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G-2015-129

December 2015

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La publication de ces rapports de recherche est rendue possible grâce au soutien de HEC Montréal, Polytechnique Montréal, Université McGill, Université du Québec à Montréal, ainsi que du Fonds de recherche du Québec – Nature et technologies.

Dépôt légal – Bibliothèque et Archives nationales du Québec, 2015.

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The publication of these research reports is made possible thanks to the support of HEC Montréal, Polytechnique Montréal, McGill University, Université du Québec à Montréal, as well as the Fonds de recherche du Québec – Nature et technologies.

Legal deposit – Bibliothèque et Archives nationales du Québec, 2015.

Welfare implication of reforming energy consumption subsidies

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December 2015

Les Cahiers du GERAD

G-2015-129

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Abstract: Reforming energy consumption subsidies, in particular for fossil fuels, has been frequently referred to as a quick-win policy to enhance environmental mitigation. In addition to producing environmental benefits, the removal of such subsidies may release a sizeable portion of a country's national budget for use on more productive targets. One of the most recognized challenges of such reform is "selling" the new energy prices to citizens, particularly those with a more fragile purchasing power. Several empirical and technical studies, of which some have been acknowledged by international organizations, have prescribed that the reform might be supported by a direct compensation mechanism in order to raise the necessary public support and ensure feasibility.

This is what was done, for instance, during the recent energy subsidy reform in Iran. However, the compensation mechanism implemented in Iran's reform was successful at the beginning, but did not proceed as expected. This has raised questions about the feasibility and sustainability of the direct compensation mechanism, and even of the reform policy itself.

In this paper, we consider a model where direct compensation is the instrument proposed to restore consumers' utility against increased energy prices. We investigate the feasibility of a reform policy under such a compensation constraint, and we incorporate possible side effects of the reform on non-energy production costs. We find that, when prices of Other Goods are affected by the announced reform policy, the feasibility of a subsidy reform critically depends on the value of certain parameters: the initial subsidization rate, the energy intensity of the economy, and the expected side effects of the reform.

Key Words: Energy reform, consumption subsidies, direct compensation, welfare impact.

1 Introduction

An energy subsidy is defined as any regulation or government action that lowers the price paid by energy consumers, lowers the cost of energy production or raises the income received by energy producers (IEA 2014). Governments have been distributing subsidies through various actions, such as limits on market access or price, credit transfers, tax refunds or reductions, as well as trade restrictions. In this paper, we are focusing on subsidies that promote over consumption by reducing the price of energy paid by consumers.

Various voices spoken out in favor of cutting or modifying energy subsidies. An important example is the 2009 Group of Twenty Summit, where major economies committed to “reduce fossil-fuel subsidies while preventing adverse impact on the poorest” (World Bank 2010), a commitment that was emulated by Asia-Pacific Economic Cooperation leaders in the same year (Beaton et al. 2013). According to the 2014 *World Energy Outlook* (IEA 2014), at least 27 countries among the 40 fossil-fuel-subsidized economies have implemented partial reforms. Although such claims for reform have been established, the International Energy Agency’s (IEA) latest estimate (IEA 2014) indicates that, in 2013, the amount of world subsidies directed to fossil-fuel consumption alone is around \$550 billion. To offer a better understanding of the opportunity cost of such subsidies, this amount is more than four times higher than the amount of subsidies to renewable energies and four time higher than the amount invested globally to improve energy efficiency. According to an estimate by International Monetary Fund (Clements et al. 2013), simply removing energy consumption subsidies could result in a 13% decline in worldwide CO_2 emissions.

Governments’ main motivation for implementing a subsidy reform, aside from environmental considerations, is to increase national welfare by eliminating the gap between domestic and reference energy prices. As such, one of the first issues that must be addressed by an administrative body is determining a target level of regulated prices after a reform. The closer the current price approaches the reference price, the lower is the energy consumption in the domestic market, which both decreases national energy expenditures and mitigates local and global environmental damage. For instance, Pineau (2008) gives an example of a North American energy market where modifying regulated electricity prices could generate a substantial additional revenue, even if the consumption of low-income households were to remain almost unchanged. In the literature on carbon taxation, there are even more examples showing how redistributing the revenue of a reform may benefit low- and even middle-income citizens (see for instance Williams et al. (2014), who analyze the question for the U.S.; and Zhang & Baranzini (2004), who consider it more globally). Although the aforementioned publications document theoretical benefits from decreasing energy subsidies, there still exist several risk factors that may jeopardize the success of such a reform (see for instance Ellis 2010 and Clements et al. 2013).

One of the most important challenges is the implementation of a compensatory mechanism to win over the consumers (particularly from low-income households) to the reform. Indeed, in many energy-subsidized countries, the domestic prices of energy carriers are controlled directly by governmental bodies or their affiliated companies. In the absence of a competitive domestic market, cheap energy has been prevalently used for decades to foster public support. Such a persistent addiction cannot be resolved without a tranquilizer. Many researchers have suggested reinvesting the revenue derived from the reform into healthcare, education and green technologies, in order to increase national welfare (see for instance Laan & Beaton 2010). In that way, the benefits of a subsidy reform is anticipated to reach households, though probably with some delay. However, citizens are quite sensitive to energy pricing, and may not be sufficiently patient or confident to foresee the benefits of the policy makers’ plan. Another classical recommendation (Clements et al. 2013) is to redistribute a portion of the reform revenue directly to needy households, in order to protect their fragile purchasing power. Still, challenges remain in how to target such households and how to provide them with their compensation.

As partially reflected by Ellis (2010), energy consumption subsidies are particularly prevalent in developing countries, where there is no reliable and updated information infrastructure about household income. In addition, discrimination in compensatory paybacks may induce citizens to understate their income, or even provoke them into positioning themselves against the reform. In that context, a convenient solution may be a lump-sum direct deposit to all consumers, as proposed by Jensen and Tarr (2003). They claim, after

studying the case of Iran, that even if the reform revenue was redistributed equally among households, the average welfare would increase considerably. This claim was put to the test in the ambitious reform launched by Iran in December 2010, when the most energy-subsidized economy at that time decided to dramatically adjust its low-priced energy carriers. To avoid making the millions of low-income households suffer from this reform, the government committed to a direct deposit to all households, a provision that was also endorsed by international organizations (Moshiri 2015). The reform was accepted peacefully by all income classes, beyond even the most optimistic predictions. However, after a smooth beginning, a number of difficulties were encountered, and consequently, the second phase of the reform was temporarily postponed. These difficulties, ranging from an excessively large national budget deficit to extraordinary inflation and devaluation shocks, raised some significant doubts about the prescribed compensatory mechanism.

In this paper, we explore the net welfare effect of an energy subsidy reform using such a compensatory mechanism. Based on a partial equilibrium model, we analyze the feasibility and optimality of a price-adjustment reform accompanied by a lump-sum cash payment to all consumers to compensate them for the increase in their energy cost. We study three different scenarios, distinguished by the pricing policy of the suppliers of Other Goods (OG). In the first scenario, reform occurs in a single open economy in which the change in domestic energy price does not have any effect on the price of OG. In the second scenario, we assume that the reform does not have a side effect on non-energy production costs, but does affect the energy component of the production cost of OG. In the third scenario, we expand the reform's side effect to include non-energy-based production costs.

Findings in the literature on the impact of removing an energy subsidy in countries such as Iran conclude that the net welfare effect is positive, although different methods and assumptions are applied. A first category of models, as described in Birol et al. (1995), focuses on the price of energy goods in the domestic market and does not consider any potential impact on the price of non-energy goods. The authors simply assume that any energy saved due to a price increase can be exported to the global market and therefore results in a positive national welfare. This corresponds to our first scenario. A second group of papers, for example Jensen and Tarr (2003), incorporate an extra supply cost from the other sectors, based on the direct share of energy in the production cost; that is, the price of OG and services increases as a result of the reform only if the price of energy used during production increases. This corresponds to our second scenario. Finally, Saboohi (2011) assumes that an increase in energy prices may result in an expectation of inflation in the transportation sector, and that therefore, OG prices may increase beyond the extra energy-based cost of production. Our paper contributes to this literature by providing a unifying model where the various scenarios are characterized by parameter values. Moreover, we find that the net welfare effect of a reform is not necessarily positive, and derive the required conditions for a reform to be feasible.

The rest of the paper is organized as follows. Section 2 presents the partial equilibrium model used to represent an economy where the price of energy is subsidized (before and after a reform). The optimal reform ratio and the welfare implications of such a reform are analyzed under three contrasting scenarios in Sections 2.3, 2.1 and 2.2. Illustrative examples are provided in Section 3. Section 4 concludes.

2 Our model and its implications

There are several methods to address and quantify the impact of energy consumption subsidies. In this paper, similarly to international organizations such as the International Energy Agency (IEA), we use the price gap method. With this approach, a benchmark price is needed to estimate subsidies embedded in the market. According to Koplow (2009), two prevalent methods are used to determine reference prices: the export/import price, considered an opportunity cost, for easily traded fuels such as oil and gasoil; and the long-run marginal cost, for possibly non-traded energy carriers, such as electricity. In our model, we assume that the reference is the import/export price; this price is the opportunity cost of each energy unit that is consumed today but may be saved as a result of a potential reform, facilitating the evaluation of the immediate rewards from reducing energy subsidies.

The gap between a *reference price* (the amount that consumers should actually pay) and the *current price* (the subsidized price) is considered to be a subsidy for each unit of energy consumed. Within this model,

the ratio of the reference price over the current average consumer price is called the *subsidization rate*, which we denote by γ . In energy-subsidizing countries, $\gamma > 1$. Subsidization-rate data is regularly published by international organizations, such as the IEA.

Apart from the subsidization rate, a reform planner would take into account the sensitivity of the consumer expenditure bundle and of Other Goods production costs to energy prices. More precisely, define the following parameters:

- $\alpha \in (0, 1)$: share of energy in the expenditure bundle of a representative consumer;
- μ : average amount of domestic energy required for the production of one unit of OG;
- π : non-domestic-energy part of the marginal production cost of OG.

Using this information, the reform planner decides on the new price of energy, or on the *reform ratio*, which is defined in our model as the ratio of the reformed price over the current price of energy. This decision happens under the constraint of a direct deposit to consumers that keeps their utility unchanged before and after the price reform.

Consider a small open economy including a typical consumer who maximizes his utility over the consumption of energy and OG, a governmental energy provider, and a supplier of OG in a fully competitive market. The consumer maximizes his utility, given by

$$u(E, G) = E^\alpha G^{1-\alpha},$$

under the budget constraint

$$Ep + Gg \leq r$$

where

E : energy consumption

G : OG consumption

r : income

p : price of energy

g : price of OG.

The solution of the representative consumer's optimization problem yields

$$E^* = \frac{\alpha r}{p}; G^* = \frac{(1-\alpha)r}{g} \quad (1)$$

where it is apparent that the consumer allocates a share α of his expenditure bundle to energy.

In the sequel, we consider two situations indexed by $i \in \{0, 1\}$ where $i = 0$ corresponds to an initial situation where the price of energy is subsidized, while $i = 1$ corresponds to the situation after a reform consisting of an increase in the price of energy in the domestic market. We denote by p_i , g_i , π_i and r_i , respectively, the price of energy, the price of OG, the non-energy production cost of OG and the consumer income in scenario i , and by E_i , G_i and $U_i = u(E_i, G_i)$ the corresponding optimal energy consumption, OG consumption and utility.

Denote by \bar{p} the international (reference) price of energy, and assume that the price of energy before the reform is $p_0 = \frac{\bar{p}}{\gamma}$, where $\gamma > 1$ is the energy subsidization rate. Assume that the government decides to increase the price of energy in the domestic market to $p_1 = \kappa p_0 = \frac{\kappa}{\gamma} \bar{p}$, where the constant $\kappa \in (1, \gamma]$ defines the *reform ratio*. The rationale of such a reform could be to increase energy exports or to decrease the cost of energy imports. Here we assume that this increase in the price of energy may have an impact on the price of OG, so that $g_1 = m g_0$ with $m \geq 1$. Clearly, the utility of consumers would be negatively affected by an increase in the prices of energy and OG. We assume that, to compensate for the utility reduction, the government plans a direct subsidy program, allocating an additional amount to the consumer's income, that is, $r_1 = c r_0$ where $c > 1$ is the *compensation ratio*.

We then have, according to (1),

$$E_0 = \frac{\alpha r_0}{p_0}; G_0 = \frac{(1 - \alpha) r_0}{g_0} \quad (2)$$

$$E_1 = c \frac{E_0}{\kappa}; G_1 = c \frac{G_0}{m} \quad (3)$$

$$\frac{U_0}{U_1} = \frac{\kappa^\alpha m^{1-\alpha}}{c}. \quad (4)$$

If the government uses the direct subsidy program to restore the consumer's utility to its pre-reform level, then the compensation ratio should satisfy

$$c = \kappa^\alpha m^{1-\alpha}. \quad (5)$$

Equation (5) links the parameters controlling the government subsidy programs. Having set the desired energy price by deciding on κ , the government can determine the necessary direct-subsidy budget to keep the consumer's utility unchanged during the reform. We now evaluate such a reform by determining its impact on the national welfare.

The increase in the domestic price of energy would change the national total energy consumption, that is, both the household consumption E , and the producers' consumption μG , where μ represents the average amount of (domestic) energy required for the production of one unit of OG. The net opportunity cost of one unit of energy for the government is $\bar{p} - p_i$; hence, assuming a decrease in total energy consumption, the government revenue would be impacted by the reform in two ways: a decrease in import costs (or an increase in export revenues), and a change in domestic energy revenue (higher-cost energy times reduced consumption). Accounting for the direct subsidy cost, the net change in government revenues as a function of the reform ratio κ is then

$$\begin{aligned} w(\kappa) &= (p_1 - \bar{p})(E_1 + \mu G_1) - (p_0 - \bar{p})(E_0 + \mu G_0) - (r_1 - r_0) \\ &= (\kappa p_0 - \gamma p_0) \left(\frac{c}{\kappa} \frac{\alpha r_0}{p_0} + \frac{c \mu}{m} \frac{(1 - \alpha) r_0}{g_0} \right) - (p_0 - \gamma p_0) \left(\frac{\alpha r_0}{p_0} + \mu \frac{(1 - \alpha) r_0}{g_0} \right) - (c r_0 - r_0) \\ &= r_0 \left(1 + \alpha(\gamma - 1) + \theta(\gamma - 1)(1 - \alpha) + \kappa^\alpha m^{1-\alpha} \left(\theta \frac{(1 - \alpha)(\kappa - \gamma)}{m} + \frac{\alpha(\kappa - \gamma)}{\kappa} - 1 \right) \right) \end{aligned} \quad (6)$$

where $\theta \equiv \mu \frac{p_0}{g_0} < 1$.¹

We want to determine, for a given energy subsidization rate γ , whether or not a reform policy where consumers are compensated (characterized by the reform ratio κ) would have a net positive impact on government revenues.

2.1 Reform with a fixed OG price

We first assume that $m = 1$, as in Birol et al. (1995). In that case, the direct subsidy $c = \kappa^\alpha$ and Equation (3) yields

$$E_1 = \kappa^{\alpha-1} E_0; G_1 = \kappa^\alpha G_0.$$

Using (6), the value of the reform as a function of the reform ratio is then

$$\begin{aligned} w(\kappa) &= r_0 \left(1 + \alpha(\gamma - 1) + \theta(\gamma - 1)(1 - \alpha) + \kappa^\alpha \left(\theta(1 - \alpha)(\kappa - \gamma) + \frac{\alpha(\kappa - \gamma)}{\kappa} - 1 \right) \right) \\ &= r_0 \left(1 + \alpha(\gamma - 1) - \kappa^{\alpha-1}(\alpha(\gamma - \kappa) + \kappa) + \theta(1 - \alpha)(\gamma - 1 - \kappa^\alpha(\gamma - \kappa)) \right) \end{aligned}$$

where κ may take any value in the interval $(1, \gamma]$, and where $\kappa = \gamma$ corresponds to removing all subsidies and fixing the energy price to the reference price.

¹This dimensionless parameter represents the domestic energy cost to produce \$1 of OG.

Compute the difference

$$\frac{w(\gamma) - w(\kappa)}{r_0} = \alpha\kappa^{\alpha-1}\gamma - \gamma^\alpha + \kappa^\alpha(1-\alpha)(1 + \theta(\gamma - \kappa)).$$

Notice that, for any constant T and for $\alpha < 1$ and $\gamma > 1$, $T\alpha\gamma - \gamma^\alpha$ is a convex function of γ admitting a global minimum at $\gamma = T^{\frac{1}{\alpha-1}}$. Therefore, $\alpha\kappa^{\alpha-1}\gamma - \gamma^\alpha$ is bounded below by $-\kappa^\alpha(1-\alpha)$, and consequently $\frac{w(\gamma) - w(\kappa)}{r_0} > 0$ for all $\kappa \in (1, \gamma]$. It is therefore optimal for a government to, among all possible reforms, remove all subsidies by setting the reform ratio equal to the subsidization rate. Moreover, since $w(\gamma) - w(1) > 0$, removing all subsidies would be welfare enhancing, which is not necessarily true for any reform ratio κ .²

Notice however that when $\theta = 0$, that is, when no domestic energy is used to produce OG, the function $w(\kappa)$ is non-decreasing in κ ,

$$w'(\kappa) = r_0\kappa^{\alpha-2}\alpha(1-\alpha)(\gamma - \kappa) \geq 0,$$

meaning that any reform towards the reference price, with full consumer compensation, would be welfare enhancing with respect to the current situation ($\kappa = 1$).

To conclude, according to the assumptions in this first scenario, a government should remove all subsidies, and this reform would be welfare enhancing, increasing the revenues of the government while preserving the utility of the representative consumer. This analysis is performed under the assumption that the price of OG is not affected by an increase in the price of domestic energy. This can be true if there is a perfect competitive market in a small open economy, where any excess demand of OG is immediately satisfied with no change in the marginal cost of producers. However, this assumption may be unrealistic, and one may anticipate that an increase in the domestic price of energy would trigger an increase of the price of OG. Indeed:

- The price of a wide range of crucial services and products is directly linked to the price of energy. Transportation is a typical example. A counter example would be a case where the increase in the price of domestic energy would be directed solely to households, while OG producers would continue to receive a subsidy. This however is probably not a plausible scenario due to huge administration costs, expensive infrastructures and high corruption risks.
- Energy subsidies are more prevalent in developing countries and natural-resource-dominant economies (Birol et al. 1995). Such countries usually suffer from many structural problems, such as barriers against foreign trade and lack of competitiveness in the domestic market, which consequently cause a weaker supply side.

Accordingly, in the following two sections, we consider more realistic scenarios, where an increase in the price of energy triggers an increase in the price of OG.

2.2 Increased production cost of OG due to their energy component

In this second scenario, as in Jensen and Tarr (2003), we assume an increase in the price of OG based on the direct share of domestic energy in their production cost. If the price of OG is set to the marginal production cost, we then have

$$g = \pi + p\mu,$$

where we assume that the cost π_0 of other production factors is unaffected by the reform. Accordingly, the price of OG before and after the reform is given by

$$\begin{aligned} g_0 &= \pi_0 + p_0\mu \\ g_1 &= \pi_0 + \kappa p_0\mu \\ &= g_0 + \mu p_0(\kappa - 1) \end{aligned}$$

²For extreme situations where γ, α and θ are very high, there exists a range of values for κ where a reform is not welfare enhancing.

so that

$$m = \frac{g_1}{g_0} = 1 + \theta(\kappa - 1) > 1. \quad (7)$$

We then have, using (6),

$$\frac{w(\kappa)}{r_0} = 1 + (\gamma - 1)(\theta(1 - \alpha) + \alpha) + \kappa^\alpha (1 + \theta(\kappa - 1))^{1-\alpha} \left(\theta \frac{(1 - \alpha)(\kappa - \gamma)}{1 + \theta(\kappa - 1)} + \frac{\alpha(\kappa - \gamma)}{\kappa} - 1 \right).$$

Differentiating with respect to the reform rate yields

$$w'(\kappa) = r_0 \alpha \kappa^{\alpha-2} (1 - \theta)^2 (1 - \alpha) \frac{(\gamma - \kappa)}{(\theta(\kappa - 1) + 1)^{\alpha+1}}, \quad (8)$$

which is positive for any $\kappa < \gamma$, indicating that the optimal reform consists of fixing $\kappa = \gamma$, as in the preceding section, and that any reform ratio $\kappa > 1$ is welfare increasing.

2.3 Increase of non-energy production cost of OG

In this third scenario, we assume a side effect of the reform on the non-energy cost of producing OG. This could be caused by inflationary expectations about the price of other production factors, such as labor and capital, or simply by a history-based common belief, as mentioned in Saboohi (2001) and Moshiri (2015).

Accordingly, assume an impact of the reform on the non-energy production cost characterized by a parameter $\lambda > 1$, such that

$$g_1 = \pi_1 + p_1 \mu = \lambda \pi_0 + \kappa p_0 \mu = \lambda g_0 + \mu p_0 (\kappa - \lambda)$$

and consequently,

$$m = \frac{g_1}{g_0} = \kappa \theta + \lambda (1 - \theta).$$

If this increase in the production cost is a result of the reform, it would be reasonable to assume that its magnitude is related to the severity of the reform. We therefore assume that the increase in the non-energy production cost is proportional to the increase in the domestic energy price, that is,

$$\begin{aligned} \lambda &= 1 + \delta(\kappa - 1) \\ m &= \kappa \theta + (1 - \theta)(1 + \delta(\kappa - 1)) \end{aligned} \quad (9)$$

where the *dilatation factor* δ is strictly positive (we would also expect that $\delta < 1$, that is, that the increase in non-energy costs should be less than the increase in the energy price).

We then have, using (6),

$$\begin{aligned} \frac{w(\kappa)}{r_0} &= (1 + \alpha(\gamma - 1) + \theta(\gamma - 1)(1 - \alpha)) \\ &\quad + \kappa^\alpha (\kappa \theta + (1 - \theta)(1 + \delta(\kappa - 1)))^{1-\alpha} \left(\theta \frac{(1 - \alpha)(\kappa - \gamma)}{\kappa \theta + (1 - \theta)(1 + \delta(\kappa - 1))} + \frac{\alpha(\kappa - \gamma)}{\kappa} - 1 \right) \end{aligned}$$

and

$$\begin{aligned} \frac{w'(\kappa)}{r_0} &= \frac{\kappa^{\alpha-2} (1 - \alpha) (1 - \theta)}{m^{\alpha+1}} \left(\alpha \lambda (1 - \delta) (\gamma - \kappa) (1 - \theta) - \kappa^2 m \delta \right) \\ &= \frac{\kappa^{\alpha-2} (1 - \alpha) (1 - \theta)}{m^{\alpha+1}} D(\delta) \end{aligned}$$

where

$$\begin{aligned} D(\delta) &= \alpha (1 + \delta(\kappa - 1)) (1 - \delta) (\gamma - \kappa) (1 - \theta) - \kappa^2 (\kappa \theta + (1 - \theta)(1 + \delta(\kappa - 1))) \delta \\ &= -\delta^2 (\kappa - 1) (1 - \theta) (\alpha (\gamma - \kappa) + \kappa^2) \\ &\quad + \delta (\alpha (1 - \theta) (\kappa - 2) (\gamma - \kappa) - \kappa^2 (1 + \theta(\kappa - 1))) + \alpha (1 - \theta) (\gamma - \kappa). \end{aligned}$$

We now show that if $\delta \geq \delta^*$ where

$$\delta^* = \frac{\alpha(1-\theta)(\gamma-1)}{\alpha(1-\theta)(\gamma-1)+1} < 1, \quad (10)$$

then $D(\delta) < 0$ for any $\kappa \in (1, \gamma]$, so that $w'(\kappa) < 0$ for all $\kappa \in (1, \gamma]$ and no reform can be welfare enhancing. Notice that D is a concave quadratic function of δ , with $D(0) \geq 0$ and $D(1) < 0$ for fixed $\kappa \in (1, \gamma]$. This means that, for a given reform ratio, $D(\delta)$ is negative for all $\delta \geq 1$ and is positive if δ is sufficiently small. Assume that $\delta \in [\delta^*, 1)$. We then have

$$\begin{aligned} D(\delta) &= -\delta^2(\kappa-1)(1-\theta)(\alpha(\gamma-\kappa)+\kappa^2) - \delta(\alpha(1-\theta)(\gamma-\kappa)+\kappa^2(1+\theta(\kappa-1))) \\ &\quad + \alpha(\delta(\kappa-1)+1)(\gamma-\kappa)(1-\theta) \\ &< -(\delta^*)^2(\kappa-1)(1-\theta)(\alpha(\gamma-\kappa)+\kappa^2) - \delta^*(\alpha(1-\theta)(\gamma-\kappa)+\kappa^2(1+\theta(\kappa-1))) \\ &\quad + \alpha((\kappa-1)+1)(\gamma-\kappa)(1-\theta) \\ &= \frac{\alpha(\kappa-1)(1-\theta)}{(\alpha(\gamma-1)(1-\theta)+1)^2} (-\kappa^2(\gamma-1)(\theta+\alpha(\gamma-1)(1-\theta)) \\ &\quad - \kappa(\alpha(\gamma-1)(\gamma+1)(1-\theta)+\gamma) + \alpha\gamma(\gamma-1)(1-\theta)) \\ &< \alpha(\kappa-1)(1-\theta) \frac{(\gamma-1)(-\theta-\alpha\gamma(1-\theta))-\gamma}{(\alpha(\gamma-1)(1-\theta)+1)^2} < 0. \end{aligned}$$

On the other hand, if $\delta < \delta^*$, then

$$\begin{aligned} \frac{w'(1)}{r_0} &= -\delta(1-\theta)(1-\alpha)(\alpha(\gamma-1)(1-\theta)+1) + \alpha(1-\theta)^2(1-\alpha)(\gamma-1) \\ &> -\delta^*(1-\theta)(1-\alpha)(\alpha(\gamma-1)(1-\theta)+1) + \alpha(1-\theta)^2(1-\alpha)(\gamma-1) \\ &= 0, \end{aligned}$$

which means that there exist reform ratios in $(1, \gamma)$ such that the reform is welfare improving. If this is the case, then the reform ratio maximizing the net gain $w(\kappa)$ will achieve a positive result. Notice that

$$\frac{w'(\gamma)}{r_0} = -\frac{\gamma^\alpha}{m^\alpha} (1-\alpha)(1-\theta)\delta$$

which indicates that removing all subsidies is not optimal. The optimal reform is obtained by solving the FOC $w'(\kappa) = 0$, which has at least one solution in $(1, \gamma)$ since the function w is increasing at 1 and decreasing at γ . The FOC yields the following cubic equation for κ :

$$\begin{aligned} &-\kappa^3\delta(\delta+\theta(1-\delta)) - \kappa^2\delta(1-\delta)(\alpha+1)(1-\theta) \\ &-\alpha\kappa(1-\theta)(1-\delta)(1-\delta-\gamma\delta) + \alpha\gamma(1-\theta)(1-\delta)^2 = 0. \end{aligned}$$

As an illustrative example, assume that $\alpha = 0.0345$, $\theta = 0.25$ and $\gamma = 5$. The threshold value for the dilatation factor from (10) is then 0.094; Accordingly, if the increase in the non-energy production cost of OG is larger than 9.4% of the increase in domestic energy prices, then no feasible reform exists (any reform will decrease the government's revenue). If the dilatation factor is less than 9.4%, then there exists an optimal and feasible reform policy. Figure 1 is a plot of the function $w(\kappa)$ for various values of δ . For $\delta = 1\%$, we find that the optimal reform would be to increase the energy price to 2.3 times its initial subsidized level, while for $\delta = 5\%$, the optimal reform would be to increase the energy price by 30%.

3 Empirical evidence

In this section, we use our model to analyze the case of the Iranian reform, and then compare the threshold values of the dilatation factor in various countries where energy prices are subsidized.

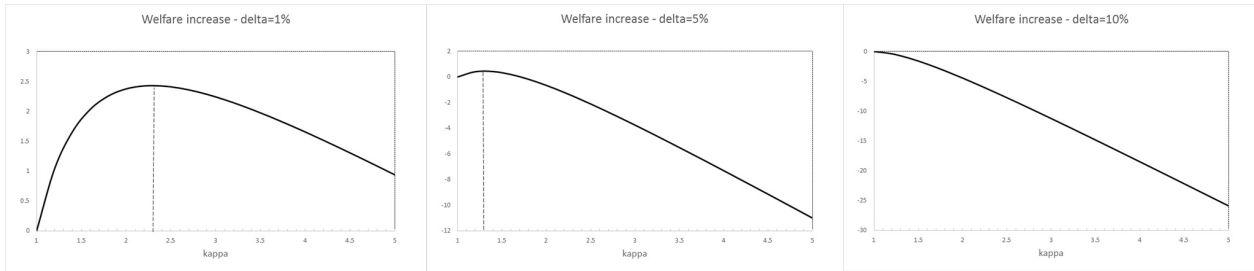


Figure 1: Net change in government revenue from a reform as a function of the reform ratio κ and of the inflationary factor δ . Parameter values are $\alpha = 0.0345$, $\theta = 0.25$ and $\gamma = 5$. Welfare is expressed in percentage of consumer income.

Iran, which had traditionally subsidized energy prices up to more than 80%, launched an ambitious reform plan in late 2010. The initial plan was designed to phase out almost all energy subsidies in successive steps over 5 years. In the first phase, the price of the main energy carriers was increased sharply. For instance, the average price of gasoline more than doubled, although it remained far from the import price at the Iranian border.³ The plan, which was accompanied by a compensatory payment in the form of a direct deposit to all households, proceeded well at the beginning. However, Iran faced some major devaluation and inflationary shocks following this first step, and the second phase of the reform was suspended by authorities.

The potential inflationary impact of the reform was at the center of public debate before the initiation of the Iranian reform. While the government was underestimating (almost neglecting) such effects, Iran's parliamentary research center announced that the inflation rate might reach up to 50% after the reform. In its analysis of the national budget (Maleki 2010), this research center predicted a 37.6% increase in the price of goods due to the inflationary impact of the reform.

Table 1 presents estimated values for the parameters of our model for the case of Iran in 2010. Using these parameter values, the feasibility threshold for the dilatation factor is $\delta^* = 9.4\%$. The government's optimistic view ($\delta = 0$) corresponds to our second scenario, described in Section 2.2. According to this scenario, using (7) and the parameter values in Table 1, the increase factor for OG prices would have been $m = 1.25$. On

Table 1: Parameter values for the Iranian economy in 2010.

| Parameter | Estimated value | Computation | Source |
|-------------------|------------------------------|--------------------------------------|---|
| γ | 5 | $\gamma = \frac{p_0}{\bar{p}}$ | IEA (2010): $\frac{\bar{p}-p_0}{\bar{p}} = 80\%$ |
| r_0 | 419.118 (\$10 ⁹) | | IMF (2013): GDP (2010) in current prices |
| κ | 2 | | Iranian newspapers (see Footnote 3) |
| α | 0.0345 | $\alpha = 0.7\alpha_u + 0.3\alpha_r$ | Iranian Ministry of Energy (2011): $\alpha_{urban} = 3\%$, $\alpha_{rural} = 4.5\%$; Proportion of urban households = 70% |
| $\frac{\mu}{g_0}$ | 0.998 kg-oe/\$ | | US EIA (2015): Energy intensity |
| E_0 | 58.127 MT-oe | $E_0 = 37\% \times 157.1$ | Iranian Ministry of Energy (2011): Total energy consumption=157.1 MT-oe; share of household sector=37% |
| p_0 | 0.2488 \$/kg-oe | $p_0 = \frac{\alpha r_0}{E_0}$ | Equation (1) |
| θ | 0.25 | $\theta = p \frac{\mu}{g_0}$ | |

³More specifically, gasoline was sold under a two-tariff pricing at that time: during the first phase of the reform, the lower price (for a quota of 60 litres allocated to eligible vehicles) was multiplied by 4, while the higher price was multiplied by 1.75. See Reza-Farzin et al. (2011) for more details.

the other hand, the pessimistic estimation of Iran's parliament ($m \simeq 1.376$) is captured in our third scenario, described in Section 2.2; using (9), this would correspond to a dilatation factor of $\delta = 17\%$.

Figure 2 represents the welfare impact of a reform, as a function of the reform ratio, for both sets of assumptions. If one assumes that $\delta = 0$, a surplus is anticipated after compensating the consumers for all possible reform ratios; on the other hand, if one assumes that $\delta = 17\%$, a deficit is anticipated for all possible reform ratios.

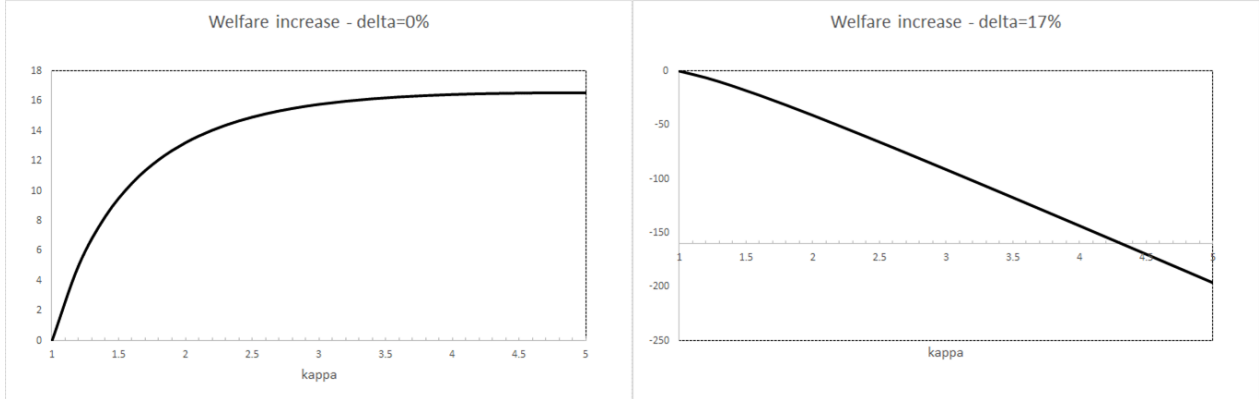


Figure 2: Welfare impact as a function of κ under two different assumptions for the inflationary factor δ . Parameter values are those of Table 1.

With hindsight, the optimistic assumption of $\delta = 0$ is shown to have been wrong. According to various unofficial sources, the Iranian economy suffered a deficit of around \$18 billion in the first year of the reform (the deficit might in fact have been dramatically more than that, but was partly covered up by the reformist government). With $\delta = 17\%$, which corresponds to a 37.6% increase in the price of other goods, our model predicts a net deficit of \$41 billion for $\kappa = 2$. This amount is around twice the observed deficit, which may partially reflect an overestimation of the increase in prices by the reporting authority. To obtain a deficit of \$18 billion with our model, δ should be set at 9.8%, which is still beyond the feasibility threshold of 9.4%. This finding is consistent with the temporary suspension of the reform, as there would be no room for a feasible policy under such side effects.

The threshold value of the dilatation factor δ is increasing in γ and α and decreasing in θ . Table 2 presents the threshold values of the parameter δ for various countries, based on their subsidization rate in 2013, as reported by the IEA, under two contrasting assumptions about the values of the parameters α and θ . One notices that, for a majority of countries, a feasible reform policy accompanied by full compensation is dramatically limited by its potential indirect effect on non-energy production factors. The three big oil exporters—Algeria, Saudi Arabia and Venezuela—are exceptions, as they have more manoeuvring room to look for a feasible reform policy.

Table 2: Subsidization rate and dilatation factor threshold values under different assumptions for α and θ .

| Country | γ | Threshold δ | |
|--------------|----------|-------------------------------|--------------------------------|
| | | $\alpha = 0.05, \theta = 0.1$ | $\alpha = 0.03, \theta = 0.25$ |
| Algeria | 4.44 | 13.42% | 7.19% |
| Argentina | 1.42 | 1.86% | 0.94% |
| China | 1.03 | 0.12% | 0.06% |
| India | 1.25 | 1.11% | 0.56% |
| Indonesia | 1.46 | 2.01% | 1.01% |
| Iran | 4.37 | 13.16% | 7.04% |
| Nigeria | 1.40 | 1.79% | 0.90% |
| Russia | 1.26 | 1.15% | 0.58% |
| Saudi Arabia | 4.41 | 13.29% | 7.12% |
| Venezuela | 13.70 | 36.36% | 22.22% |

4 Conclusion

By introducing a model composed of a reformist regulator, a typical consumer and a supplier of other goods, we reaffirmed the claim that a reform of energy consumption subsidies accompanied by direct compensation to the consumer may result in a net positive welfare in the case where the reform would have no indirect impact on non-energy production costs. We also show that it is then optimal for the regulator to reduce the price gap to zero.

However, if we incorporate some structural properties of subsidized economies, such as inflationary expectations, these results do not hold. More specifically, we show that if the reform has a side effect on the non-energy costs of producing OG, proportional to the extent of the price-gap reduction, the feasibility of the reform is limited to a range of values for the non-energy dilatation factor. The upper bound for the dilatation factor depends on the share of energy in the expenditure bundle of consumers, the energy intensity of suppliers and the economy's initial energy-subsidization rate.

In an economy where the indirect effect of reform on the price of OG is estimated to be less than this threshold, there exists an optimal reform ratio, which is feasible, and does not consist of reducing the price gap to zero.

On the other hand, in an economy where this indirect effect is estimated to be higher than the threshold, no reform with universal direct compensation is feasible. One possible avenue for the regulator could be to devise a robust mechanism to compensate only the lower-income households in order to decrease the cost of the reform. Another possibility would be to find means to reduce the indirect impact of the reform on the supply of OG, such as, for instance, reducing the import barriers and tariffs for OG.

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