Short- and long-run macroeconomic impacts of the 2010 Iranian energy subsidy reform

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Abstract
This paper examines the short- and long-run effects of the 2010 Iranian energy subsidy reform on macro indicators including GDP and inflation. The subsidy reform, which consists of a simultaneous energy subsidy cut and a cash transfer to households, is not fiscally motivated but instead aims to reduce energy consumption. Using timeseries to analyse the dynamics of the macro variables in response to the subsidy reform elements (energy price increase, and cash transfer), this study reveals that the subsidy reform has a negative effect on the economy in the short- and mid-term, and the cash transfer to households does not fully compensate for this adverse effect. These results are robust and consistent across specifications. The main channel that transmits the effect of energy price to GDP is value-added of industry and service sectors. The long-run analysis rejects the existence of a long-run relationship between the energy subsidy reform and GDP. The findings indicate that the energy subsidy reform does not result in a reduction in energy consumption. These findings challenge the environmental aspect of the fossil fuel subsidy reforms as stand-alone policies without major reforms in the energy efficiency of economic sectors.

Keywords Energy subsidy reform · Energy consumption · Macroeconomic · GDP · Short and long run · Iran

JEL classification C54 · Q48 · C22 · O53

Introduction
The history of subsidizing goods as a response to the increasing urban demand for a stable supply of goods dates back at least to the 1940s (Economic reform working group n.d.a). In the 1970s, increasing oil price revenues stimulated subsidization via
two channels. First, the government earned more money from oil exports and was able to extend subsidies to a wider range of goods and services. Second, the gap between the fixed energy carriers’ domestic price and the international price multiplied. Consequently, the subsidy on energy took up a considerable share of public expenditure, to the extent that in 2006 the energy subsidy became nearly 87% of total subsidy and 77% of public expenditure (Economic reform working group n.d.a). Subsidies are known to encourage excessive use and even lead to energy wastage. Moreover, the distribution of the energy subsidy does not help inequalities. On average, in 2009, the richest decile of urban and rural households benefitted 5.3 and 14.3 times more, respectively, than the poorest decile from fuel subsidies (Ministry of Energy 2010). Meanwhile, subsidy reforms are delicate policies that can be put to an end by social unrest, strikes and riots. These factors motivated the Iranian government to embark on a budget-neutral energy subsidy reform in December 2010. In practice, the energy subsidy reform or Subsidy Removal and Cash Transfer (SRCT), consists of the following two parts: subsidy removal on the price of energy and a cash transfer to households. As a result, the prices of energy carriers increased several fold (see Table A.1 in appendix). Simultaneously, an unconditional universal cash transfer (derived from the subsidy removal) was granted to households. The cash transfer amounted to 405,000 Iranian Rials\(^1\) (IR) per person per month and is being transferred to the bank account of the head of the households on a bi-monthly basis. Hence, unlike other energy subsidy reforms, SRCT did not aim for fiscal consolidation but rather to restrain energy consumption and to distribute subsidies equally.

This research aims to investigate the impact of this subsidy reform on macro indicators and particularly GDP. The majority of research on the impact of SRCT on GDP has applied Computable General Equilibrium (CGE) models (Jensen and Tarr 2003; Eslami et al. 2012; Shahmoradi et al. 2011; Hosseinasab and Hazeri 2012). Bearing in mind that the magnitude of the energy price shock after the reform is massive (the average of energy price increased nearly three folds), the outcome of models that rely on ex-ante stylized facts and parameters are plausibly subject to the Lucas critique Lucas (1976). Moreover, the existing studies hardly distinguish between the short and long run impact of SRCT. This research aims to investigate the short run impact of the reform using Vector Autoregressive (VAR) and address the long run relationships by Autoregressive Distributed Lag (ARDL) models (Engle and Yoo 1987; Naka and Tufte 1997; Pesaran and Shin 1998). Also, this study explores the channels that the impact of energy subsidy reform elements (i.e. energy price increase, and cash transfer) transmits to GDP.

The findings show that despite the fact that all savings of the subsidy removal has been transferred to households, SRCT had an adverse impact on export, value-added of industry and service sectors, capital formation and GDP in short- and mid-term (5 years). The main channel that transmits the negative impact of SRCT to GDP is the value-added of industry and service sectors. Yet, the reform has no long-run impact on GDP. The main objective of SRCT was to reduce the energy consumption.

\(^1\) It was equivalent to nearly 8 percent of GDP per capita, in 2010.
Our analyses do not show any significant indication that SRCT could restrain the energy consumption in mid- or long-term.

The remainder of this paper is organized as follows: Sect. 2 reviews the studies on subsidy reforms in Iran and other developing countries. Section 3 clarifies the research design from theory to practice. Section 4 explores data. Section 5 elaborates the empirical methodology. Section 6 discusses the empirical results within a short- and long-term framework. And Sect. 7 concludes.

Existing research on the energy subsidy reform

There is a wide range of studies on forecasting the impact of energy subsidy reforms on macro indicators such as GDP, inflation, energy consumption or emission. Table 1 summarises studies that aimed to investigate the impact of energy subsidy reforms on GDP or welfare. For example, a World Bank (2003) study using an input–output table forecasted that the complete phase out of energy subsidies would increase the inflation rate to 40% and lower welfare. The study also showed that a flat rate compensation to all households would be able to restore welfare loss. Similarly, Jensen and Tarr (2003), examined the impact of a range of reforms (including energy subsidy) on economic growth, with a computable general equilibrium (CGE) model. They argued that the elimination of the energy subsidy and the redistribution of savings from subsidy removal could both stimulate GDP growth and reduce income inequality. Shahmoradi et al. (2011) used a CGE simulation in which energy prices increased up to Persian Gulf fob prices and households, production firms and the government received 60, 30 and 10%, respectively, of the savings from the subsidy cut. Contrary to the previous studies, the outcome showed that GDP and household welfare decrease by 2.2 and 5.2% point, respectively. Hence, the compensation schemes mitigate the negative impact but cannot fully offset the negative impact of subsidy removal. Furthermore, the non-energy price index increases by 26%. Similarly, Hoseinasab and Hazeri (2012) confirmed that cash transfer cannot completely counteract the adverse effect of the subsidy cut. Yet, the greater the share of households and manufacturing firms (compared to government share), the lower the negative impact of the subsidy reform. The authors also pointed out the inflationary impact of the cash transfer. Eslami et al. (2012) examined three alternative scenarios of increases in electricity prices and cash transfer using a CGE model with a 2005 social accounting matrix. They found that cash transfers to households does not offset the negative impact of the complete removal of the electricity subsidy. Farajzadeh and Bakhshoodeh (2015) suggested that the redistribution of subsidy removal between manufacturing firms and households is more beneficial compared to the redistribution of the savings only among the households. The first option corresponds to 15% decline in GDP and 10% inflation while the latter reduces GDP by 21% and increases inflation by 13 percentage points. On the contrary, Gharibnavaz and Waschik (2015) found that SRCT increases the welfare of households by 45% point, on average but doubles the consumer price index. The authors blamed the international sanctions for the declining economy and (partially for) inflation.
| References                  | Country | Method | Description                                                                 | Brief result                                                                 |
|-----------------------------|---------|--------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------|
| World bank (2003)           | Iran    | IO     | Complete removal of energy subsidies; flat rate cash transfer to households  | Cash transfer neutralizes the negative impact of subsidy removal; improves income distribution; GDP growth |
| Jensen and Tarr (2003)       | Iran    | CGE    | Energy subsidy removal; redirecting the savings to the economy              | Positive impact on GDP (2.1%) and significant reduction in fuel demand        |
| Shahmoradi et al (2011)     | Iran    | CGE    | Elimination of energy subsidies; different rates of cash transfer to households, firms, and government | In the best scenario, GDP and welfare decrease by 2.2 and 5.2% and non-energy price index increases 26% |
| Eslami et al. (2012)        | Iran    | CGE    | Electricity subsidy removal and redirecting the savings in the form of cash transfer to households | Cash transfer cannot compensate the negative impact of complete elimination of electricity subsidy removal and GDP decreases by 2.5% |
| Hosseinasab and Hazeri (2012)| Iran    | CGE    | Energy subsidy removal and cash transfer to households, firms and government | The more the share of the households and firms, the less the negative impact of the subsidy removal. Yet, cash transfer cannot fully compensate the adverse effect. The reform has inflationary impact |
| Farajzadeh and Bakhshoodeh (2015)| Iran | CGE    | Energy subsidy removal along with different alternatives of cash transfer | The best option of cash transfer is to divide the savings between households and firms. Still, it causes a decline in GDP |
| Gharibnavaz and Waschik (2015)| Iran | CGE    | Energy subsidy removal and cash transfer to households                      | Increase of households’ welfare by 45% but consumer price index will be two folds |
| Lofgren (1995)               | Egypt   | CGE    | Removing the energy subsidies to reach the intl. price level; different scenarios for spend the saving | In all scenarios the GDP decreases in the range of 1.7–3.2%. energy consumption decreases by 6–8% |
| Abouleinein et al. (2009)   | Egypt   | CGE    | Subsidy removal to level the production cost of fuels; different options of spending the savings | Lowers the growth rate by 1.5% and increase inflation by 12%. Redirecting half of the savings to the poorest two quintiles is the superior option to mitigate the negative impact |
| Breisinger et al. (2019)    | Egypt   | CGE    | Phasing out the energy subsidies                                           | Hampers the growth in short run but improves growth perspective and household welfare in long run. Social protection measures are needed |
| References            | Country  | Method | Description                                                                 | Brief result                                                                                                                                                                                                 |
|-----------------------|----------|--------|-----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Lin and Jiang (2011)  | China    | CGE    | Elimination of energy subsidies and redirecting the savings to light industries and poor | At least 35% of savings should be redirected to the economy to mitigate the negative impact of the subsidy removal and protect the purchasing power of the poor                                                  |
| Liu and Li (2011)     | China    | CGE    | Subsidy removal of coal and fuel                                            | Cut of subsidies of coal and fuel causes 0.5 and 3.8 percentage shrinkage of GDP                                                                                                                                   |
| Lin and Li (2012)     | China/ world | CGE | Unilateral and multilateral removal of fossil fuel subsidies                | Unilateral subsidy removal will decline China’s economy more than multilateral subsidy removal. Subsidy removal affects the production mode to non-industrial goods                                               |
| Breisinger et al. (2012)| Yemen   | CGE    | Subsidy removal of fuels and redirecting half of the savings to the poor    | Cash transfer mitigates the negative impact of subsidy removal for the poor. In long run it has a development effect and poverty reduction due to increase of return to factors including labour |
| Solaymani et al. (2014)| Malaysia| CGE    | Complete elimination of energy subsidies                                   | It decreases household’s consumption by 5.7% from the base scenario. Poverty increases especially in rural areas                                                                                               |
| Timilsina and Pargal (2020)| Bangladesh| CGE | Subsidy removal of electricity and natural gas                              | It has a positive impact on GDP by improving government revenues                                                                                                                                     |
| Acharya and Sadath (2017)| India  | ECM, ARDL | Complete removal of energy subsidies                                       | Price increase diminishes the real income and households’ welfare                                                                                                                                  |
| Sarrakh et al. (2020) | Saudi Arabia | IO | Total removal of energy subsidies; redirecting 50% of the subsidies to economy | Total removal of subsidies adversely affects GDP but with reallocating 50% of the subsidies many sectors can restore but not energy-intensive industries |
On the impact of energy subsidy reform on energy consumption, Shahmoradi et al. (2011) using a CGE suggested that without technological improvement in production and household energy consumption, energy price increase alone do not curb the energy consumption. On the contrary, Solaymani (2021) using cointegration methodology found that energy subsidy removal (i.e. energy price increase) reduces energy consumption and CO2 emission. In the same vein, Tabatabaei and Asef (2021) investigated the impact of energy price liberalization on energy consumption intensity. The results showed that in response to price liberalization, the consumption of oil and diesel decreases, whereas the consumption of natural gas increases. Authors suggested improving the culture of energy consumption before price liberalization to achieve sustainable reduction in energy intensity of the country.

Numerous studies on forecasting of the impact of energy subsidy reform, in other countries, have been carried out. Breisinger et al. (2012) used a dynamic CGE model to examine a range of scenarios for fuel subsidy reforms, in Yemen. The results show that gradual rather than abrupt subsidy cuts (within 3 years) are preferable from a poverty-reduction and growth perspective. Moreover, phasing out the subsidies, using half of the savings for fiscal consolidation, and redistributing the other half directly to at least a third of the poorest populations can alleviate the negative effects on poor households in the short-term and have a positive effect on the economy in the long run. Overall, the authors predicted a decrease of poverty in the long run. The main driver of poverty reduction is the increased return to the factors (including labour productivity), which in turn is driven by increases in economic growth in the long run.

Lin and Jiang (2011) also applied a CGE model in the Chinese context to demonstrate that the elimination of energy subsidies causes a decline in GDP, employment, and households’ welfare. However, if at least 35% of the savings from subsidy cuts is redirected to the economy again (i.e., through investments in light industry, infrastructure, health, and education), negative impacts are mitigated, and the economy will recover and thrive. The authors advised on implementing effective measures to protect the purchasing power of the poor against the negative impacts of the subsidy cut. Additionally, Liu and Li (2011) found that coal and fuel subsidy removal cause GDP to decline (by 0.5 and 3.8% points, respectively. The authors suggested gradual elimination of the subsidy, first on coal and then on oil so that firms could have enough time to adjust to the changes. Meanwhile, Lin and Li (2012) examined the impact of fossil fuel subsidy removal in China with a multi-region CGE model (i.e., which includes China, Brazil, India, and OECD countries). In one scenario, the authors predicted that different sectors in different countries would be affected when all the regions eliminate the subsidy simultaneously. The industrial outputs of China, Brazil, and India, for instance, would significantly decline while OECD countries would experience slight increases in their outputs. In total, the subsidy removal would cause the world to experience a decline in industrial goods and slight increase in non-industrial outputs, eventually shifting production from industrial to non-industrial goods and inducing a structural change in the world economy. In another scenario, China’s unilateral removal of subsidies would cause the Chinese economy
to decline while other countries’ economies would be better off. Furthermore, subsidy elimination in China would reduce total industrial output and increase non-industrial output globally.

For Egypt, Lofgren (1995) used a CGE model to analyse the impacts of subsidy elimination. The author analysed the following three scenarios: savings from subsidy removal are directed to foreign investment (investing in foreign assets), domestic investment, and transfers to households. The results suggest that foreign investments would have strong adverse effects on GDP, household income, consumption, and employment. In short, redirecting savings to foreign investment would have the most contractionary effects. Abouleinein et al. (2009) concur and add that redirecting half of the savings to households could mitigate the negative impact of subsidy elimination on the economy. Moreover, gradual subsidy cut (within 5 years) and cash transfers to the populations belonging to the two poorest quintiles could be more effective compared to universal cash transfer, in terms of distributional impact and economic growth. Breisinger et al. (2019) using dynamic CGEs, considered different scenarios such as labour market liberalisation, alternative uses of savings derived from the subsidy removal and different social protection schemes. Authors concluded that energy subsidy removal has an adverse impact on GDP in short term (3 years) but conditioned to policy measure can improve the growth perspective in long run. Moreover, social protection nets to protect the household consumption in necessary in short and long term.

Solaymani et al. (2014) also used a CGE model to analyse the Malaysian context and suggested that complete elimination of the subsidies leads to a significant decline in household income and consumption and increases poverty. In particular, rural households that are employed in the agriculture sector are the most adversely affected.

For Saudi Arabia, Sarrakh et al. (2020) using input–output table suggested that total removal of energy subsidies adversely affects the economy especially energy intensive industries. Yet, with reallocation of 50% of the savings of the subsidy removal to health and social work sectors, the majority of sectors except those that heavily rely on energy consumption would restore. Authors also suggested compensatory measures for low-income households.

Timilsina and Pargal (2020) built a CGE to forecast the impact of removing subsidies on electricity and natural gas in Bangladesh. Authors found that subsidy removal increases the real government revenues and GDP. Investment funds was suggested as the best option for recycling the savings of subsidy removal in the economy. However, from distribution perspective, lump-sum transfer to households could be a better choice.

For India, Anand et al. (2014) estimating price elasticities suggested that full removal of energy subsidies reduces households’ welfare and add to general price level. Similarly, Acharya and Sadath (2017) applied Auto Distributed Lag (ARDL) and Error Correction Model (ECM) to estimate price and income elasticities and confirmed that energy subsidy removal increases the general price level and diminishes household welfare.
Banday and Aneja (2018) rejected the hypothesis that energy is neutral for growth using panel timeseries data of G7\(^2\) countries. The study revealed that non-renewable energy consumption has a long run positive effect of economic growth. Similar results suggested by Aneja et al. (2017) for BRICS\(^3\) countries. Moreover, there is a unidirectional causality from GDP to CO2 emission for BRICS countries except Russia. (Banday and Aneja 2019).

There is, therefore, a plethora of studies using CGE models to examine the effect of energy subsidy reforms on GDP. Specifically, in the case of Iran, the various studies yield different outcomes. Three out of seven studies forecasted positive or at least a neutral impact of subsidy removal and cash transfer while the other four reject the assumption that redirecting subsidy removal can fully compensate for the reform’s adverse effects, although they all agree that cash transfers could mitigate the reform’s negative impact.

The use of CGEs is due to the fact that these models incorporate and connect all sectors, therefore, providing an overview of the entire economy. However, CGEs are highly dependent on stylized facts based on historical data prior to the introduction of the reform and, therefore, are subject to the Lucas critique: “... Given that the structure of an econometric model consists of optimal decision rules of economic agents, and that optimal decision rules vary systematically with changes in the structure of series relevant to the decision maker, it follows that any change in policy will systematically alter the structure of econometric models. … For issues involving policy evaluation, … for it implies that comparisons of the effects of alternative policy rules using current macro-econometric models are invalid regardless of the performance of these models over the sample period or in ex ante short-term forecasting” (Lucas 1976: 41). This critique is even more salient in the case of the energy subsidy reform in Iran, wherein the price of all energy carriers (i.e., fuels and electricity) increased between 2 and 21 times. With respect to the magnitude of the reform scheme in Iran (characterized by massive change of energy price for all sectors, and an unprecedented universal unconditional cash transfer to households) and with reference to Lucas (1976), it is legitimate to doubt the validity of models that highly rely on ex-ante stylized facts and parameters and to seek the use of an alternative model.

Research design

Theoretical foundation

As discussed earlier, the energy subsidy reform in Iran (SRCT) consists of two simultaneous parts as follows: a subsidy cut (increase in energy price) and a cash transfer to households. Hence, the reform influences both aggregate demand and supply sides. An increase in the price of a basic production input, in this case energy,
will shift the aggregate supply curve to the left (see Fig. 1). This shift diminishes the output and elevates the general price level (Rasche and Tatom 1981; Brown and Yucel 2002; Barro 2007; Zarepour and Wagner 2022b).

On the demand side, the subsidy removal and (consequently) energy price increase affects the real budget of households and may induce a contraction on the demand side, i.e., moving backward along the demand curve (Bohi 1991; Kilian 2008; Rentschler et al. 2017; Rentschler and Bazilian 2017; Zarepour and Wagner 2022a). On the other hand, cash transfers are likely to have a positive effect on aggregate demand and may shift the demand curve to the right. Therefore, the counterbalance of the impact of the subsidy removal and cash transfer determines the equilibrium position at point B or B’ in Fig. 1.

**Choice of method**

An alternative yet common approach, to examine the effect of a policy on macro indicators, is a Vector Auto Regression (VAR) framework, developed by Sims (1980). Numerous studies have applied the VAR methodology to investigate the impact of a policy/shock on the economy of Iran. (Farzanegan 2011; Farzanegan and Markwardt 2009; Dizaji and Van Bergeijk 2013; Dizaji 2014; Rafat 2018; Khooshnevis Yazdi et al. 2017).

A VAR consists of a set of linear equations of variables in which each variable is in turn explained by its own lagged values, plus current and past values of the other variables. It does not require a particular theory or sets of assumptions, but it can incorporate a wide range of theories (Arora 2013). Hence, VAR is flexible and is also a powerful forecasting tool (Stock and Watson 2001), as it can predict

![Fig. 1 Aggregate demand and supply in response to energy subsidy reform](image-url)
short- and long-run outcomes and does not require assumptions about the exogeneity of variables.

**Conceptualization of the VAR**

Inspired by theoretical foundation, Figure 2 visualizes the VAR conceptual framework by demonstrating the channels that connect the elements of the energy subsidy reform to macro indicators. On the supply side, energy price elevation increases the production cost that can affect exports, meaning that more expensive products are less competitive in the international market (Hosseinasab and Hazeri 2012). Moreover, energy price increases can reduce the value added (if a producer cannot fully transmit the increase in production cost to consumers) (Hope and Singh 1999; Rentschler et al. 2017) and cause a decline in capital formation (Atkeson and Kehoe 1999). As a result, an increase in the energy price reduces output and increases inflation. However, these impacts would be different in the long term when the production firms have enough time to adjust (Bohi 1991; Hope and Singh 1999; Rasche and Tatom 1981; Brown and Yucel 2002; Barro 2007).

On the demand side, an increase in energy prices affects aggregate demand via substitution and income effects. An increase in energy prices can reduce energy
consumption directly (substitution effect). However, the increase in the general price level due to the increase in energy prices and also the prices of other goods and services (particularly energy-intensive products) results in a decline in real disposable income, lowering purchasing power and consequently diminishing aggregate demand (income effect) (Rentschler et al. 2017; Rentschler and Bazilian 2017; Zarepour and Wagner 2022b).

The second element of SRCT is the cash transfer to households. The cash transfer enhances purchasing power and subsequently private consumption. The cash transfer is unconditional and universal, and every household receives the same amount regardless of their income level. Private consumption is more likely driven by low-income households since their marginal propensity to consume is higher than the average. On the other hand, cash transfer keeps circulating in the economy and augments money volume that may add to inflation (Salehi-Isfahani, 2016).

### Data

To examine the short- and long-run effects of the energy subsidy reform on macro indicators, timeseries of the following variables are used. Data are adopted from the time-series databank of Central Bank of Iran⁴ (CBI) from 1965 to 2010 (46 observations) (see Table 2 for a description of the variables. Data on the price and

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⁴ See: [http://tsd.cbi.ir/Display/Content.aspx](http://tsd.cbi.ir/Display/Content.aspx) accessed by 25-02-2019.
consumption of energy carriers are meanwhile collected from the ‘Energy Balance Sheet’ provided by the Iranian Ministry of Energy.5

Energy price (\(peng\)) is the average price of the main energy carriers including LPG, gasoline, gasoil, kerosene, natural gas, and electricity and it is measured in Ton of oil equivalent (Toe) terms. The conversion of the units to Toe is according to the unit conversion guidelines of the Ministry of Energy. Energy price is used in current Iranian Rials (IRI) to veer away from the tendency of inflation to mask the magnitude of the prices. The main objective of this research was to investigate the effect of the energy subsidy reform (that introduces new sets of (nominal) prices) and to do so it is important to incorporate nominal prices rather than real ones. Investigation of the effect of such reforms based on the nominal energy price (by incorporating nominal energy price in the model) is not uncommon in the literature. (Rasche and Tatom, 1977; Eltony 2004; Wang and Zhu 2015; Huntington 2017). Moreover, as a supplementary analysis, the effect of the real energy price in the short and long run is discussed.

Given that increase of energy price is accompanied by a cash transfer to households, broad definition of money volume or M2 (\(mony\)) is included in the models. Increase of energy price directly and indirectly affects the economic sectors particularly industries and service sectors. The value-added of industry and service sectors (\(vains\)) is the indicator that highlights this link. The energy price increase can potentially be transmitted to capital formation in these economic sectors. Thus, gross capital formation (\(capform\)) is also included in the model.

Private consumption (\(pcon\)) is simultaneously affected by increase in energy prices, negatively and by cash transfer, positively. Public consumption (\(gcon\)) is another potential link that can transmit the effect of energy subsidy reform to GDP. Furthermore, energy price increases can influence the price competitiveness of products in international markets and affect net exports (\(expr\)). Inflation (\(inf\)) is a common by-product of the energy subsidy reforms so it is included in the variable list. Finally, energy consumption (\(econt\)) can potentially be affected by increase in energy prices and also affects other macro indicators including GDP. All variables except inflation rate (\(inf\)) are in logarithmic form.

Additionally, to take into account the effect of the Islamic revolution in 1979 and Iran–Iraq war during 1980–1988 two dummies are included in the models. These two dummies have also been employed in many recent VAR studies (Farzanegan and Markwardt 2009; Farzanegan, 2011; Dizaji and Van Bergeijk 2013).

### Modelling and empirical methodology

#### Time series econometric issues

The first issue in time series analysis is the stationary status of variables. According to Perron (1989), possible structural break can cause a bias that

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5 See: [http://pep.moe.gov.ir/accessed by 10-08-2019.](http://pep.moe.gov.ir)
decrease the chance of rejecting a false null hypothesis (Glynn et al. 2007). To address this issue, Table 3 compares the results of three tests, i.e. Augmented Dickey-Fuller (ADF), Perron (1989), and Zivot and Andrews (2002) that incorporate endogenous structural break in timeseries. The outcome is conclusive, all variables except inflation rate and export are nonstationary $I(1)$ ($p$ value ≤ 0.05).

The second issue is to use the variables on level or to differentiate the nonstationary ones to make them stationary. According to Hamilton (1994), the estimated parameters of a VAR in level, using non-stationary variables, are consistent. Even if the VAR in difference is the correct model, still many hypothesis tests based on VAR on level has the same asymptotic distribution as VAR in difference. Moreover, if any seemingly non-stationary variable is differenced while it is stationary, or it has any stationary linear combination as in the cointegrated VAR, then VAR in difference form is mis-specified (Hamilton 1994; Engle and Yoo 1987; Khan and Ali 2003). VAR modeling in levels has better predictive power when variables are mixed, i.e., some variables are stationary and some are not (Khan and Ali 2003). More importantly, we lose useful information while differencing. In this regard, variables at level for the VAR models are used.

The third issue is the use of unrestricted VAR versus the vector error correction models (VECM), which is the restricted form of the former. Numerous studies have shown that in short horizons, unrestricted VAR is better in forecasting (Engle and Yoo 1987; Clements and Hendry 1995; Hoffman and Rasche 1996; Naka and Tufte 1997). Since the first part of this research is focused on the short-term impact of the subsidy reform and given the better performance of the unrestricted VAR compared to VECM in the short run forecasting, I opt to use an unrestricted VAR.

| Table 3 | Unit root tests comparison |
|---------|-----------------------------|
|         | Augmented dickey-fuller | Perron | Zivot-Andrews |
| GDP     | Nonstationary I(1)        | Nonstationary I(1) | Nonstationary I(1) |
| Energy price | Nonstationary I(1) | Nonstationary I(1) | Nonstationary I(1) |
| Money(M2) | Nonstationary I(1)        | Nonstationary I(1) | Nonstationary I(1) |
| Capital formation | Nonstationary I(1) | Nonstationary I(1) | Nonstationary I(1) |
| Value-added of industry and service | Nonstationary I(1) | Nonstationary I(1) | Nonstationary I(1) |
| Private consumption | Nonstationary I(1) | Nonstationary I(1) | Nonstationary I(1) |
| Public consumption | Nonstationary I(1) | Nonstationary I(1) | Nonstationary I(1) |
| Export | Stationary                | Stationary | Stationary |
| Inflation rate | Stationary                | Stationary | Stationary |
| Energy consumption | Nonstationary* I(1) | Nonstationary I(1) | Nonstationary I(1) |

Note: The null hypothesis of all tests is that the series has a unit root test with structural break in both intercepts and trend. Results are based on 5% statistical significance.

*Shows the null hypothesis fails to be rejected at 5% but it is rejected at 10% statistical significance level.
Impulse response functions

An unrestricted VAR is used to investigate the response of macro variables to an innovation in energy price and money volume (liquidity), in the short run. In a VAR framework, all variables are considered to be endogenous, and no prior theoretical restriction is imposed. A VAR consists of a set of linear equations of variables, in which each variable is in turn explained by its own lagged variables, plus current and past values of other variables. The response of one variable to an innovation to another variable(s) in the system is called Impulse Response Function (IRF). The general form of VAR in a form of ‘infinite’ moving average (MA) can be written as follows:

\[ y_t = \varepsilon_t + \Psi_1 \varepsilon_{t-1} + \Psi_2 \varepsilon_{t-2} + \ldots \]  

(1)

This form contains the following impulse responses or dynamic multipliers:

\[ \frac{\partial y_{t+s}}{\partial \varepsilon_t} = \Psi_s \]  

(2)

The row \( i \), column \( j \) element of matrix \( \Psi_s \) represents the response of one unit increase in the \( j \)th variable’s innovation at time \( t \) for the value of the \( i \)th variable at time \( t + s \), holding all other innovations constant (Hamilton 1994).

The impulse response function can be generalized to simultaneous innovations with different magnitudes by creating a vector, such that each element of it is the magnitude of the impulse. If the first element of the \( \varepsilon_t \) changes by \( \delta_1 \) while the second element changes by \( \delta_2 \) and the \( n \)th element by \( \delta_n \), then the impulse responses would be as follows:

\[ \Delta y_{t+s} = \frac{\partial y_{t+s}}{\partial \varepsilon_{1t}} \delta_1 + \frac{\partial y_{t+s}}{\partial \varepsilon_{2t}} \delta_2 + \ldots + \frac{\partial y_{t+s}}{\partial \varepsilon_{nt}} \delta_n = \Psi_s \delta, \]  

(3)

where

\[ \delta = (\delta_1, \delta_2, \ldots, \delta_n) \]  

(4)

(Hamilton 1994).

The impulse responses demonstrate the current and future responses of each variable in response to an innovation in the variable of interest. By using IRF, not only

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6 It is common in the literature to use the MA form of VAR to extract the impulse response functions because the resulted responses are orthogonalized. Nevertheless, one can extract IRFs form an AR form. However, the procedure to make them orthogonalized is complicated. The central point here is that any autoregressive form of order \( p \), AR(\( p \)), can be written as MA(\( \infty \)). For example AR(1) can be written as follows:

\[ y_t = \phi_1 y_{t-1} + \varepsilon_t \]  

If we substitute \( y_{t-1} \) recursively, we will have an infinite moving average form as MA(\( \infty \)) (Hamilton 1994): 

\[ y_t = \phi_1 y_{t-1} + \varepsilon_t = \phi_1 (\phi_2 y_{t-2} + \varepsilon_{t-1}) + \varepsilon_t = \ldots = \sum_{s=0}^{\infty} \phi^s \varepsilon_{t-s} \]
is the magnitude of the response observable, but the statistical significance of the response also becomes apparent. When the horizontal zero line in the IRF graphs falls outside the confidence interval (at 5% significance), the null hypothesis (that there is no effect on the variable of interest due to the shock), can be rejected. We can use Eq. 3 to construct a simultaneous innovation to two or more variables to simulate the energy subsidy reform that has two elements (increase in energy price and cash transfer).

**Empirical results**

**Short-term analysis: transmission channels**

There are numerous variables from both the supply and demand side that may be affected by the energy subsidy reform, and which could eventually also transmit their impact to GDP (see Fig. 2 for conceptualization of the VAR). To clarify potential transmission channels, numerous Parsimonious VARs are employed. It is a practical strategy to identify the potential links particularly when the length of the time series is limited. (Christiano et al. 1996; Jansen 2003; Dizaji and Van Bergeijk 2013). Table A.2 in appendix summarizes different criteria for lag order selection in parsimonious VARs. Maximum number of lags was set up to 3. Different criteria suggest different number of lags for models. Akaike criteria have advantages over Schwartz criterion, on theoretical and practical grounds (Burnham and Anderson 1998, 2004; Liew 2004). Thus, I proceed with the number of lags suggested by AIC. Table 4 demonstrates the outcome of parsimonious VARs in response to an innovation in the energy price in Panel A and to money volume (M2) in Panel B, respectively. Each line of this table depicts different specifications of VAR with the sign and significance of the result within a 4-years tim span. Cholesky decomposition is used to define the impulse. As an example, the first line of the table follows this Cholesky ordering: energy price, value-added of industry and service sectors, capital formation, and GDP. This ordering indicates that a shock to energy price affects the value-added of industry and service sectors, and this in turn alters the capital formation and finally GDP. Accordingly, this VAR states that the increase in energy price has no significant impact in the first year, but it has a diminishing effect on capital formation and GDP, afterward, which becomes significant in year 2 and 3. In this VAR, the intermediate variable is the value-added of industry and service sectors. This intermediate variable i.e. value-added decreases significantly in year 2 and 3. Panel A of Table 4 demonstrates a consistent negative impact on capital formation and GDP in response to an increase of energy price via different transmission channels. Albeit only the following three of these channels are statistically significant: Value-added, export and inflation. Innovation in energy price has inflationary impact from the first year that becomes significant in years 1 and 2 before it wanes at the end of the time span.

Panel B of Table 4 demonstrates the effect of the second element of the subsidy reform, i.e., cash transfer represented by an innovation to money volume, via parsimonious VARs. An innovation in M2 has an immediate positive effect on all
Table 4  Effect of energy subsidy reform elements on macro indicators

Panel A: effect of one SD impulse to energy price

| VAR no | Intermediate variable | Capital formation | GDP |
|--------|-----------------------|-------------------|-----|
|        | Year 1 | Year 2 | Year 3 | Year 4–5 | Year 1 | Year 2 | Year 3 | Year 4–5 | Year 1 | Year 2 | Year 3 | Year 4–5 | Year 1 | Year 2 | Year 3 | Year 4–5 |
| 1      | Value-added  | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative |
| 2      | Private consumption | Negative | Negative | Negative | Negative | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative |
| 3      | Energy consumption | Negative | Negative | Negative | Negative | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative |
| 4      | Inflation  | Positive | Positive | positive | Nil | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative |
| 5      | Export  | nil | Negative | Negative | Nil | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative |
| 6      | Public consumption | Negative | Negative | Negative | Nil | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative | Nil | Negative | Negative | Negative |

Panel B: effect of one SD impulse to money volume (M2)

| VAR no | Intermediate variable | Capital formation | GDP |
|--------|-----------------------|-------------------|-----|
|        | Year 1 | Year 2 | Year 3 | Year 4–5 | Year 1 | Year 2 | Year 3 | Year 4–5 | Year 1 | Year 2 | Year 3 | Year 4–5 | Year 1 | Year 2 | Year 3 | Year 4–5 |
| 7      | Value-added  | Positive | Positive | Positive | Nil | Nil | Positive | Nil | Nil | Nil | Positive | Nil | Nil | Nil | Nil |
| 8      | Private consumption | Positive | Positive | Positive | Positive | nil | Positive | Positive | Nil | nil | Nil | Positive | Nil | Nil | Positive | Nil |
| 9      | Energy consumption | Positive | Positive | Positive | Positive | Nil | Positive | Positive | Nil | Positive | Nil | Positive | Nil | Positive | Nil |
| 10     | Inflation  | Positive | Positive | Positive | Nil | Nil | Positive | Nil | Nil | Nil | Positive | Positive | Positive | Nil | Positive | Positive | Positive |
| 11     | Export  | Positive | Nil | Negative | Nil | Nil | Negative | Nil | Negative | Nil | Negative | Nil | Nil |
| 12     | Public consumption | Positive | Positive | Positive | Positive | Nil | Positive | Positive | Nil | Nil | Positive | Positive | Positive | Nil | Positive | Positive | Positive |

Note: Each line represents a VAR model. Significant effects (at 5% level) effects are in bold. All models include two dummies for 1979 Islamic revolution (drev) and Iran-Iraq war during 1980–1988 (dwar) to control for exogenous structural breaks.
intermediate channels. Albeit this impact is significant only for private and energy consumption, in years 1 and 2. Nevertheless, this positive impact weakly transmits to GDP. Comparing Panels A and B of Table 4 indicates that the negative effect of energy price increase on GDP, from all channels except energy consumption, is statistically significant. While the positive effect of cash transfer on GDP, from all channels, is statistically insignificant. In other words, it is unlikely that unconditional universal cash transfer can overcome the negative impact of the energy price increase. Cholesky ordering (that implies the order of variables) is a suitable method for incorporating the concept of transmission channels to the VARs. The alternative method is generalized impulse responses that do not care for order of variables in the model. It is noteworthy that the results are identical with the application of the generalised impulse method.

**Short-term analysis: extended VAR**

Having numerous VARs not only clarifies the transmission channels of the energy subsidy reform but as shown in Table 4, but also demonstrates the robustness of the negative impact of the energy price increase on GDP. Nonetheless, in this step, all variables are put together in an extended VAR for further examination. Extended VAR can address the omitted variable problem that may occur in parsimonious models. For the extended VARs, the Akaike criteria suggests a maximum lag of 3. Figures 3 and 4 illustrate the response of variables to a one standard deviation impulse in energy price and money volume (M2), respectively. Figure 3 shows that the energy price impulse has a negative impact on value-added of industry and service sectors, private, public and energy consumption, capital formation and GDP. This impact is statistically significant for capital formation in year 1 or 2, and on GDP in year 2. The magnitude is highest in year 2 or 3. On energy consumption, Fig. 3 shows that energy price increase has a declining effect on energy consumption, but it is not statistically significant. Figure 3 also confirms the inflationary effect of energy price increase in both years 1 and 2. Moreover, it shows a distinctive cyclical movement of inflation in response to energy price impulse.

Figure 4 demonstrates the response of macro indicators to an impulse involving the second element of the energy subsidy reform, cash transfer, that is represented by a one standard deviation increase in the volume of money. This impulse significantly increases private and public consumption, energy consumption, value-added and export, in the first year, and then it becomes insignificant. The response of this impulse is significantly positive on GDP in year 3. The response of other variables including inflation to this innovation is not statistically significant.

So far, the effects of the energy price increase and cash transfer have been discussed individually. To simulate the energy subsidy reform, we need a customized simultaneous synchronized innovation as a shock to the system. Given the features of the subsidy reform and by utilising Eq-3, the innovation vector is customized with respect to the weights of the shock to energy price and money volume. Recalling that variables in the VAR are in logarithmic form, a 1-unit impulse represents a 1% change in the variable. Therefore, the percentage of the change of the variables of interest due to the subsidy
reform is calculated as follows so that the policy can be replicated. Given that cash compensation for the energy subsidy cut is 405,000 IRI per person per month, we have the following:

Annual money volume per person due to cash transfer = 405,000 * 12 = 4.86 million IRI

Total per capita money volume in 2011 is 46.97 million IRI, so the change in money volume due to cash transfer (as a part of subsidy reform) is as follows:

Note: This figure shows the temporal response of macro indicators to a one standard division shock to energy price. The horizontal line shows time (years). The red (dotted) lines show the confidence interval (bands) at 5% significance level. All models include two dummies for 1979 Islamic revolution (drev) and Iran-Iraq war during 1980-1988 (dwar) to control for exogenous structural breaks.

Fig. 3 Response to energy price innovation
The magnitude of the energy price shock can be obtained by comparing energy price in year 2010 and 2011 (before and after the reform):

\[
\frac{4.86}{46.97} \approx 10\%
\]

The magnitude of the energy price shock can be obtained by comparing energy price in year 2010 and 2011 (before and after the reform):

\[
= \frac{3132.7}{1150.4} \approx 272\%
\]

Vector \( \delta \) is the customized impulse that can simulate a proportionate shock to the system. The number of the elements in this vector is the same as the number of the endogenous variables in the VAR that is 10.

Note: This figure shows the temporal response of macro indicators to a one standard division shock to money volume (M2). The horizontal line shows time (years). The red (dotted) lines show the confidence interval (bands) at 5% significance level. All models include two dummies for 1979 Islamic revolution (\(drev\)) and Iran-Iraq war during 1980-1988 (\(dwar\)) to control for exogenous structural breaks.

**Fig. 4** Response to cash transfer innovation
Figure 5 demonstrates the response of the variables to this customized synchronous shock. In year 2, the negative impact of the energy subsidy reform on $u_1 = (2.72, 1.0, 0, 0, 0, 0, 0, 0, 0, 0)$

Note: This figure shows the temporal response of macro indicators to a customized innovation that simulate both elements of the energy subsidy reform simultaneously. The horizontal line shows time (years). The red (dotted) lines show the confidence interval (bands) at 5% significance level. All models include two dummies for 1979 Islamic revolution ($d_{rev}$) and Iran-Iraq war during 1980-1988 ($d_{war}$) to control for exogenous structural breaks.

**Fig. 5** Response to a synchronized customized innovation (simulation of the energy subsidy reform)

$$\delta = (2.72, 1.0, 0, 0, 0, 0, 0, 0, 0, 0)'$$

Figure 5 demonstrates the response of the variables to this customized synchronous shock. In year 2, the negative impact of the energy subsidy reform on...
value-added of industry and service sectors, capital formation and GDP is approximately 7, 15 and 5%, respectively. Albeit this impact, is only statistically significant for capital formation. Energy consumption reduction in response to the simulated energy subsidy reform is trivial (less than 0.7%). Figure 5 also shows that inflation increases up to 14% in year 2.

In sum, the upshot from the small VARs and the extended VARs with ordinary and customized innovations are comparable and the following may be concluded: (i) Energy subsidy reform has substantial adverse effects on value-addition of industry and service sectors, on capital formation and GDP, in the short run. (ii) Energy subsidy reform has a cyclical inflationary effect. (iii) Cash transfer mitigates the negative effect of energy price on private consumption but does not fully offset it and (iv) the models do not demonstrate compelling evidence that the energy subsidy reform decreases energy consumption.

A final point, I use nominal energy price throughout the analysis as from a policy evaluation viewpoint, it is more important to identify the effect of the new sets of energy prices on the economy rather than the real prices. Nevertheless, as a supplementary analysis, I use real energy price ($r_{peng}$) to replicate the results of the extended VARs with the inclusion of real energy price instead. Figures A.1 to A.3 in appendix demonstrate the response of macro indicators to a one standard error innovation in the real energy price, cash transfer, and simultaneous innovation, respectively. These graphs are comparable with Figs. 3, 4, 5. Value-added, private consumption, capital formation and GDP decline in response to real energy price increase. The dynamics and magnitude of the effect of cash transfer in the VAR with real energy price (Figure A.2 in appendix) is identical with Fig. 4. Figure A.3 in appendix shows the customized simultaneous shock to real energy price and cash transfer. Similarly, the dynamics and the magnitude of the impact is comparable to Fig. 5. Simultaneous shock has a diminishing impact on the value-added, capital formation and GDP. Decline in GDP reaches trough (approximately 4%) in year 3 before recovery begins.

**Variance decomposition**

The analysis of variance decomposition of forecasting errors gives us an idea of the proportion of the forecasting error explained by the variable itself or by other variables. Table 5 demonstrates the variance decomposition of the extended VAR. For value-added, energy consumption and export, the largest proportion of the variation is explained by their own trend. Value-added, in turn, explains a majority of the fluctuation in capital formation and GDP within the 5-year time span. Money volume (M2) explains approximately half of the variation in private consumption and energy consumption.

Value-added of industry and service sectors is the major determinant of variance in inflation in the first year. After year 1, energy price explains up to 53% of the fluctuation in inflation (supply-side drivers). The cash transfer can explain no more than 14% of the inflation forecast error. For GDP, energy price accounts for up to 25% of its variation after year 1. Meanwhile, money volume (M2) explains a larger portion of
Table 5 Variance decomposition

| Year | Energy price | Money (M2) | Value-added | Private cons | Energy cons | Public cons | Export | Inflation | Capital formation | GDP |
|------|--------------|------------|-------------|--------------|-------------|-------------|--------|------------|-------------------|-----|
| 1    | 100          | 0.00       | 0.00        | 0.00         | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 2    | 82.88        | 0.00       | 0.83        | 1.79         | 5.72        | 4.43        | 3.69   | 0.47       | 0.18              | 0.02|
| 3    | 60.28        | 4.97       | 2.72        | 14.85        | 4.25        | 3.23        | 7.11   | 0.64       | 1.67              | 0.28|
| 4    | 32.54        | 10.15      | 17.77       | 12.08        | 2.58        | 3.84        | 17.87  | 0.82       | 2.10              | 0.25|
| 5    | 29.24        | 6.99       | 12.85       | 9.54         | 9.13        | 13.97       | 15.87  | 0.81       | 1.40              | 0.20|

Money volume (M2)

| Year | Energy price | Money (M2) | Value-added | Private cons | Energy cons | Public cons | Export | Inflation | Capital formation | GDP |
|------|--------------|------------|-------------|--------------|-------------|-------------|--------|------------|-------------------|-----|
| 1    | 1.17         | 98.83      | 0.00        | 0.00         | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 2    | 0.65         | 74.86      | 17.21       | 0.62         | 5.23        | 1.03        | 0.02   | 0.00       | 0.36              | 0.03|
| 3    | 0.62         | 77.52      | 14.77       | 0.38         | 4.38        | 1.77        | 0.02   | 0.30       | 0.22              | 0.03|
| 4    | 2.42         | 76.46      | 15.33       | 0.28         | 3.31        | 1.78        | 0.02   | 0.22       | 0.17              | 0.02|
| 5    | 2.14         | 77.78      | 15.15       | 0.29         | 2.64        | 1.60        | 0.01   | 0.17       | 0.19              | 0.02|

Value-added (industry and service)

| Year | Energy price | Money (M2) | Value-added | Private cons | Energy cons | Public cons | Export | Inflation | Capital formation | GDP |
|------|--------------|------------|-------------|--------------|-------------|-------------|--------|------------|-------------------|-----|
| 1    | 0.98         | 10.70      | 88.32       | 0.00         | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 2    | 19.03        | 18.34      | 58.94       | 0.61         | 1.55        | 1.01        | 0.41   | 0.08       | 0.02              | 0.01|
| 3    | 17.48        | 39.12      | 33.20       | 0.29         | 0.84        | 8.60        | 0.34   | 0.05       | 0.09              | 0.00|
| 4    | 13.89        | 42.15      | 31.88       | 0.83         | 1.46        | 8.37        | 0.82   | 0.06       | 0.47              | 0.08|
| 5    | 11.21        | 39.34      | 34.48       | 0.61         | 1.08        | 8.00        | 4.29   | 0.15       | 0.75              | 0.09|

Private consumption

| Year | Energy price | Money (M2) | Value-added | Private cons | Energy cons | Public cons | Export | Inflation | Capital formation | GDP |
|------|--------------|------------|-------------|--------------|-------------|-------------|--------|------------|-------------------|-----|
| 1    | 0.69         | 49.55      | 40.90       | 8.86         | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 2    | 3.88         | 58.26      | 28.46       | 4.50         | 2.33        | 2.17        | 0.30   | 0.01       | 0.08              | 0.01|
| 3    | 8.39         | 50.16      | 30.06       | 3.35         | 3.01        | 3.63        | 0.90   | 0.25       | 0.19              | 0.06|
| 4    | 8.82         | 45.19      | 32.83       | 2.37         | 3.33        | 5.18        | 1.73   | 0.19       | 0.31              | 0.06|
| 5    | 9.84         | 41.47      | 33.05       | 2.28         | 3.58        | 6.49        | 2.42   | 0.30       | 0.50              | 0.07|
Table 5 (continued)

| Year | Energy consumption | Value-added | Money (M2) | Private cons | Energy cons | Public cons | Export | Inflation | Capital formation | GDP |
|------|--------------------|-------------|------------|--------------|-------------|-------------|--------|------------|-------------------|-----|
|      |                    |             |            |              |             |             |        |            |                   |     |
| 1    | 3.18               | 49.89       | 0.14       | 44.98        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 2    | 5.25               | 66.76       | 0.08       | 19.63        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 3    | 3.93               | 58.90       | 0.36       | 22.20        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 4    | 9.54               | 56.58       | 0.27       | 18.66        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 5    | 12.56              | 53.80       | 0.25       | 16.15        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
|      |                    |             |            |              |             |             |        |            |                   |     |
| 1    | 8.70               | 37.61       | 0.39       | 50.95        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 2    | 15.40              | 42.99       | 0.38       | 24.73        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 3    | 14.69              | 48.77       | 0.37       | 34.53        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 4    | 14.62              | 39.27       | 0.28       | 29.85        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 5    | 21.78              | 32.04       | 0.27       | 29.85        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
|      |                    |             |            |              |             |             |        |            |                   |     |
| 1    | 5.76               | 37.61       | 0.39       | 40.95        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 2    | 15.40              | 42.99       | 0.38       | 24.73        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 3    | 14.69              | 48.77       | 0.37       | 34.53        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 4    | 14.62              | 39.27       | 0.28       | 29.85        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 5    | 21.78              | 32.04       | 0.27       | 29.85        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
|      |                    |             |            |              |             |             |        |            |                   |     |
| 1    | 5.76               | 37.61       | 0.39       | 40.95        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 2    | 15.40              | 42.99       | 0.38       | 24.73        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 3    | 14.69              | 48.77       | 0.37       | 34.53        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 4    | 14.62              | 39.27       | 0.28       | 29.85        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
| 5    | 21.78              | 32.04       | 0.27       | 29.85        | 0.00        | 0.00        | 0.00   | 0.00       | 0.00              | 0.00|
Table 5 (continued)

| Year | Energy price | Money (M2) | Value-added | Private cons | Energy cons | Public cons | Export | Inflation | Capital formation | GDP |
|------|--------------|------------|-------------|--------------|-------------|-------------|--------|------------|-------------------|-----|
| 5    | 53.02        | 9.52       | 15.68       | 1.63         | 3.67        | 9.59        | 4.99   | 1.53       | 0.29              | 0.09|

Capital formation

| Year | Energy price | Money (M2) | Value-added | Private cons | Energy cons | Public cons | Export | Inflation | Capital formation | GDP |
|------|--------------|------------|-------------|--------------|-------------|-------------|--------|------------|-------------------|-----|
| 1    | 10.60        | 0.04       | 76.90       | 0.43         | 0.25        | 0.01        | 0.01   | 9.05       | 2.72              | 0.00|
| 2    | 17.67        | 5.73       | 68.40       | 0.34         | 4.66        | 0.61        | 0.30   | 1.72       | 0.57              | 0.01|
| 3    | 22.26        | 17.69      | 46.54       | 0.41         | 2.80        | 7.62        | 0.88   | 1.25       | 0.53              | 0.01|
| 4    | 21.45        | 22.38      | 38.16       | 1.05         | 2.58        | 10.84       | 1.58   | 1.08       | 0.80              | 0.07|
| 5    | 18.38        | 22.48      | 39.59       | 1.02         | 2.20        | 8.60        | 4.65   | 1.72       | 1.27              | 0.09|

GDP

| Year | Energy price | Money (M2) | Value-added | Private cons | Energy cons | Public cons | Export | Inflation | Capital formation | GDP |
|------|--------------|------------|-------------|--------------|-------------|-------------|--------|------------|-------------------|-----|
| 1    | 0.43         | 9.07       | 86.66       | 0.96         | 0.85        | 0.23        | 0.66   | 0.46       | 0.50              | 0.17|
| 2    | 25.46        | 9.32       | 55.19       | 1.35         | 0.38        | 5.28        | 0.49   | 2.22       | 0.21              | 0.09|
| 3    | 23.72        | 28.87      | 32.61       | 0.53         | 0.14        | 11.42       | 1.64   | 0.81       | 0.22              | 0.05|
| 4    | 17.47        | 35.79      | 29.22       | 1.01         | 0.99        | 9.66        | 3.54   | 1.02       | 1.16              | 0.13|
| 5    | 15.61        | 32.69      | 28.15       | 0.83         | 2.50        | 11.64       | 6.24   | 0.82       | 1.37              | 0.16|

Note: This table demonstrates the variance decomposition of the forecast errors of the extended VAR.
GDP variance after year 3 (up to 33%). For energy consumption, the historical trend of energy consumption and money volume are the major determinants of variation. Energy price has a relatively small portion in the variation of energy consumption—it is no more than 5% but it increases in year 5–13%.

These findings confirm the findings of the previous section (impulse response function analysis). It shows the influence of value-added on capital formation and GDP. Energy price influences GDP but its effect diminishes over time. It also reveals that the determinants of inflation variation are more rooted in the supply side (energy price and value-added) and cash transfer and private consumption are less influential.

**Long-run analysis: bounds test**

The previous sections discussed the impact of the subsidy reform on macro variables within a short time span, using impulse response functions and variance decomposition within a VAR framework. However, a cointegration analysis is necessary to address the question in the long run.

A cointegrated vector is a linear combination of nonstationary series with stationary residuals. For example, if \( x_t \) and \( y_t \) are both I(1), and the residuals is stationary \( u(t) \sim I(0) \), then \( x_t \) and \( y_t \) are cointegrated of order (1,1). The economic interpretation of a cointegrating relationship is that if two or more series are cointegrated, they have a long-run equilibrium relationship and even if the individual series have a stochastic trend (i.e., nonstationary), the combination of the series will move tightly together, and the difference between them will remain stable. (Harris 1995).

In this regard, if macro variables, and particularly GDP, move together with energy price and/or money volume (M2) (i.e., if there is a long run relationship between GDP and elements of the subsidy reform), it may be concluded that the subsidy reform has a long-term impact on the economy. Utilizing Auto Regressive Distributed Lag (ARDL) model and Bounds test, we may check for the existence of long-run relationships between energy prices and/or money volume (M2), and important macro indicators. I chose to use the ARDL model and Bounds tests developed by Pesaran and Shin (1998) and Pesaran et al. (2001) because this method is compatible with the mix of I(0) and I(1) variables in the system. Thus, inconclusive unit root tests for some variables are not problematic. Furthermore, in this model, different variables may be assigned with different number of lags. Last, it is featured with a post-estimation coefficient diagnostic test (Bounds test) to ensure the (non)existence of a long-run relationship at different significance level. Bounds tests consist of two sets of asymptotic critical values that provide a band that covers all possible mix of variables from I(0) to I(1). If the F-statistics falls outside the bounds a conclusive inference can be drawn without needing to know whether the variables are stationary or not. However, if the F-statistics falls between the bounds, the test is inconclusive and the knowledge of degree of integration of variables is necessary to draw any conclusive inference (Pesaran et al. 2001). The basic form of an ARDL regression is presented as follows:

\[
y_t = \beta_0 + \beta_1 y_{t-1} + \cdots + \beta_k y_{t-p} + \alpha_0 x_t + \alpha_1 x_{t-1} + \cdots + \alpha_q x_{t-q} + \varepsilon_t, \hspace{1cm} (5)
\]

where the disturbance term, \( \varepsilon_t \), is well-behaved and serially independent.
From Table 3, it is known that none of the variables are I(2), i.e., all the tests show that the variables are either stationary or become stationary after one difference. Thus, the application of the ARDL model is compatible with the dataset at hand. Panel A of Table 6 shows the (non)existence of any relationship between selected macro indicators and energy price. Each row represents a macro indicator as the dependent variable while energy price is the dynamic regressor, i.e., it can take lags. All models include an intercept, a trend and two dummies for Islamic revolution and Iran–Iraq war. The third column, model specification (lag structure), shows the optimal lag structure suggested by the Akaike criteria. The first number shows the number of lags of the dependent variable on the right side of the equation and the rest of the numbers show the number of lags of the dynamic regressors. For example, in the first row the optimal model structure is (2,2) that means 2 lags are assigned to GDP (dependent variable) and 2 lags to energy price (dynamic regressor). The default maximum number of lags is 4. Yet, in case of serial correlation of the residuals,⁷ the number of lags added up to the number that resolves the serial correlation problem, for a significance level of 5%. In the absence of serial correlation, the Bounds test shows the (non)existence of cointegrated vector in the last column. If the F-statistic of Bounds test (fourth column) is larger than the upper

Table 6  (Non)Existence of long run relationship between energy subsidy reform and main macro indicators

| Dependent variable | Model specification (lag structure) | F-statistics of bounds test | Long run relationship |
|--------------------|------------------------------------|-----------------------------|-----------------------|
| Panel A: Energy price | GDP (2,2) | 5.348 | No |
| | Value-added of industry and service (4,0) | 0.211 | No |
| | Private consumption (2,0) | 1.063 | No |
| | Energy consumption (4,0) | 2.519 | No |
| Inflation (5,3) | 17.378 | Yes |
| Panel B: Money volume | GDP (2,0) | 5.934 | No |
| | Value-added of industry and service (4,4) | 1.313 | No |
| | Private consumption (6,6) | 2.312 | No |
| | Energy consumption (6,2) | 5.886 | No |
| Inflation (2,4) | 14.174 | Yes |
| Panel C: Energy price and money volume | GDP (2,2,0) | 4.166 | No |
| | Value-added of industry and service (4,4,4) | 0.287 | No |
| | Private consumption (6,0,6) | 1.766 | No |
| | Energy consumption (4,0,4) | 4.986 | No |
| Inflation (4,3,3) | 10.192 | Yes |

*Note: All models include an intercept, a trend and two dummies for Islamic revolution and Iran–Iraq war to control for structural breaks. Exogenous variable(s) in Panel A is energy price, in panel B is money volume and in panel C are both energy price and money volume together.

⁷ Breusch–Godfrey serial correlation LM test is used.
bound, a long-run relationship exists. If it is smaller than the lower bound, there is no long-run relationship and if it falls between the boundaries, then the test is not conclusive. The critical lower and upper bounds, provided by Pesaran et al. (2001), depend on the number of observations and dependent variables. The critical lower and upper bounds, at the 5% level of significance, for Panel A and B of Table 6 are 7.08 and 7.91, respectively. The F-statistics of the first model, in the first row of Table 6 is 5.348 that is less than the lower critical bound. Therefore, there is no long-run association between energy price and GDP. Likewise, no long-run relationship exists between energy price and value-added of industry and service sector, private consumption, or energy consumption. However, inflation and energy price move together in long run.

Panel B of Table 6 demonstrates possible long-run relationships between macro indicators and cash transfer [represented by money volume (M2)]. The critical values are the same as in Panel A. Panel B shows that there is only a long-run association between inflation and money volume. Panel C includes both energy price and money volume as dynamic regressors in the model. The critical values here are 5.36 and 6.37 for the lower and upper bounds, respectively. Like the first two panels of Table 6, Panel C shows that there is no long-run relationship between the energy subsidy reform elements (i.e., energy price and cash transfer) and GDP, value-added, private consumption, or energy consumption. Nonetheless, energy subsidy reform has a long-run inflationary effect. Comparing this result with the outcome of short-term analysis indicates that inflation has a cyclical movement.

Similar to the aforementioned findings, Table A.3 in appendix confirms that there is no long-run relationship between real energy price and cash transfer, and the main macro indicators except inflation.

**Discussion and concluding remarks**

This article investigated the short- and long-run macroeconomic impact of the Iranian energy subsidy reform (SRCT) on macro indicators, particularly GDP, energy consumption and inflation, using timeseries in the period 1965–2010. Due to the flexibility that VAR modeling offers and its powerful performance in short-term forecasting (Stock and Watson 2001; Charney and Vest 2003; Arora 2013), this research applied VAR modelling to forecast the effect of the reform in short-run and ARDL model and bounds test for long-run investigation. The analysis incorporated both elements of subsidy reform (i.e., energy price increase, and cash transfer) individually and together. The findings show that although SRCT was a budget neutral policy and all savings of the subsidy removal redirected back to the economy in the form of a cash transfer to households, it had adverse impact on value-added of industry and service sector, capital formation, and GDP in short- and mid-term (5 years). The outcome of the short (and mid-term) analysis supports the findings of Shahmoradi et al. (2011), Eslami et al. (2012) and Hosseinasab and Hazeri (2012) that applied CGEs. Macro indicators reach a trough in year 2 or 3 and thereafter started to return to their initial levels. This research did not find any evidence that
the reform per se can influence GDP in long run. (Bound tests reject the possibility of a long run association between the subsidy reform and GDP).

Consistent with the findings of Rahmati and Pilehvari (2018) and Zarepour and Wagner (2022b), the results indicate that value-added of industry and service sector is the main channel which transmits the negative effect of the higher energy price to GDP. Therefore, the stability in economy is essential for economic agents and particularly for industries to recover from the energy price shock in mid-term.

This study showed that both elements of the energy subsidy reform, i.e. energy price increase, and cash transfer, have inflationary impact. The results corroborate the findings of Saboohi (2001), Gharibnavaz and Waschik (2015), Bhat et al. (2018), Shahmoradi et al. (2011), Hosseinasab and Hazeri (2012). The inflationary impact can negate the increase of real energy price and erode the real value of cash transfer. To defuse the inflation, contractionary policy measures such as selling government binds can be adopted (Bhat et al. 2018).

The main objective of SRCT is to curb the energy consumption. In contrast to Solaymani (2021), our findings do not indicate any meaningful reduction in energy consumption in response to the energy subsidy reform either in mid-term or in the long run. This can be taken as indication that on the average the energy consumption is at the essential level with respect to current level of technology in economic sectors such as industrial, residential and transport (Zarepour 2022). These findings are consistent with the outcome of Shahmoradi et al. (2011) and contest the environmental and sustainability aspect of energy reforms as an intrinsic outcome of energy subsidy reforms. In line with earlier research, this study also suggests that energy price reforms as stand-alone policies are not effective in energy consumption management. Removing barriers to adopt energy-efficient technologies are essential part of effective energy consumption management policy (Barkhordar et al. 2018; Ranjbar Fallah 2001; Shahmoradi et al. 2011).

This study focuses on linear relationships among variables. Examining possible nonlinear associations could be a ground for future studies. Moreover, micro-level investigations in channels that energy price increase affects the value-added of industries or affects the inflation are avenues for future research.

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Consent to publication  The author gives consent for the publication of the paper.

Research involves human or animal participant  This article does not contain any studies with human participants or animals performed by any of the authors.

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