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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 the manufacturing sector 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 the energy-sensitivity of the studied firm-groups. The subsidy reform reduced output and value-added by 3 and 7%, respectively. Profits decreased by nearly 9%. Heterogeneity analyses show that the manufacturing sector has 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. We conclude that for successfully implementing an energy subsidy reform while maintaining growth in the manufacturing sector, direct and indirect costs have to be considered. Importantly, the results can inform expected energy reforms to mitigate climate change.

1. Introduction

The Iranian economy is known for being highly subsidized. Subsidies for energy carriers, such as fuels and electricity, affect not only consumers but also producers, in particular the manufacturing sector. Yet, as of December 2010, the Iranian government implemented a large-scale energy subsidy reform (SRCT) to remove the energy subsidies and adjust the local price of energy carriers including fuels, natural gas and electricity with global prices. The local authorities called the reform 'the largest economic surgery in the history of Iran' affecting all economic sectors. 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 folds, 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.[1] Such huge increases in energy prices do not go unnoticed and are likely to have non-negligible implications for an economy of which the manufacturing sector forms an important part. In the 2000s the manufacturing sector of Iran produced on average about 1000 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 (Fig. 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 step upward trend from roughly above 400 trillion Iranian Rial in 1994 to almost 1400 trillion Iranian Rial in 2010 (Fig. 1). However, with the introduction of the energy subsidy reform manufacturing value-added was reduced by 27%. This shrinkage in the manufacturing sector is not only unprecedent in the last two decades but also represents the largest sectoral shrinkage compared to all other sectors in that same year. The value-added of the industry and service sectors has been identified as the main channel that transmitted the adverse impact of the subsidy reform to GDP (Zarepour and Wagner, 2022).

The composition of the Iranian manufacturing sector makes it susceptible to changes in energy prices. Nearly 80% of the value-added of the manufacturing sector is produced in highly or moderately energy-intensive industries. These are food and beverage products (ISIC15), petroleum coke and refined petroleum products (ISIC23), chemical

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[1] Detailed price information is provided in Table A.1 in appendix A.

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products (ISIC24), non-metallic mineral products (ISIC26), basic metals (ISIC27), and fabricated metal products (ISIC28).

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 using a detailed, unbalanced 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 design to establish a causal relationship between the energy subsidy reform, i.e., the increase in energy prices, and the responses of the manufacturing sector. First, we employ an explorative before-after comparison with firm-group level fixed-effects to account for structural differences. Second, we identify the differential impact the reform had on the more energy-*sensitive* firms by constructing a counterfactual of firms that are less sensitive to the energy price. We identify that the energy subsidy reform considerably affected the performance of the manufacturing firms. As such output, value-added and operating-surplus (a proxy for profit) declined by at least 3, 7, and 9%, respectively. Robustness checks on the balanced panel and for the sub-sample analysis excluding the most energy-intensive industry, namely petroleum coke and refined petroleum products, confirm our findings.

International organizations are forcefully promoting the removal of fossil fuel subsidies, primarily due to their expected contribution to greenhouse gas emissions. Globally, in recent years energy subsidy reforms have been in the spotlight as reflected in the G20 summit 2009 and in the United Nations' Sustainable Development Goals (Rentschler and Bazilian, 2017). Meanwhile numerous energy subsidy reforms have been implemented across the globe (IMF, 2013): Ghana (2005), Indonesia (2003, 2005), Iran (2010), Mauritania (2008, 2011), Mexico (2001,2002), Niger (2011), Nigeria (2011), Peru (2010), and Yemen (2005, 2010). However, despite the United Nations' emphasis on the need for energy subsidy reforms, the existing literature reveals a dearth of research utilizing impact evaluation techniques to explore the ramifications of energy subsidy reforms on manufacturing firms. Only few studies shed light on this issue: Ayakwah and Mohammed (2014) found that fuel price adjustments in Ghana adversely impacted the growth of small and medium businesses by raising the costs of transportation, raw materials, and capital. Rentschler and Kornejew (2017) demonstrated the long-term negative effects of energy subsidy reforms on the profitability of the manufacturing and mining sectors in Indonesia. Similarly, Rahmati and Pilehvari (2019) revealed a 3% reduction in the productivity of Iranian firms due to the energy subsidy reform. To put the results in perspective, the literature identifies three channels through which energy price increases can affect firms (Rentschler and Kornejew, 2017; Rentschler et al., 2017). The first is a direct channel, reflecting the actual rise in energy costs, which can have a greater impact on industries that are more energy-intensive. The second channel is indirect, and refers to the increase in the costs of intermediate inputs that are highly energy-embodied. Metals such as iron and steel are highly energy-embodied. Industries that intensely consume such inputs tend to be affected by the pass-through costs of upstream industries (Kim et al., 2010; Sijm et al., 2006; Fabra and Reguant, 2014; Sadath and Acharya, 2015). The third channel is attributed to the demand side. Increases in the energy price may cause increases in the general price level and thus diminish the consumers' purchasing power. As a result, manufacturing firms face demand contraction (Zarepour and Wagner, 2022; Ayakwah and Mohammed, 2014; Kilian, 2008).

Conducting further exploratory analyses of our data we find observational evidence that the increase in energy prices affected the firms through all three aforementioned channels. Yet, 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 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 the results present an ex-post evaluation of a large-scale energy reform, they can be used to inform energy policies that are likely to be put in place to mitigate climate change. The reforms necessary to ensure the needed industry contribution to the desired limit on global warming to well below 2 degrees compared to pre-industrial levels will have repercussions on firm performance and the study at hand can give an indication on possible effects as well as mitigating and reinforcing firm characteristics.

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

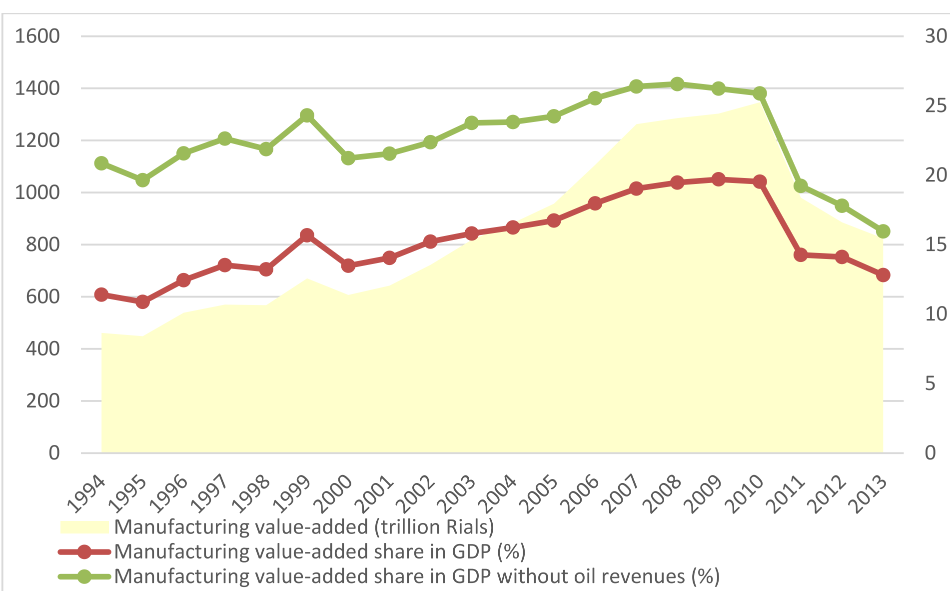

Fig. 1. Manufacturing sector's role in the economy.
Note: Manufacturing value-added is denoted in real terms (2011 = 100) and in trillion Iranian Rials, based on national accounts data published by the Statistical Center of Iran (2015).

energy prices affect the manufacturing sector. Sections 4 introduces the data. The research design and empirical identification strategy are presented in Section 5. Section 6 discuss the results and Section 7 concludes.

2. Energy consumption and intensity of the manufacturing sector in Iran

Data about energy consumption of the manufacturing sector can either be obtained from the supply side, or from the demand side. For the first case, data can be accessed from the Iranian Ministry of Energy which provides energy balance sheets. The second source is provided by the Statistical Center of Iran (SCI) and is taken from the firms' own reports in the survey about manufacturing firms with 10 and more workers. Each of these references has their own advantages 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 work informally. In turn, the available firm-level data includes informal firms but only represents those firms with 10 workers and more.

The total yearly energy consumption of the manufacturing sector according to both sources is presented in Table 1. The Ministry of Energy statistics show an increasing trend in energy consumption by the manufacturing sector. It starts at 37.73 million tons of crude oil of energy (Toe) in 2009, increases to 42.46 million Toe in 2011 when the reform hit and continues raising until 2013. In turn, the survey data suggest fluctuations in energy consumption across the years with 2009 reporting the highest energy consumption and 2010 the lowest. Yet, there is no indication that energy consumption was reduced in response to the subsidy reform. This observation is in line with findings by Ranjbar Fallah (2001) who estimated energy demand functions for the Iranian manufacturing sector, showing that the increase in the energy price did not curb energy consumption due to the technological inflexibility of the sector.

Yet, the total energy consumption of the manufacturing sector as well as average firm level use only provide limited information since they disguise industry-specific energy dependence. We capture energy dependence with the energy-intensity of the manufactures. It 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 Toe per each real billion Iranian Rial value-added (2011 = 100). To calculate the total energy consumption, the quantities of all energy carriers 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. Then, the energy intensity measure is calculated at the 2-digit level ISIC code using the survey data of manufacturing firms with 10 and more workers. We have opted for the 2-digit level since data about the *quantity* of energy consumed is only available at the 2-digit ISIC level. We use the years 2009 and 2010, i.e., the period before the introduction of the energy subsidy reform, for the calculation to avoid conflating our classification with reform impacts. The average consumption over that period is used. The resulting energy intensity measures are presented in Table 2.

Table 1
Total manufacturing energy consumption (million Toe).

	2009	2010	2011	2012	2013
Total manufacturing sector energy consumption[a]	37.73	41.16	42.46	44.52	45.27
Total energy consumption of manufacturing firms with 10 and more workers[b]	43.42	39.98	42.08	40.57	42.07

Source: [a]Ministry of Energy, Energy balance sheets; [b]Statistical enter of Iran, Survey of manufacturing firms with 10 and more workers.
Note: Toe is the abbreviation for 'Ton of oil equivalent'.

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

ISIC	Industry code	Energy intensity[a]	Energy intensity classification[b]
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.[c]	29	10.13	Low
Manufacture of office, accounting, and computing machinery	30	2.61	Low
Manufacture of electrical machinery and apparatus n.e.c.[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.[c]	36	14.72	Moderate
Recycling	37	42.37	Moderate
Average without ISIC code 23		25.76	
Average		55.27	

Source: Survey of manufacturing firms with 10 and more workers.
Note: Energy intensity is classified in three categories: (1) low, (2) moderate, and (3) high.
[a] 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.
[b] 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 moderately energy-intensive; industries with below median energy intensity, i.e., below 12.07 Toe, are classified as low energy-intensive.
[c] n.e.c.: not elsewhere classified;

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 that 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). Manufactures 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.

The availability of rich energy resources has had a great influence on the shape of the Iranian manufacturing sector. Even after the energy reform nearly half of the manufacturing value-added is produced in highly energy-intensive industries showing their importance for the Iranian economy (Fig. 2). Yet, the decrease in the manufacturing value added of highly energy-intensive firms from 60 to 48% after the reform hints at the fact that the energy subsidy reform had a major impact on the firms.

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, affected the 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. Yet, the magnitude and the persistence of the effect over time depends on the production function and the existence of a substitute for energy (Hope and Singh, 1999). Bohi (1991) developed a model that illustrates how energy prices influence the output through price and substitution effects. In this model, output is a function of capital, labor 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 labor and 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 the real wages are sticky the substitution effect between energy and labor 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 the 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 the production and further adds to the negative price effect (Bohi, 1991).

When the input ratios are interchangeable, in response to rising energy prices firms have to move to a higher capital-to-output and/or labor-to-output ratio. These adjustments often imply productivity improvements, i.e., the employment of more (energy) efficient technologies. Kong et al. (2020) studied whether energy price increases induced innovation that led to energy-saving using data of 1735 Chinese firms for the period 2003–2006 finding evidence that firms innovated more as measured by patent applications. Similarly, Golder (2011) associated the improvement in the productivity of energy inputs in the manufacturing sector of India between 1992 and 2008 with increases in energy prices and related technological improvements. Yet, 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 the profit margin is 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. Yet, 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 whether inputs such as capital and energy are substitutes or complements. Bardazzi et al. (2015) using 2000–2005 data of Italian manufacturing firms identified that energy is the most elastic input. They show that capital and energy tend to be substitutes in low-technology sectors and weak complements in other sectors. In turn, Arnberg and Bjorner (2007) using a micro-panel dataset of manufacturing firms in Denmark found that both electricity and other fuels are complementary to capital inputs. Deininger et al. (2018) investigated the substitutability between the input factors capital, labor, energy and raw material with respect to the

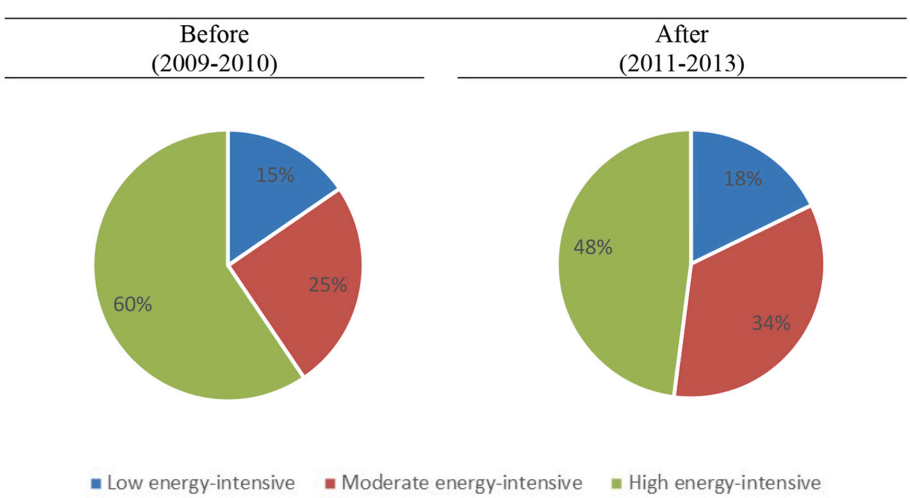

Fig. 2. Manufacturing value-added based on energy intensity.
Source: Survey of manufacturing firms with 10 and more workers.
Note: Highly energy-intensive are manufactures that consume above average energy (Toe) per value-added. Moderately energy-intensive are manufactures that consume less than the average Toe per value-added but more than the median. Manufacturers with below median energy consumption are considered low energy-intensive.

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 manufactures. There, energy and capital are complementary; a 10% increase in the energy price reduced capital use by nearly 1%. Thus, overall, the existing literature provides inconclusive findings.

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 labor, 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. (2008) attribute the different outcomes of the studies to differences in the underlying assumptions. The authors compiled and synthesized the heterogenous empirical studies on the substitution between energy and capital in a meta-analysis and show that assumptions related to returns 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 cross-price 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., 2008). Likewise, Haller and Hyland (2014) show that with the same dataset opposing results can be calibrated due to differences in model specification and differences in the aggregation of energy inputs. In short, the literature relying on the calibration of macro-models calls for a different approach to shed further light on the relationship between capital and energy.

3.2. Indirect channels for energy prices to affect firm performance

Next, we turn to indirect channels for energy prices to affect firm performance. A first indirect channel that connects the impact of energy prices with 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 the increase 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 B, showing that already the dependence on one input for which the costs are directly passed through can severely affect the price of products from downstream 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 that other industries can pass-through the energy price (Rentschler et al., 2017). The existing empirical literature supports the pass-through argument; pass-through has been documented by Kim et al. (2010), Sijm et al. (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 the aggregate demand since it affects consumer budgets and in particular decreases the demand for energy-intensive products (Bohi, 1991; Kilian, 2008; Rentschler et al., 2017; Rentschler and Kornejew, 2017). Sadath and Acharya (2015) analyzed the effect of rising energy prices for the 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 in investment transmitted through both channels, i.e., the demand and the supply side. Similarly, Ayakwah and Mohammed (2014) emphasized the negative impact of increases in energy prices transmitted through the demand side for the case of Ghana.

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 introduced theoretical links we assessed data-driven studies about energy subsidy reforms.

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

There is only a limited number of studies addressing the impact of energy subsidy reforms on manufacturing firms (Rentschler et al., 2017). For the case of Ghana, Ayakwah and Mohammed (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 the SMEs through increases in the costs of transportation, raw materials, capital and also through the demand channel since the real income of the consumers was reduced 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 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) employ cross-sectional, micro-level firm data for the year 2013 and demonstrate 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 shows that firms respond to variations in energy prices by adjusting the energy mix, increasing energy productivity and passing the costs through to the end-users.

Few researchers address the impact of the Iranian energy subsidy reform on manufacturing firms. Rahmati and Pilehvari (2019) used the data of manufacturing firms 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 declined the firms' productivity by 3% one year after the reform. Barkhordar et al. (2018) scrutinized the potential opportunities for increasing energy efficiency in the manufacture of some energy-intensive products namely steel, cement, brick, glass and aluminum. The authors suggest that there is an energy savings potential equivalent to 80 petajoule (or 1.9 million Toe) in the 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. Data

Five rounds of the annual survey of manufacturing firms with 10 and more workers are employed. These data are collected by 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.

Each observation in the dataset is a 'firm-group'. Firm-groups consist of a group of firms that share the same 4-digit ISIC code and are located in the same province. Each observation has a six-digit ID, the first four digits represent the ISIC code, and the last two digits code for the province. For example, observation 269,902 represents a group of firms with ISIC2699, which codes for manufacture of other non-metallic mineral products not elsewhere classified (n.e.c.) and are located in Mazandaran province that has the code 02. In 2009, this firm-group consists of 26 firms with 882 workers. The real value of total input of this firm-group is 770,426.4 million IR and the real value of total output is 1,309,898 million IR.

Further note that some observations in 2009 and 2010 only contain 1 or 2 firms. Yet, since 2011, the Statistical Center of Iran does not publish the ISIC-codes that comprise <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 >2 firms. Table 3 shows the structure of the panel data for the timeframe of the analysis. Every individual year consists of roughly 20% of the observations and contains at least 1000 observations. Yet, note that the dataset is not a balanced panel.

An overview of the major firm-group indicators for each year in the period 2009–2013 is presented in Fig. 3. We present the three outcome indicators under study: (i) output, (ii) manufacturing value-added and (iii) manufacturing value-added inclusive operating-surplus in billion IR. Not a single indicator shows a substantial change between the year 2009 and 2010. After the introduction of the energy subsidy reform 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.

In appendix A we show the composition of value-added (in billion Iranian Rial) with respect to industry type (Fig. A.1). The main contributors to manufacturing value-added are the food and beverage products (ISIC15), petroleum coke and refined petroleum products (ISIC23), chemical products (ISIC24), non-metallic mineral products (ISIC26), basic and fabricated metals (ISIC27–28), machinery and communication equipment (ISIC 29–33) and vehicles and other transport (ISIC34–35).

To further put the performance dynamics presented in Fig. 3 in perspective, Fig. 4 presents the composition of the value of the major manufacturing inputs over time. Raw materials comprise $>90\%$ of the value of all inputs. To avoid that raw materials mask the rest of the input composition, Fig. 4 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 value of 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) has increased in 2011 which is indicative of a direct effect of the subsidy reform. Yet, in 2012 and 2013 they revert back 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 the manufacturing firms. The graph also highlights that fuel and electricity costs contribute a small share to the total input costs relative to raw materials and the combined other inputs.

To further disentangle the increase in energy spending observed in Fig. 4 we also present the temporal relationship between output, inputs and operating-surplus vis-à-vis the energy inputs (Fig. 5). The development of output, input and operating-surplus are measured on the right-hand side at the secondary axis. Output and input show a synchronized movement over time. Yet, the fluctuation in the operating-surplus is smaller than that of output and value-added suggesting that under unstable circumstances firms try to smoothen out fluctuations in the operating-surplus. On the left axis the costs of energy inputs are 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 energy input reaches its maximum cost 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 initial shock stemming from 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 likely to fail. The relationship changes and needs to be modelled more carefully exploiting the full dynamics being present in a micro panel dataset.

Further note that electricity and fuels have equal shares in the energy consumption of manufacturing firms (Fig. 5). The share of energy costs in total output before the reform is 1.6% and in 2011 with the introduction of the reform it reaches to approximately 2.1%.

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 studied firm-groups before and after the subsidy reform of December 2010.

Total output slightly decreased after the reform from 2.4 million IR to 2.2; however, the reduction is not statistically significant (p-value = 0.736). Raw materials that constitute the major input factor to the production process exhibit a similarly insignificant reduction from 1.7 million IR to 1.6 (p-value = 0.848). As expected, the costs of some inputs such as fuel, electricity and water have increased after the reform. Yet again, the simple comparison of means does not identify any statistically significant difference.

The number of workers does not show a significant change over time either. On average a firm- group employs a bit >980 workers. Yet, their real compensation has significantly decreased from 144,283 IR before the reform to 103,523 IR afterward (p-value = 0.005). Firm capital has two elements: fixed capital and inventory change. Although overall capital formation shows no significant change after the reform, fixed capital formation has considerably dwindled. It decreased by 43,861 IR (p-value = 0.009) which amounts to 45%. Moreover, we observe a significant decrease in non-manufacturing services after the introduction of the energy subsidy reform from 68,667 IR to 43,013 IR (p-value = 0.014). 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 shrinkage in value-added of 64,247 IR or 10% and an even bigger decline in operating-surplus from 520,710 to 472,208 IR. Yet, only the reduction in operating-surplus is statistically significant (p-value = 0.000). Thus, simply comparing average firm statistics before and after the reform does not yield major insights. We need to account for industry specific effects to further disentangle whether the overall observed increase in

Table 3
Shape of the panel data.

Year	No. of firm-groups	Percentage of the sample
2009	1149	20.39
2010	1118	19.87
2011	1117	19.82
2012	1118	19.84
2013	1134	20.12
Total	5636	100

Source: Survey of manufacturing firms with 10 and more workers, firm-groups that contain at least 3 firms.

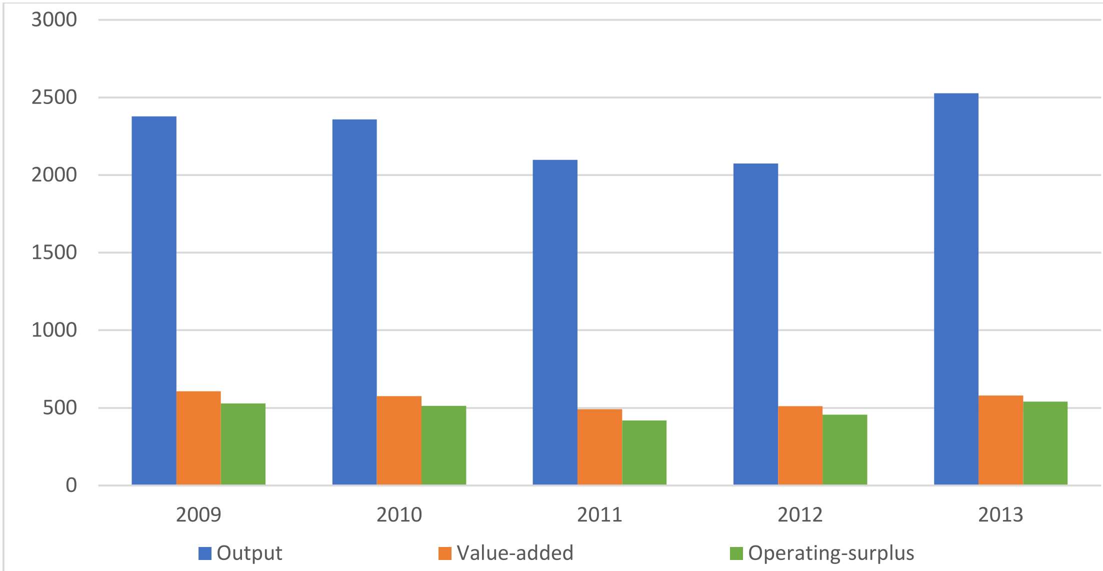

Fig. 3. Overview of manufacturing indicators over time (in Billion Iranian Rial).

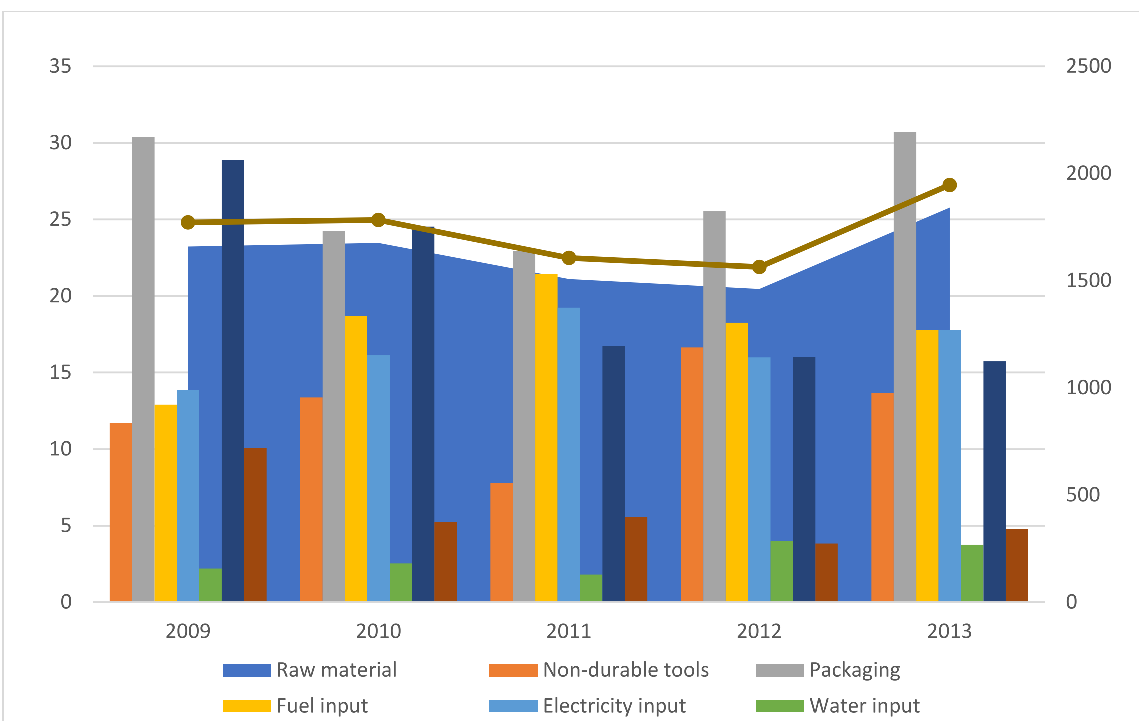

Fig. 4. Composition of the major input of manufacturing firms (in billion Iranian Rial).

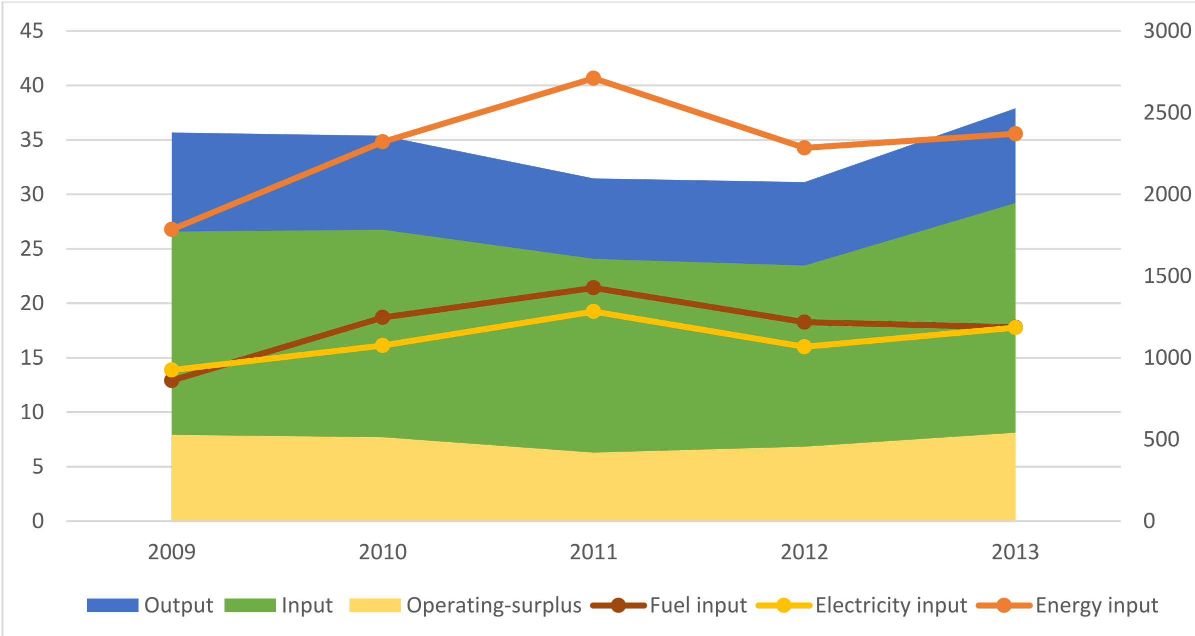

Fig. 5. Temporal relationship between output, input and operating-surplus vis-à-vis the energy inputs (in billion Iranian Rial).

spending on energy manifests itself in performance losses.[2]

5. Research design and identification strategy

We seek to estimate the causal effect of the increase of the energy price due to the energy subsidy reform (SRCT) on manufacturing firms. Our 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 affects energy prices, we set up a series of empirical models. As a first step for the analysis of a universal reform, we use the most common approach that is a before-after analysis combined with fixed-effects. The empirical model looks as follows:

$$y_{ipt} = \boldsymbol{F}_{ipt}\alpha + \beta\, SRCT_t + \delta\, Sanct_t + t_t + \gamma_{ip} + \varepsilon_{ipt}, \quad (1)$$

where y_{ipt} is the output indicator for firm-group i in province p at time t; we measure output with three indicators that represent the performance of the 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 accounts). The latter is meant to proxy manufacturing profit. These indicators are widely used to measure firm performance (Rentschler and Kornejew, 2017; McKenzie, 2017; Rajan and Zingales, 1998; Golder, 2011; Sadath and Acharya, 2015).

$\boldsymbol{F}_{ipt}$ denotes the matrix of firm-group specific, variable factors that are likely to affect performance. The following firm-group level confounding factors are included: The value of raw materials, non-durable tools and equipment, packaging material, energy inputs, and water inputs; we also control for payments for manufacturing services, worker's compensation and capital formation. All these control variables are denoted in million IR and expressed in logarithmic form. In addition, we account for the number of firms in the firm-group in logarithmic form. $SRCT_t$ 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; β is the parameter of interest. In addition, we include a proxy for the international sanctions, $Sanct_t$, expressed in Iran's oil exports in million Toe (in logarithmic form) to capture economy-wide dynamics. The model is completed with a time trend t_t and firm-group×province fixed effect γ_{ip}. The latter also allows us to partial out to what extent individual firm groups are structurally prone to the sanctions.

The unit of analysis in our research is the firm-group consisting of 2 or more firms with similar 4-digit ISIC codes that are located in the same province. Following the recommendation of Abadie et al. (2017), who advise against clustering at aggregate level, we cluster the standard errors at the level of the unit of analysis, i.e., the firm-group×province level. This is in line with other recent research on firms and firm performance (Asatryan et al., 2022; Gassen and Muhn, 2018; Algan et al., 2020; Brenøe et al., 2020; Marin et al., 2018).

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.

Yet, knowing the limits of a before-after analysis, we also attempt to create a counterfactual. As counterfactual, we identify the less energy-*sensitive* industries. To form the control group, we considered two main channels through which energy prices may influence manufacturing firms. The first channel is the direct channel operating through the immediate increase in the costs of energy. Based on this channel, we argue that firms that consume more energy as input tend to be affected more

[2] Table A.2 in Appendix A 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-group characteristics in the analysis in addition to the firm-group×province specific effects.

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 output[a]	2,368,989	15,343,393	2,234,730	14,227,129	0.736
Manufacturing input	1,777,634	12,684,549	1,706,622	12,383,348	0.834
Raw material	1,667,868	12,304,121	1,604,728	12,123,958	0.848
Non-durable tools and equipment	12,531	78,207	12,707	134,615	0.955
Packaging material	27,366	111,815	26,416	104,075	0.744
Energy	30,743	174,670	36,819	203,177	0.245
Fuel	15,763	122,064	19,149	114,671	0.289
Electricity	14,980	87,012	17,670	108,690	0.324
Water	2366	26,455	3190	47,759	0.454
Payments for manuf. services	26,737	322,794	16,153	155,670	0.101
Major repairment	7695	145,472	4733	54,510	0.282
Number of workers	981	2443	985	2460	0.955
Wage and non-wage compensation	144,283	624,343	103,523	461,777	0.005***
Average compensation per worker	109	45	77	65	0.000***
Firm number	12.79	21.38	12.12	18.70	0.208
Capital formation	150,617	1,057,783	123,216	1,382,676	0.424
Fixed capital formation[b]	97,809	847,173	53,948	388,650	0.009***
Inventory change	52,807	481,732	69,268	1,296,448	0.563
Net non-manufacturing services[c]	−63,696	485,788	−38,402	254,008	0.011**
Payments for non-manuf. services	68,667	511,124	43,013	269,683	0.014**
Receipts for non-manuf. services	4971	51,881	4610	76,032	0.844
Manufacturing value-added[d]	591,355	3,285,369	528,108	2,628,897	0.424
Inclusive operating-surplus[e]	520,710	3,219,039	472,208	2,544,398	0.000***

Note: The before reform sub-sample consists of 2267 observations and the after-reform sub-sample of 3369 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); * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

[a] Manufacturing 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.

[b] Fixed capital formation refers to net capital (goods, equipment and assets) accumulation within the accounting period.

[c] 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 laboratory activities, training and commissions.

[d] Manufacturing value-added is the difference between total output and total input.

[e] 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.

by the energy price increase (treatment group). In turn, low-energy-intensive industries (compare classification in Table 2) lend themselves as good starting point for the construction of the control group. However, firms can be affected by the increased energy prices through the indirect channel: this is the case when they employ highly energy-embodied raw/intermediate input materials. The price increase will pass-through industries that are high consumers of highly energy-embodied materials such as cement or metals (Kim et al., 2010; Sijm et al., 2006; Fabra and Reguant, 2014). Therefore, we zoomed into the main inputs of low energy-intensive industries and removed two additional industries from the control group, manufacturing of machinery (ISIC29) and motor vehicles (ISIC34) that intensively use basic and fabricated metals as input. The remaining industries form our control group and are referred to as 'less energy-*sensitive*'. To make the selection process apparent, we detail it in a flowchart (Appendix A, Fig. A.2).

Thus, our control group consists of industries that are less-energy-*sensitive* 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 as we cannot rule out that the less-energy-*sensitive* firms were not at all affected by the reform. The resulting empirical model looks as follows:

$$y_{ipt} = \boldsymbol{F}_{ipt}\alpha + \theta\, C_{ip} + \beta\, SRCT_t{}^{*}C_{ip} + \delta\, Sanct_t + t_t + \gamma_{ip} + \varepsilon_{ipt}, \qquad (2)$$

where C_{ip} takes on the value of 1 for industries that constitute the treatment group and 0 otherwise and controls for structural differences between the groups. The interaction term $SRCT_t$ * C_{ip} represents the treatment. We are interested in β, the average treatment effect (subsidy reform) on the treated (all energy sensitive industries). The remaining variables are as introduced above. Again, standard errors are clustered at the firm-group×province level. By comparing results from the two models and incorporating further robustness analyses we can credibly attribute the impact of the energy subsidy reform on the performance of manufacturing firms.

6. Results

Since the simple average statistics comparing before and after the reform outcomes across firm-groups do only yield limited insights, we proceed with the multivariate analysis accounting for firm-group-×province specific effects. First, we present the main results akin to the empirical models specified above. The second and third part introduce 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 marginal effects; these are obtained by exponentiating the original coefficients: (exp(coefficient)-1)*100. All models include all control variables as introduced in Section 5.

6.1. Main results

The main results are presented in Table 5. Panel A and B report the empirical results of the before-after analysis employing the firm-group×province 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 overall effects. Panel B focuses

Table 5
Impact of the energy subsidy reform on manufacturing firms.

		Output	Value-added	Operating-surplus
Panel A	**Overall impact (2009–2013)**			
	SRCT	−0.065***	−0.125***	−0.148***
		(0.019)	(0.030)	(0.055)
	Impact	−6.3%	−11.8%	−13.8%
	N	4861	4848	4693
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes
Panel B	**Immediate impact (2009–2011)**			
	SRCT	−0.082***	−0.144***	−0.206***
		(0.020)	(0.031)	(0.062)
	Impact	−7.9%	−13.4%	−18.6%
	N	2905	2897	2804
	Control for international sanctions	Yes	Yes	Yes
	Time trend	No	No	No
	Time trend and control for international sanctions	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes
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	4861	4848	4693
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes

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 firm-group×province level. Standard errors clustered at the firm-group×province 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 million Toe, in log) and a time trend.
The control group for the counterfactual analysis in Panel C 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). A table with the full set of regression estimates is provided in Appendix C.

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.

We observe a contraction in all three performance indicators that is less pronounced over the whole study period (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 shrinkage in operating-surplus is large (almost 19%). This can be considered as evidence of *absorption.* In the short-run, firms seem to take in the energy price by compromising their profit margin (Rentschler et al., 2017; Rentschler and Kornejew, 2017).

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. 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 help 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 our empirical model being rigorous in accounting for firm-group×province 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 as captured by Iran's oil exports and a time trend. Notably, we do not find any reason why national and/or international shocks should affect the control and treatment groups differently. 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. Yet, on top of the impact from the sanctions we identify the negative impact of the subsidy reform. Put differently, the presented results about the impact of the energy subsidy reform are purged from the impacts of the international sanctions.[3]

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

As a supplementary analysis and to gauge the validity of our 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 the energy price. 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 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% (Panel A). 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.

[3] Detailed results are made available by the authors upon request.

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	4861	4848	4693
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes
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	4295	4282	4147
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes

Note: Impact of the energy price on the performance of manufacturing firms with 10 and more workers for the period 2009–2013 using fixed-effect models. All models employ firm-group×province specific effects. Standard errors clustered at firm-group×province 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. A table with the full set of regression estimates is provided in Appendix C.

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-*sensitive* 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 larger as for the full sample. Moreover, the difference between the two groups is significant. This analysis further supports our choice of control group for the difference-in-difference analysis. Alternatively, we also employed a specification with the real energy price (Appendix A, Table A.3). 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.

6.3. Robustness checks

6.3.1. 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. Having two time periods before the introduction of the energy subsidy reform allows us to assess the pre-treatment trends (Hastings, 2004; Davis and Weinstein, 2002). Fig. 6 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 and being reinforced in 2013. In turn, the less energy-*sensitive* firms only see a small performance impact from the reform and then a steady performance. These differences highlight the need to account for firm-group specific

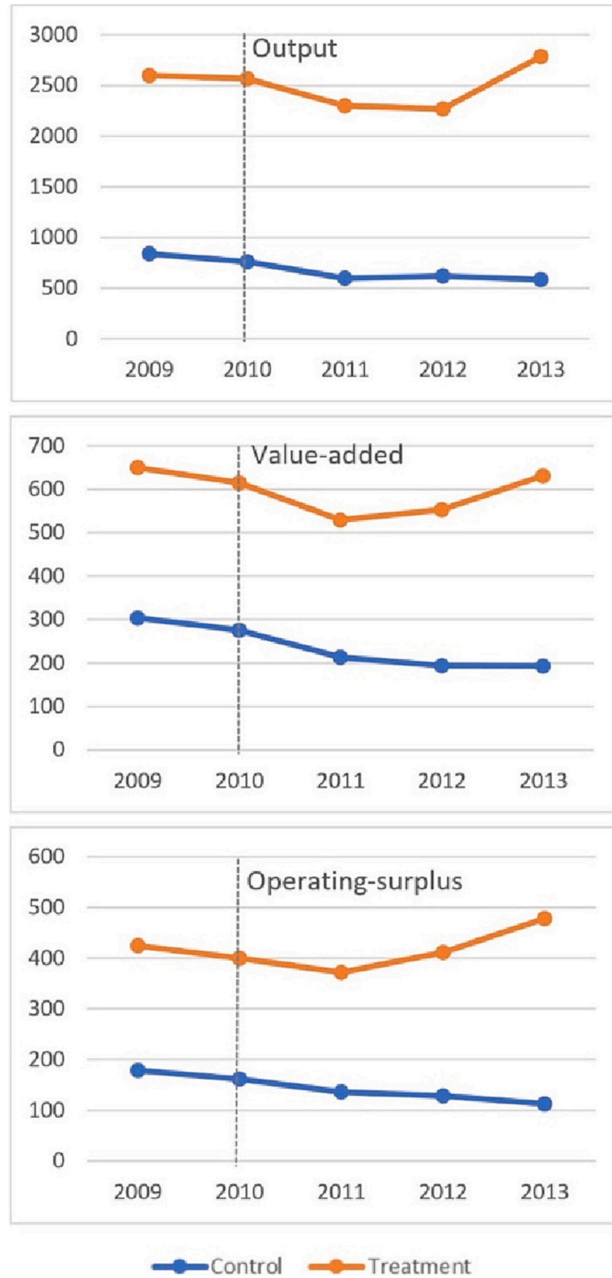

Fig. 6. Pre-subsidy reform trends.
Note: All performance indicators are presented in billion Iranian Rials.

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 firm-group×province specific effects.

Apart from visual inspection, we address the parallel trends with a fixed-effects model containing leads and lags of the treatment variable (Autor, 2003; Hastings, 2004; Davis and Weinstein, 2002). We estimate the following model:

$$y_{ipt} = \boldsymbol{F}_{ipt}\alpha + \delta\, Sanct_t + t_t + \gamma_{ip} + \sum\nolimits_{j=2009}^{2010} \zeta_j D_j + \sum\nolimits_{k=2011}^{2013} \varsigma_k D_k + \varepsilon_{ipt.}$$

In the model D_j is the interaction term of the time dummies with the treatment group. If leads of the treatment, i.e., the coefficient estimates ζ_j associated with the pre-treatment situation are statistically zero, we can conclude that the parallel-trend assumption is not violated.

Table A.4 (Appendix A) presents the outcome of the model. Both, the *t*-test and *F*-statistic show that the null hypothesis that lead coefficients are statistically zero cannot be rejected. Hence, there is no evidence that the assumption of pre-reform parallel trends between the control and treatment group is violated.

6.3.2. Balanced sample

Our study sample is unbalanced. Over the years more and more firm-groups (4-digit ISIC codes) 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, the fixed-effects models 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 Table A.5 in Appendix A. The findings are akin to those from the models estimated with the full sample (Table 5). The difference in the coefficient estimates amounts to <1 percentage point and all estimates are statistically significant.

6.3.3. Excluding the manufacture of coke and refined petroleum products

Manufacture of coke and petroleum products (ISIC23) is the most energy-intensive industry; hence it can be hit the most by the direct channel of increased energy costs. To explore whether the estimates of our models presented in Table 5 are driven only by this industry, we remove firm-groups that are active in this industry from the sample and present sub-sample results in Table A.6 (Appendix A). Comparing the coefficient estimates associated with the reform in Tables 5 and A.6 reveals that the variation is <3%. Therefore, we conclude that the negative impact of the energy subsidy reform on manufacturing is not driven by one particular energy-intensive industry. Moreover, these findings further reinforce the importance of the indirect channel of the energy price transmission observed in earlier studies (Rentschler et al., 2017; Kim et al., 2010; Sijm et al., 2006; Fabra and Reguant, 2014).

6.4. Heterogeneity analysis

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, moderately, and highly 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 the highly energy-intensive industries are the ones that are affected the most by the energy reform. But in fact, the data show that the moderately energy-intensive industries experienced the largest impact, nearly 2 percentage points more compared to the high energy-intensive group. Looking into the composition of the high energy-intensive group reveals that 4 out of 5 highly 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

Table 7
Heterogeneity analysis.

		Output	Value-added	Operating-surplus
Panel A	**Energy-intensity**			
	Low energy-intensity[a]			
		−0.026	−0.066	−0.098
		(0.032)	(0.067)	(0.120)
	Impact	−2.6%	−6.4%	−9.3%
	N	1076	1075	1039
	Moderate energy-intensity[a]			
		−0.083***	−0.140***	−0.180**
		(0.027)	(0.046)	(0.088)
	Impact	−8%	−13.1%	−16.5%
	N	2133	2122	2061
	High energy-intensity[a]			
		−0.068	−0.132**	−0.126
		(0.041)	(0.054)	(0.089)
	Impact	−6.6%	−12.4%	−11.8%
	N	1652	1651	1593
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes
	Technology-intensity			
	Low and medium-low technology[b]			
		−0.078***	−0.142***	−0.161**
		(0.023)	(0.036)	(0.066)
	Impact	−7.5%	−13.2%	−14.9%
	N	3541	3529	3415
	Medium-high and high technology[b]			
Panel B		−0.026	−0.078	−0.134
		(0.027)	(0.057)	(0.103)
	Impact	−2.6%	−7.5%	−12.5%
	N	1320	1319	1278
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes

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

[a] 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 note to Table 2.

[b] 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.

direct and an indirect effect (Appendix B). 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 moderately 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 moderately energy-intensive firms highlighting that it is them who are shouldering most of the negative repercussions of the energy reform.

Table 8
Mitigating and reinforcing firm characteristics.

		Output	Value-added	Operating-surplus
	Large firms[a]			
Panel A		−0.076**	−0.189**	−0.250
		(0.033)	(0.083)	(0.171)
	Impact	−7.3%	−17.2%	−22.1%
	N	532	532	516
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes
	Large fixed-capital[b]	−0.044	−0.103	−0.112
Panel B		(0.055)	(0.099)	(0.217)
	Impact	−4.3%	−9.8%	−10.6%
	N	1133	1126	1081
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes
	Food and beverages industry			
Panel C		−0.128***	−0.210***	−0.314***
		(0.039)	(0.069)	(0.118)
	Impact	−12%	−18.9%	−26.9%
	N	1129	1118	1086
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes
	Located in provinces with low GDP[c]			
Panel D		−0.077	−0.137	−0.120
		(0.056)	(0.089)	(0.190)
	Impact	−7.4%	−12.8%	−11.3%
	N	636	630	597
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes

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

[a] Large firms refers to the firm-groups where more than half of the manufacturing firms have 100 workers and more.

[b] Large fixed-capital refers to firm-groups where the ratio of capital formation to output is more than average.

[c] 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.

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 classification 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, firm-groups, where more than half of the firms have >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 win margin.

Next, we turn to the role of fixed-capital in mitigating the price shock. In Panel B we present results for firms with a large fixed-capital meaning that the ratio of capital 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 (2022) identified a significant decline in households' food expenditure due to SRCT. Our firm-group results suggest that indeed this industry has been hit considerably. Output shrunk by 12% and operating surplus by more than one quarter. Last, 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 bigger 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 energy price increase to manufacturing firms. Both high and moderately energy-intensive industries are considerably affected by the subsidy reform. Yet, technological advancement and a solid capital base have shown to lessen the negative repercussions of the Iranian energy subsidy reform.

7. Conclusion and policy implication

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 can be transmitted to firms. The first one is a direct channel and manifests itself in the increase of the energy price and the related increases in the energy costs for the manufactures. 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 highly 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 contract aggregate demand. Such reduction in consumer demand can transmit from down-stream industries all the way up (Zarepour and Wagner, 2022).

In order to empirically identify the impact of the reform on the 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 and more for the period 2009 to 2013 and studied 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 that simultaneously accounted for firm-group×province specific effects. Next, we employed a difference-in-difference model. 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. The immediate impact (i.e., 6–9 months after the reform) is larger compared to the overall impact up to 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 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 highly 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 had invested considerably in fixed-capital could mitigate the price increase more easily.

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 our findings and the coherence of the findings across models makes us confident that the identified patterns are meaningful and do not result by chance. Second, the analysis is at the 4-digit ISIC level and only includes firms with 10 workers 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.

The implications of this study are fourfold: First, policymakers do good in conducting a careful and detailed analysis of economic responses prior to subsidy reforms. For the case of Iran, the obvious measure of energy-intensity of a firm could not fully map the sensitivity of a firm to the energy price reforms. Manufactures with moderate or low energy-intensity but high dependency on energy-embodied materials were considerably affected due to snow-ball effects resulting from pass-through of up-stream firms. Second and related, empirical methods that do not account for the indirect effect of the energy price increase or rely on pre-reform parameters are likely not the best candidates to accurately measure and attribute the impact of an energy price reform. The presented micro results highlight the importance to carefully dissect the data and to account for structural differences along with dynamic effects at the smallest possible level. Third, the literature suggests that a substitution between energy and capital is likely in the long-run (Koetse et al., 2008). While the paper at hand only provides information about immediate and 3-year impacts, it hints at several substitution possibilities. Indeed, the availability of capital is one mechanism, another one is the availability and affordability of technologies. We deduct that there is potentially a large role for alternative, energy efficient technologies not only in response to energy subsidy reforms but also in response to expected reforms that attempt to reduce CO2 emissions to mitigate negative impacts from economic activities on the climate. This leads us to the final and most important point of the study. Since we evaluated a universal energy reform that implemented severe subsidy cuts, we can learn from the results to inform energy policies to mitigate climate change. The industry will have to make a contribution to keep global warming well below 2 degrees compared to pre-industrial levels. Yet, it will come at a cost. Not only does the study at hand give an indication about possible effects as well as mitigating and reinforcing firm characteristics, it also allows us to draw conclusions about the best possible timing. For the case of Iran, hefty 2012 international sanctions caused volatility and uncertainty to the economy and counteracted developments toward energy-efficient technological advancement and toward sustained firm growth. Put differently, the timing of climate friendly energy reforms along with possible mitigating initiatives to transform the economy toward CO2 neutrality will be an additional critical aspect.

CRediT authorship contribution statement

Zahra Zarepour: Conceptualization, Data curation, Formal analysis, Investigation, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **Natascha Wagner:** Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Software, Supervision, Validation, Writing – review & editing.

Appendix A. Figures and Tables

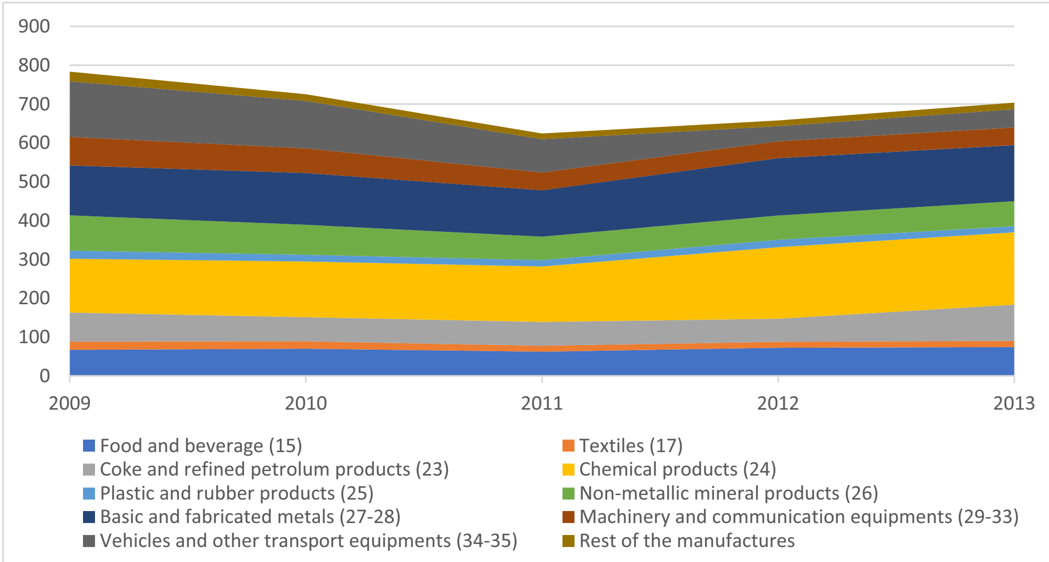

Fig. A.1. Composition of manufacturing value-added based on industry (in billion Iranian Rial).

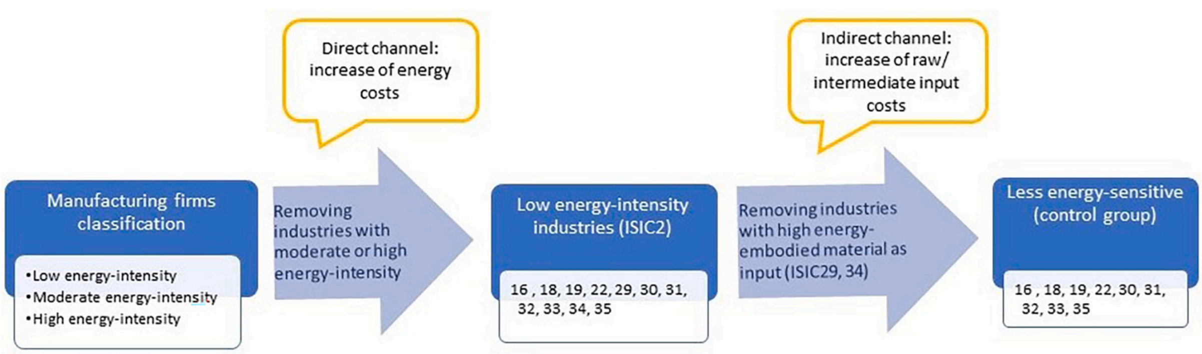

Fig. A.2. Forming the control group of less energy-sensitive industries.

Table A.1
Energy carriers' prices for the manufacturing sector before and after the reform.

	Before the reform	After the reform
Gasoline	4000	7000
Gas Oil	165	3500
Kerosene	165	1000
Fuel oil (Mazut)	95	2000
Natural gas	189	700
Liquefied gad	31	5400
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.

Table A.2
Selected statistics of the 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]	801,726	1,482,148	601,509	1,080,745	0.044**	2,582,671	16,300,000	2,452,273	15,100,000	0.773

(continued on next page)

Table A.2 (*continued*)

Variables–Control group	Control group					Treatment 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 input	511,431	999,025	401,349	801,852	0.116	1,950,269	13,500,000	1,880,483	13,200,000	0.856
Raw material	483,293	962,398	378,436	783,773	0.122	1,829,374	13,100,000	1,768,068	12,900,000	0.870
Non-durable tools and equipment	5337	23,906	5983	33,930	0.786	13,512	82,855	13,603	142,744	0.979
Packaging material	6573	12,323	5156	11,483	0.129	30,201	118,829	29,248	110,405	0.772
Energy	4050	6937	3786	5565	0.586	34,382	185,888	41,219	215,899	0.248
Fuel	1131	2228	1314	2427	0.322	17,758	129,993	21,525	121,871	0.299
Electricity	2919	4996	2471	3807	0.190	16,624	92,617	19,694	115,545	0.321
Water	300	567	494	5650	0.571	2647	28,190	3549	50,789	0.470
Payments for manuf. Services	9974	32,522	6141	18,682	0.054*	29,022	343,834	17,486	165,532	0.115
Major repairment	882	3007	660	1975	0.251	8624	155,049	5275	58,002	0.284
Number of workers	744	944	690	822	0.429	1014	2579	1025	2599	0.887
Wage and non-wage compensation	96,588	149,125	61,857	102,137	0.004***	150,786	663,025	109,073	489,900	0.109
Average compensation per worker	107	38	76	32	0.000***	110	46	77	68	0.000***
Firm number	10	11	9	9	0.222	13	22	13	20	0.278
Capital formation	60,701	201,821	52,168	119,383	0.494	162,876	1,124,609	132,680	1,471,010	0.437
Fixed capital formation	26,092	86,106	15,311	38,745	0.029**	107,587	902,108	59,095	413,219	0.011**
Inventory change	34,609	148,718	36,857	105,053	0.819	55,289	510,554	73,585	1,379,531	0.571
Net non-manufacturing services $^{+}$	−23,143	51,588	−12,810	38,809	0.003***	−69,225	517,266	−41,811	269,848	0.015**
Payments for non-manuf. Services	26,611	53,336	14,753	40,069	0.001***	74,401	544,264	46,777	286,506	0.019**
Receipts for non-manuf. Services	3467	21,125	1942	11,646	0.232	5176	54,752	4966	80,821	0.919
Manufacturing value-added*	290,295	588,317	200,160	332,755	0.012**	632,402	3,493,553	571,790	2,793,028	0.498
Inclusive operating surplus□	170,564	431,540	125,492	244,707	0.087*	412,391	2,394,489	420,906	2,287,895	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 4968 observations. The before-reform treatment group sub-sample consists of 1995 observations and the after-reform treatment group sub-sample of 2973 observations. For more details on the content of the variables compare the note to Table 5 in the main manuscript.

Table A.3
Effect of the real energy price on the performance of manufacturing firms.

		Output	Value-added	Operating-surplus
	Overall			
		−0.079***	−0.140***	−0.152***
		(0.018)	(0.030)	(0.055)
Panel A	N	4861	4848	4693
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes
	Less energy-sensitive industries			
	(Control group)	−0.010	−0.048	−0.022
		(0.044)	(0.086)	(0.144)
	N	566	566	546
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
Panel B	Firm-group×province specific effects	Yes	Yes	Yes
	Energy-sensitive industries			
	(Treatment group)	−0.086***	−0.149***	−0.166***
		(0.020)	(0.032)	(0.059)
	N	4295	4282	4147
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes

Note: Impact of the real energy price on the performance of manufacturing firms with 10 and more workers for the period 2009–2013 using Firm-group×province specific effects models. Standard errors clustered at the firm-group×province 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.

Table A.4
Parallel trend between control and treatment group pre-subsidy reform.

	Output	Value-added	Operating-surplus
Y2009*treatment	0.004	0.020	0.064
	(0.035)	(0.068)	(0.122)
Y2010*treatment	0.017	0.044	0.084
	(0.019)	(0.036)	(0.066)
F-statistic (Y2009*treatment = Y2010*treatment = 0)	0.87	1.77	1.51
N	4861	4848	4693
Time varying firm-group covariates	Yes	Yes	Yes
Control for international sanctions	Yes	Yes	Yes
Firm-group×province specific effects	Yes	Yes	Yes

Note: All models employ firm-group×province specific effects. Standard errors clustered at the firm-group×province level are presented in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; N is the number of observations.
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.

Table A.5
Impact of the energy subsidy reform employing the balanced panel.

		Output	Value-added	Operating-surplus
	Overall impact (2009–2013)			
	SRCT	−0.061***	−0.113***	−0.130**
		(0.020)	(0.031)	(0.056)
	Impact	−5.9%	−10.7%	−12.2%
Panel A	N	4278	4270	4159
	Time varying firm-group covariates	yes	yes	yes
	Control for international sanctions	yes	yes	yes
	Time trend	yes	yes	yes
	Firm-group×province specific effects	yes	yes	yes
	Immediate impact (2009–2011)			
	SRCT	−0.083***	−0.143***	−0.211***
		(0.022)	(0.032)	(0.065)
	Impact	−8%	−13.3%	−19%
Panel B	N	2530	2526	2459
	Time varying firm-group covariates	yes	yes	yes
	Control for international sanctions	yes	yes	yes
	Time trend	no	no	no
	Firm-group×province specific effects	yes	yes	yes
	Difference in Difference			
	SRCT*treatment	−0.036**	−0.068**	−0.090*
		(0.018)	(0.029)	(0.052)
	Impact	−3.5%	−6.6%	−8.6%
Panel C	N	4278	4270	4159
	Time varying firm-group covariates	yes	yes	yes
	Control for international sanctions	yes	yes	yes
	Time trend	yes	yes	yes
	Firm-group×province specific effects	yes	yes	yes

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×province specific effects. Standard errors clustered at the firm-group×province 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.

Table A.6
Impact of the energy subsidy reform excluding manufacture of coke and petroleum products (ISIC23).

		Output	Value-added	Operating-surplus
	Overall impact (2009–2013)			
	SRCT	−0.067***	−0.125***	−0.149***
		(0.019)	(0.031)	(0.056)
	Impact	−6.5%	−11.8%	−13.8%
Panel A	N	4805	4792	4639
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes
	Immediate impact (2009–2011)			
	SRCT	−0.084***	−0.144***	−0.208***
Panel B		(0.020)	(0.031)	(0.063)
	Impact	−8.1%	−13.4%	−18.8%
	N	2875	2867	2775
	Time varying firm-group covariates	Yes	Yes	Yes

(*continued on next page*)

Table A.6 (*continued*)

		Output	Value-added	Operating-surplus
	Control for international sanctions	Yes	Yes	Yes
	Time trend	No	No	No
	Firm-group×province specific effects	Yes	Yes	Yes
	Difference in Difference			
	SRCT*treatment	−0.035**	−0.076**	−0.096*
		(0.017)	(0.030)	(0.052)
	Impact	−3.4%	−7.3%	−9.2%
Panel C	N	4805	4792	4639
	Time varying firm-group covariates	Yes	Yes	Yes
	Control for international sanctions	Yes	Yes	Yes
	Time trend	Yes	Yes	Yes
	Firm-group×province specific effects	Yes	Yes	Yes

Note: Panel A and Panel B report the impact of the subsidy reform on manufacturing firms with 10 and more workers excluding manufacturing of coke and petroleum products (ISIC23) 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×province specific effects. Standard errors clustered at the firm-group×province 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 B. 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:

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

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.

Appendix C. Extended tables

Extended Table 5 – Panel A and Panel B

	Panel A: Overall impact			Panel B: Immediate Impact		
	Output	Value-added	Operating surplus	Output	Value-added	Operating surplus
SRCT	−0.065***	−0.125***	−0.148***	−0.082***	−0.144***	−0.206***
	(0.019)	(0.030)	(0.055)	(0.020)	(0.031)	(0.062)
Raw material	0.475***	0.208***	0.309***	0.403***	0.169***	0.266***
	(0.049)	(0.033)	(0.046)	(0.057)	(0.038)	(0.055)
Non-durable tools and equipment	0.028***	0.034***	0.046***	0.018	0.020	0.009
	(0.008)	(0.012)	(0.018)	(0.015)	(0.020)	(0.029)
Packaging material	0.012*	0.002	−0.005	0.021**	0.019	0.033
	(0.006)	(0.008)	(0.016)	(0.010)	(0.013)	(0.021)
Energy input	0.142***	0.176***	0.163***	0.150***	0.170***	0.155*
	(0.022)	(0.031)	(0.049)	(0.034)	(0.048)	(0.082)
Water input	0.017**	0.022*	0.037*	0.021*	0.007	0.031
	(0.008)	(0.012)	(0.021)	(0.012)	(0.020)	(0.034)
Payments for manufacturing services	0.045***	0.058***	0.062***	0.027	0.023	0.022
	(0.012)	(0.015)	(0.021)	(0.018)	(0.021)	(0.034)
Capital formation	0.023***	0.050***	0.066***	0.019**	0.044***	0.058***
	(0.007)	(0.009)	(0.014)	(0.009)	(0.012)	(0.022)

(*continued on next page*)

(*continued*)

	Panel A: Overall impact			Panel B: Immediate Impact		
	Output	Value-added	Operating surplus	Output	Value-added	Operating surplus
Worker's compensation	0.172***	0.248***	−0.199*	0.167***	0.251***	−0.193
	(0.038)	(0.054)	(0.111)	(0.057)	(0.083)	(0.176)
Number of firms in the firm-group	0.155***	0.302***	0.158	0.133**	0.287***	−0.001
	(0.044)	(0.061)	(0.097)	(0.061)	(0.099)	(0.162)
Proxy for international sanctions	−0.144***	−0.226***	−0.373***	−0.724**	−1.169**	−1.762*
	(0.030)	(0.049)	(0.092)	(0.300)	(0.512)	(0.971)
Time trend	−0.003	−0.014	−0.047*			
	(0.008)	(0.015)	(0.027)			
Constant	4.519***	5.796***	6.848***	8.389***	11.347***	14.927***
	(0.449)	(0.474)	(0.824)	(1.672)	(2.711)	(5.216)
N	4861	4848	4693	2905	2897	2804

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. All models use fixed effects at the firm-group×province level. Standard errors clustered at the firm-group×province level are presented in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; N is the number of observations. The proxy for the international sanctions is Iran's oil exports.

Extended Table 5 – continued – Panel C

	Panel C: Difference in difference		
	Output	Value-added	Operating surplus
SRCT*treatment	−0.034**	−0.076***	−0.096*
	(0.017)	(0.029)	(0.051)
Raw material	0.477***	0.211***	0.312***
	(0.049)	(0.034)	(0.047)
Non-durable tools and equipment	0.028***	0.034***	0.046***
	(0.008)	(0.012)	(0.018)
Packaging material	0.012*	0.002	−0.005
	(0.006)	(0.008)	(0.016)
Energy input	0.138***	0.170***	0.157***
	(0.021)	(0.031)	(0.049)
Water input	0.017**	0.022*	0.037*
	(0.008)	(0.012)	(0.021)
Payments for manufacturing services	0.045***	0.058***	0.062***
	(0.012)	(0.015)	(0.021)
Capital formation	0.023***	0.050***	0.066***
	(0.007)	(0.009)	(0.015)
Worker's compensation	0.185***	0.269***	−0.171
	(0.039)	(0.056)	(0.110)
Number of firms in the firm-group	0.158***	0.307***	0.164*
	(0.045)	(0.061)	(0.097)
Proxy for international sanctions	−0.158***	−0.250***	−0.398***
	(0.031)	(0.049)	(0.092)
Time trend	−0.014*	−0.033**	−0.067***
	(0.008)	(0.014)	(0.025)
Constant	4.545***	5.838***	6.860***
	(0.456)	(0.481)	(0.826)
N	4861	4848	4693

Note: 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 firm-group×province level. Standard errors clustered at the firm-group×province level are presented in parentheses; * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$; N is the number of observations. The proxy for the international sanctions is Iran's oil exports.

Extended Table 6 – Panel A

	Panel A: Overall impact		
	Output	Value-added	Operating surplus
Energy price (nominal)	−0.072***	−0.127***	−0.140***
	(0.017)	(0.027)	(0.050)
Raw material	0.475***	0.208***	0.310***
	(0.049)	(0.033)	(0.046)
Non-durable tools and equipment	0.027***	0.033***	0.045**
	(0.008)	(0.012)	(0.018)
Packaging material	0.012*	0.001	−0.006
	(0.006)	(0.008)	(0.016)
Energy input	0.147***	0.184***	0.170***
	(0.022)	(0.031)	(0.050)
Water input	0.018**	0.024**	0.038*
	(0.008)	(0.012)	(0.021)
Payments for manufacturing services	0.045***	0.057***	0.061***

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(*continued*)

	Panel A: Overall impact		
	Output	Value-added	Operating surplus
	(0.012)	(0.015)	(0.021)
Capital formation	0.022***	0.050***	0.065***
	(0.007)	(0.009)	(0.014)
Worker's compensation	0.158***	0.228***	−0.220*
	(0.037)	(0.054)	(0.114)
Number of firms in the firm-group	0.148***	0.291***	0.146
	(0.044)	(0.060)	(0.097)
Proxy for international sanctions	−0.075**	−0.106*	−0.246**
	(0.029)	(0.056)	(0.104)
Time trend	0.023**	0.031	−0.002
	(0.011)	(0.021)	(0.036)
Constant	5.162***	6.947***	8.140***
	(0.541)	(0.551)	(0.998)
N	4861	4848	4693

Note: Impact of the energy price on the performance of manufacturing firms with 10 and more workers for the period 2009–2013 using fixed-effect models. All models employ firm-group×province specific effects. Standard errors clustered at firm-group-×province 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. The proxy for the international sanctions is Iran's oil exports.

Extended Table 6 – continued – Panel B and C

	Panel B: Control group			Panel B: Treatment group		
	Output	Value-added	Operating surplus	Output	Value-added	Operating surplus
Energy price (nominal)	−0.009	−0.045	−0.019	−0.078***	−0.135***	−0.153***
	(0.040)	(0.078)	(0.130)	(0.018)	(0.029)	(0.054)
Raw material	0.601***	0.252***	0.297***	0.465***	0.204***	0.309***
	(0.058)	(0.055)	(0.099)	(0.051)	(0.035)	(0.049)
Non-durable tools and equipment	0.004	0.008	0.049	0.030***	0.038***	0.044**
	(0.017)	(0.022)	(0.044)	(0.009)	(0.013)	(0.019)
Packaging material	0.006	−0.012	0.008	0.012*	0.002	−0.008
	(0.010)	(0.018)	(0.033)	(0.007)	(0.009)	(0.017)
Energy input	0.131***	0.180***	0.107	0.147***	0.182***	0.178***
	(0.047)	(0.063)	(0.112)	(0.024)	(0.034)	(0.054)
Water input	0.005	−0.001	−0.006	0.019**	0.025**	0.043**
	(0.017)	(0.038)	(0.071)	(0.008)	(0.012)	(0.021)
Payments for manufacturing services	0.038*	0.030	−0.015	0.045***	0.062***	0.076***
	(0.020)	(0.026)	(0.048)	(0.013)	(0.017)	(0.024)
Capital formation	0.020*	0.061**	0.101**	0.022***	0.048***	0.061***
	(0.011)	(0.023)	(0.045)	(0.008)	(0.009)	(0.015)
Worker's compensation	0.124	0.235	−0.338	0.161***	0.231***	−0.195
	(0.088)	(0.165)	(0.303)	(0.040)	(0.057)	(0.123)
Number of firms in the firm-group	0.246**	0.370**	0.350	0.138***	0.281***	0.119
	(0.124)	(0.149)	(0.290)	(0.047)	(0.066)	(0.104)
Proxy for international sanctions	−0.099	−0.205	−0.272	−0.069**	−0.093	−0.243**
	(0.086)	(0.173)	(0.320)	(0.031)	(0.060)	(0.110)
Time trend	−0.021	−0.047	−0.118	0.030**	0.040*	0.013
	(0.031)	(0.063)	(0.104)	(0.012)	(0.022)	(0.038)
Constant	3.461***	6.341***	7.933***	5.303***	6.962***	8.092***
	(0.628)	(1.305)	(2.258)	(0.567)	(0.588)	(1.084)
N	566	566	546	4295	4282	4147

Note: Impact of the energy price on the performance of manufacturing firms with 10 and more workers for the period 2009–2013 using fixed-effect models. All models employ firm-group×province specific effects. Standard errors clustered at firm-group×province 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. The proxy for the international sanctions is Iran's oil exports.

Appendix D. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.eneco.2023.106762.

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