and (ii) pass-through, implying that the firms increased the price of intermediate outputs and/or the costs for consumers. Related, the findings suggest that the indirect effect of the energy price increase is considerable and by no means inferior to the direct effect. Put differently, moderately energy-intensive industries are affected more by the increase in the price of energy than high energy-intensive ones. Moreover, the impact of the subsidy reform on firms is heterogenous. High and medium- high technology-intensive industries are less affected by the increase in the energy price. Similarly, manufacturing firms that invested considerably in fixed-capital were able to mitigate the effects of the price increase. Hence, the availability and affordability of capital in the form of energy efficient technologies plays a crucial role and highlights the importance of non-price policies that identify and remove the administrative and financial barriers to adopt new technologies (Barkhordar et al., 2018; Solaymani, 2021) particularly for energy-sensitive industries.

Like any study of a universal reform, the presented findings have to be gauged against the limitations imposed by the study set-up and the data. We see two major limitations: first, we had to construct a quasi-experimental counterfactual. While this is undoubtedly below the gold standard of a randomized controlled trial, the robustness of the findings across models increases confidence that the identified patterns are meaningful and are not due to chance. Second, the analysis is at the 4-digit ISIC level and only includes firms with 10 worker or more for each province with more than two firms per ISIC code. Thus, we cannot draw firm specific conclusions but only about firm groups within the same region and industry. Assessing these limitations against the scale and scope of the energy subsidy reform and the potential to learn from the reform for related policy interventions, we argue that the presented analysis allows us to identify impact patterns of a powerful, real-world policy instrument.

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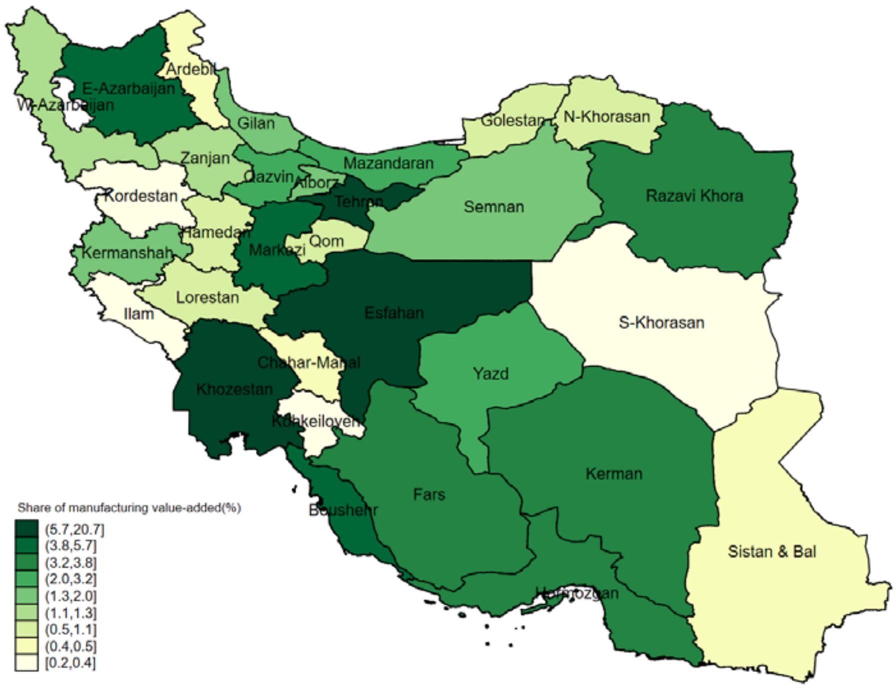
Appendices

Appendix 1
Geographical dispersion of manufacturing value-added



Note: Regional accounts data, compiled from information published by SCI.

Appendix 2
Energy carriers' prices for the manufacturing sector before and after the reform

	Before the reform	After the reform
Gasoline	4,000	7,000
Gas Oil	165	3,500
Kerosene	165	1,000
Fuel oil (Mazut)	95	2,000
Natural gas	189	700
Liquefied gad	31	5,400
Electricity	264	442

Source: Iranian Ministry of Energy, energy balance sheets

Note: Prices of fuel are denoted in current Iranian Rials per litre, the price of natural gas and electricity are denoted in current Iranian Rials per cubic meter and per kilowatt hour, respectively.

Appendix 3

Selected statistics of control and treatment group- before and after the energy subsidy reform

	Control group					Treatment group				
Variables- Control group	Before the reform		After the reform		Diff in mean (p-value)	Before the reform		After Reform		Diff in mean (p-value)
	Mean	Std. Dev.	Mean	Std. Dev.		Mean	Std. Dev.	Mean	Std. Dev.	
Manufacturing output[0]	801726.4	1482148	601508.6	1080745	0.044**	2582671	16300000	2452273	15100000	0.773
Manufacturing input	511431.4	999024.5	401348.8	801851.8	0.116	1950269	13500000	1880483	13200000	0.856
Raw material	483293.1	962397.6	378435.9	783772.9	0.122	1829374	13100000	1768068	12900000	0.870
Non-durable tools and equipment	5336.822	23905.72	5982.941	33930.39	0.786	13512.4	82855.49	13602.92	142743.9	0.979
Packaging material	6573.425	12322.54	5156.205	11483.15	0.129	30201	118829.4	29247.7	110404.5	0.772
Energy	4049.969	6936.566	3785.792	5564.7	0.586	34382.04	185887.7	41218.68	215899	0.248
Fuel	1131.184	2227.676	1314.496	2426.985	0.322	17757.62	129992.9	21524.54	121871.4	0.299
Electricity	2918.785	4995.519	2471.296	3807.316	0.190	16624.43	92616.71	19694.14	115545.4	0.321
Water	299.7662	566.8059	494.3568	5650.196	0.571	2647.303	28189.71	3548.954	50789	0.470
Payments for manuf. Services	9974.317	32521.69	6141.188	18682.13	0.054*	29022.02	343834.3	17486.32	165531.6	0.115
Major repairment	881.9903	3006.746	660.3942	1974.921	0.251	8623.831	155049.3	5275.01	58002.02	0.284
Number of workers	744.1544	944.0072	689.7121	822.1425	0.429	1013.836	2578.991	1024.54	2598.523	0.887
Wage and non-wage compensation	96587.64	149124.6	61857.06	102137	0.004***	150785.5	663024.6	109072.8	489900.4	0.109
Average compensation per worker	106.9259	38.49675	75.53906	31.80934	0.000***	109.578	45.84493	77.38985	68.02669	0.000***
Firm number	9.507	10.601	8.566	9.176	0.222	13.241	22.419	12.589	19.570	0.278
Capital formation	60701.27	201820.8	52168.11	119382.9	0.494	162875.9	1124609	132679.5	1471010	0.437
Fixed capital formation	26091.91	86106.28	15310.85	38745.15	0.029**	107587	902108.1	59094.83	413219.3	0.011**
Inventory change	34609.36	148717.9	36857.26	105053.2	0.819	55288.88	510553.5	73584.68	1379531	0.571
Net non-manufacturing services [+]	-23143.4	51588.42	-12810.3	38808.7	0.003***	-69225.3	517266.2	-41811.2	269847.6	0.015**
Payments for non-manuf. Services	26610.86	53336.39	14752.7	40069.49	0.001***	74401.06	544263.8	46777.07	286506.1	0.019**
Receipts for non-manuf. Services	3467.495	21125.17	1942.356	11646.44	0.232	5175.806	54752.31	4965.855	80820.98	0.919
Manufacturing value-added*	290295	588317.1	200159.8	332754.6	0.012**	632401.7	3493553	571790.1	2793028	0.498
Inclusive operating surplus ▫	170564	431540.2	125492.4	244706.9	0.087*	412390.9	2394489	420906.1	2287895	0.899

Note: For the control group the sample consists of 668 observations. The before-reform control group sub-sample consists of 272 observations and the after-reform control group sub-sample of 396 observations. For the treatment group the sample consists of 4,968 observations. The before-reform treatment group sub-sample consists of 1,995 observations and the after-reform treatment group sub-sample of 2,973 observations. For more details on the content of the variables compare the note to Table 5 in the main manuscript.

Appendix 4
Effect of the real energy price on the performance of manufacturing firms

		Output	Value-added	Operating-surplus
Panel A	Overall			
		-0.079***	-0.140***	-0.152***
		(0.018)	(0.030)	(0.055)
	N	4,861	4,848	4,693
Panel B	Less sensitive industries			
	(control group)	-0.010	-0.048	-0.022
		(0.044)	(0.086)	(0.144)
	N	566	566	546
	Other industries			
	(treatment group)	-0.086***	-0.149***	-0.166***
		(0.020)	(0.032)	(0.059)
	N	4,295	4,282	4,147

Note: Impact of the real energy price on the performance of manufacturing firms with 10 and more workers for the period 2009-2011 using fixed-effects models. All models employ firm-group fixed effects. Standard errors clustered at the individual firm group level are presented in parentheses; * p<0.10, ** p<0.05, *** p<0.01; N is the number of observations. Both dependent and independent variables are in logarithmic form.

Details about the confounding factors included in the models and the construction of the control group can be found in the note to Table 5.

Appendix 5
Impact of the energy subsidy reform employing the balanced panel

		Output	Value-added	Operating-surplus
Panel A	Mid-term impact (2009-2013)			
	SRCT	-0.061***	-0.113***	-0.130**
		(0.020)	(0.031)	(0.056)
	Impact	-5.9%	-10.7%	-12.2%
		4,278	4,270	4,159
Panel B	Short-term impact (2009-2011)			
	SRCT	-0.083***	-0.143***	-0.211***
		(0.022)	(0.032)	(0.065)
	Impact	-8%	-13.3%	-19%
	N	2,530	2,526	2,459
Panel C	Difference in Difference			
	SRCT*treatment	-0.036**	-0.068**	-0.090*
		(0.018)	(0.029)	(0.052)
	Impact	-3.5%	-6.6%	-8.6%
	N	4,278	4,270	4,159

Note: Estimates employing the balanced panel. Panel A and Panel B report the impact of the subsidy reform on manufacturing firms with 10 and more workers for the period 2009-2013 and 2009-2011, respectively. Panel C shows the impact of the subsidy reform using a difference-in-difference model. All models use firm-group fixed effects. Standard errors clustered at the individual firm group level are presented in parentheses; * p<0.10, ** p<0.05, *** p<0.01; N is the number of observations. The dependent variables are in logarithmic form.

Details about the confounding factors included in the models and the construction of the control group can be found in the note to Table 5.

Appendix 6
Simple theoretical example of snowball effect from pass-through

For the sake of simplicity, assume we have two firms in a production chain. Firm I is an upstream firm and Firm II a downstream firm. The pricing method is a simple mark-up, i.e. the price of the product is calculated by adding the production costs and a percentage of it. m represents the mark-up percentage.

Firm I incurs cost C_1 and sells its product to Firm II with $C_1 + mC_1$. Firm II incurs an extra cost C_2 and sells its product with the following price:

$$(C_1 + mC_1) + C_2 + m(C_1 + mC_1 + C_2)$$

Assume that as a result of an increase in the energy price, the direct cost of firm I and II increases by 1 unit. The prices of firm I and II would then be as follows:

Firm I: $C_1 + 1 + m(C_1 + 1)$

Firm II:

$$C_1 + 1 + m(C_1 + 1) + C_2 + 1 + m(C_1 + 1 + m(C_1 + 1) + C_2 + 1)$$

Solving and rewriting the above equation for Firm II results in:

$$C_1 + 2mC_1 + 3m + C_2 + m^2C_1 + m^2 + mC_2 + 2$$

We can then calculate the effect of pass-through by subtracting the before-price from the after-price for each firm.

Difference for Firm I: $(m + 1)$

Difference for Firm II: $(m + 2)(m + 1) = (m + 1)^2 + (m + 1)$

Following the same dynamics, the impact on the nth firm in the production chain is:

$$(m + 1)^n + (m + 1)^{n-1} + \cdots + (m + 1) = \sum_{i=1}^{n}(m + 1)^i$$

These calculations highlight the importance of pass-through and the serious indirect consequences it has.

With a mark-up percentage of 5% Firm I has higher unit costs of 1.05 due to a one unit input price increase, but Firm II has higher costs per unit of output produced of 2.15 since the price increase from the upstream product has been fully passed through. While admittedly simplistic, these calculations highlight the power of pass-through and the potential risks of snowball effects.