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The Value of Saving Oil in Saudi Arabia

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Key Points

What is the value of saving a barrel of oil that would otherwise had been consumed domestically? This study explores the question, taking a long-run perspective into a general equilibrium approach. In the case of Saudi Arabia, the difference between the domestic price of oil and the international price represents an opportunity to improve economic efficiency across different activities and sectors. In this context, we study different policies aimed to reduce the domestic consumption of oil. The analysis of these policies leads to the following results:

- Policies designed to curb oil consumption have positive impacts on welfare and carbon emissions, although the cost of the policies and their impact on productivity are critical.

- Welfare gains range between $6 and $56 per barrel of oil saved, depending on the policy. This range takes into account the potential decrease in the international price ($53 per barrel in this study) due to the increase in Saudi exports.

- Some of the policies studied are difficult to escalate and, therefore, the amount of oil saved is relatively small. Deploying renewable energy, shifting power generation from oil to natural gas and increasing the administered price of oil are policies that can save a significant amount of oil.

- Increasing domestic prices of energy has a positive impact on households' welfare. The growth in net public transfers to households offsets the negative impact of the energy price increase.

Summary for Policymakers

The instinctive answer to the question "What is the value of a barrel of oil saved in Saudi Arabia and instead exported?" is "The international market price." For oil saved from domestic consumption, this answer is incomplete for the following reasons:

- The rest-of-the-world demand for Saudi oil is not perfectly elastic, which impacts the revenues from exporting the oil saved.
- Domestic agents buy oil below the international price at a price set by the government, potentially leaving room for improving economic efficiency by saving oil.
- There are different ways to reduce the domestic consumption of oil.

This study analyses different policies that aim to reduce domestic consumption of oil in the long run and, thus, increase oil exports. The following policies are studied:

- Displacing oil by increasing the share of natural gas in electricity generation.
- Increasing the efficiency of natural gas power plants.
- Deploying renewable technology to displace oil.
- Increasing the administered price of oil.
- Implementing electricity efficiency programs.
- Increasing the fuel efficiency of the transportation sector.

To explore the long-run impact of these policies we develop a small open economy general equilibrium model for Saudi Arabia. In all the cases the increase in net public revenues resulting from these policies is transferred to households. The analysis of these policies leads to the following results:

- Policies designed to curb oil consumption positively impact households' welfare and help reduce Saudi carbon emissions. However the costs of these policies and their impact on productivity are critical.
- The decrease of the international price of oil, due to the increase in oil exports, reduces the potential welfare gain from these policies.
- Policies aimed to increase energy efficiency have limited scalability and, consequently, the potential positive macroeconomic impacts are relatively small.
- The increase in administered oil prices has potentially the largest impact on domestic demand of oil, on carbon emissions and on oil exports. Although increases in energy prices harm households' welfare, the growth in net public transfers to households offsets this negative impact.
- Shifting power generation from oil to natural gas has a positive impact on the Saudi economy, even if the natural gas is imported.
- The gross welfare gains of energy efficiency projects, in electricity usage or transportation, are greater than those aimed at shifting from oil power generation to natural gas or renewables. However, energy efficiency projects tend to be more expensive than those to reduce oil in power generation.

> Welfare gains for all the policies studied range between a minimum of $6 and $56 per barrel of oil saved. These policies — excluding one that increases the share of natural gas in the generation mix — reduce the level of domestic CO_2 emissions by around 370 kilograms (kg) per barrel saved.

We simulate the increase in administered prices of gasoline and electricity in January 2018. The simulations show that this policy would increase oil exports by 724000 barrels per day (bbl/d) and welfare by $2.6 billion annually in the long run. It would also reduce CO_2 emissions by 97 million tons annually.

This study is part of a larger KAPSARC initiative to inform economic decision-making in Saudi Arabia with estimates for the opportunity costs of using domestic resources, especially oil and natural gas. More generally, the initiative will deliver a framework for evaluating public investment projects that takes into account the specific characteristics of the Saudi economy.

Introduction

The Kingdom of Saudi Arabia is the largest oil exporting country and, at the same time, has one of the highest levels of oil consumption per capita – 45 barrels per year compared to 22 in the U.S. and 11 in Germany. One factor driving this high level of consumption is the low administered prices of domestic oil and oil products, also the primary sources for generating electricity in Saudi Arabia (Electricity and Cogeneration Regulatory Authority 2014). Partly in recognition of this and in order to curb domestic oil consumption, Saudi Arabia raised the price of 91- and 95-octane gasoline by about 67% and 50%, respectively in 2016 and, again, in January 2018 by about 80% and 125% respectively. Saudi Arabia also raised electricity prices for households and industries in 2016 (Council of Ministers' Decree December 28th, 2015) and, again, in January 2018 (Council of Ministers' Decree December 12th, 2017). The size of these increases in some cases exceeded 200 percent, depending on the level of households' electricity consumption. Saudi Arabia launched the National Renewable Energy Program to facilitate a shift in generation from fossil fuel to renewable technology, with the aim of achieving 9.5 gigawatt (GW) of installed capacity by 2023 (Renewable Energy Project Development Office 2017).

Taking a long run perspective and a general equilibrium approach, this study attempts to answer the question "What is the value of a barrel of oil saved and instead exported?" For a textbook economy, the marginal productivity of a barrel of oil across all activities and sectors would be identical and equal to its market price. For Saudi Arabia, this implies that its marginal productivity would be expected to be lower than the international price, given the lower administered domestic prices of oil. The difference between domestic and international prices provides a means by which the Kingdom can allocate oil more efficiently among different activities and sectors. This study is part of a larger KAPSARC initiative to inform economic decision-making in Saudi Arabia with estimates for the opportunity costs of using domestic resources, especially oil and natural gas. More generally, the initiative will contribute to delivering a framework for evaluating public investment projects that takes into account the specific characteristics of the Saudi economy.

This study analyses different policies that would reduce domestic consumption of oil and thus increase oil exports. It is important to highlight that for all the policies analyzed, the increase in net public revenues — due to the higher level of oil exports — is transferred directly to households to increase social welfare. The following policies are analyzed: increasing the share of natural gas in electricity generation; increasing the efficiency of natural gas power plants; deploying renewable technology; increasing the administered price of oil; implementing electricity efficiency programs; increasing the fuel efficiency of the transportation sector; and — for the sake of completeness — increasing directly the production of oil.

To explore the impact of these policies at a macroeconomic level we use and extend the small open economy dynamic general equilibrium model for Saudi Arabia introduced by Blazquez et al. (2017). Saudi Arabia is a critical player in the international oil market and changes to its production or exporting policy can cause a market reaction. Because of this, we expand the model by adding an oil price reaction function that links Saudi exports and international prices. Some previous studies tackle the role of Saudi Arabia in determining international oil prices and oil price volatility, such as De Santis (2003) and Nakov and Nuño (2013). More recently, Pierru et al. (2018) evaluated the impact of Saudi spare capacity on the international oil price. Furthermore, we adapt the model to explore the potential macroeconomic gains from efficiency improvements in the use of electricity and oil products. Atalla et al. (2017) conducted a partial equilibrium analysis to estimate the potential net welfare gain from the Saudi gasoline price increase in 2016.

Dynamic general equilibrium models (as used here) are becoming increasingly popular as research tools in energy economics. Such models have been used to analyze the macroeconomic effects of energy price shocks (Kim and Loungani 1992; Rotemberg and Woodford 1996) to understand the impact of fossil fuel subsidies in economies (Plante 2014; Lin and Li 2012; Schwanitz et al. 2014), and to analyze optimal policies (De Miguel and Manzano 2006 and Golosov et al. 2014). Nevertheless, previous research has seldom specifically examined Saudi Arabia using macroeconomic models, other than Blazquez et al. (2017) who analyze renewable energy development and energy pricing policies using a dynamic general equilibrium model, and Gonand (2016) who analyzes the impact of higher energy efficiency using an intergenerational macro model. Moreover, as far as we are aware, no previous effort has been made to analyze the different policy initiatives in Saudi Arabia explicitly aimed at saving oil in order to increase exports, which we attempt here.

The Model

The model used in this study extends a general equilibrium model for a small open economy calibrated for Saudi Arabia, as detailed in Blazquez et al. (2017). The model has a representative infinitely-lived household that consumes final goods and energy services. The household offers labor inelastically in the domestic labor market and saves in domestic and foreign bonds. The Saudi Arabian government owns the primary energy resources in this economy: oil and natural gas, with oil production allocated to electricity generation for the domestic market, used to produce energy services or exported. The government runs a balanced budget, transferring the net revenues to the household. The administered domestic prices of oil are below the international price of oil. Natural gas production — net of demand in industries with allocations — is sold domestically to the electricity company at an administered price.

Furthermore, in the Blazquez et al. (2017) model, the Saudi Arabian government owns the electricity company, which uses oil, natural gas, and renewable energy to produce electricity that it then sells to a competitive energy services firm. In the model, the price of electricity for consumers is fixed to cover the costs, so there is no profit or loss. The energy services firm uses oil and electricity to produce energy services and sells the services to the household and to a firm representing the rest of the economy that produces final goods and services. This representative firm uses labor, capital, and energy services to produce final goods and services that are sold to the household and, potentially, in international markets. There is also an international market for bonds that allow the Saudi Arabian economy to run a current deficit or surplus. Figure 1 shows a graphical representation of the model.

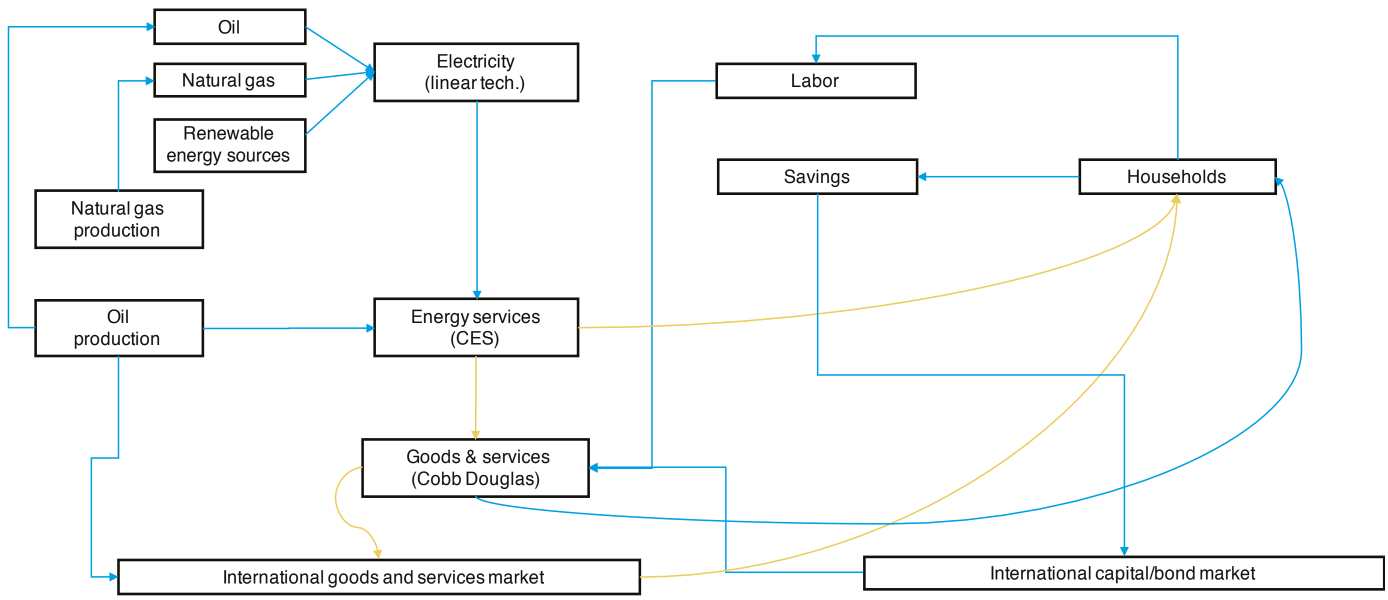

Figure 1. The model.

Source: KAPSARC analysis.

We have expanded the Blazquez et al. (2017) model in four main directions. First, we have treated the production of oil and natural gas as policy variables that can be changed. Second, the technical efficiency of natural gas power plants can be improved at a cost. Third, the energy service firm can increase the productivity of oil and electricity at a cost. Finally, we have added an international price oil response function to the model, linking the international price of oil to Saudi exports.

The appendix describes the extensions to the Blazquez et al. (2017) model and specifies how it implements the different policies.

Policies to Save and Export Additional Barrels of Oil

In this section, we describe the policies considered in the analysis; in particular, policies to reduce the use of oil in Saudi Arabia and lead to an increase in oil exports and, for the sake of completeness, an increase in oil production. A description of the policies considered precedes a discussion on the technical feasibility of scaling these policies from one barrel per day (bbl/d). In all the policies, we assume the following: first, exported oil is sold at the international price; second, the government directly finances the cost of each policy; third, the extra revenues from oil exports are transferred to households as a lump-sum transfer; and fourth, the policy is sustained over time. The policies considered are as follows:

Policy 1. Increasing the production of oil

Arguably, this is the most obvious policy that Saudi policymakers would consider in order to increase oil exports. However, as Saudi Arabia is a member of OPEC the other members of the organization have to agree with any change in Saudi production. The cost of this policy would be the additional investments and operational expenses needed to produce more oil, keeping the existing spare capacity at the same level. The cost of the policy would be $9.3 per barrel. This figure comes from Wall Street Journal (2016) estimates based on UCube: Rystad Energy's oil and natural gas database.

Policy 2. Increasing the share of natural gas to generate electricity

Electricity generation in Saudi Arabia currently relies heavily on oil. According to the Electricity and Cogeneration Regulatory Authority (2015), crude oil and oil products accounted for 68 percent of total electricity generated in Saudi Arabia. This policy recommends that Saudi Arabia imports natural gas, liquefied natural gas (LNG) in particular, to generate more electricity, displacing oil and oil products that it can then release for export. The cost of LNG imports are $8.2 per million British thermal units (MMBtu). Alternatively, it is possible that Saudi Arabia increases its production of (non-associated) natural gas.

We must highlight the relative efficiency of oil and natural gas power plants: 0.76 calorific units of natural gas displace 1.0 calorific unit of oil. In other words, to displace 1 barrel of oil, natural gas production needs to be increased by only 0.76 barrels of oil equivalent.

Policy 3. Increasing the efficiency of natural gas power plants

In the Blazquez et al. (2017) scenario, the calorific efficiency electricity generation from natural gas is 0.42, implying that one calorific unit of natural gas is transformed into 0.42 calorific units of electricity. It is technically possible to increase this parameter by investing in more efficient power plants: the electricity company could reduce the amount of oil used to generate electricity by increasing the amount of electricity generated from each unit of natural gas.

We estimate that an increase in the efficiency of a natural gas power plant of 1 percent requires an investment of $1,964 per kilowatt (kW), with a maximum technical efficiency of 0.542. This analysis is based on the cost and efficiency of a natural gas combined cycle, an advanced natural gas combined cycle and an advanced combustion turbine, as reported by the U.S. Energy Information Administration (2016).

Policy 4. Deploying renewable technology, keeping natural gas availability constant and displacing oil

At the time of writing, there is no significant renewable generation in Saudi Arabia; hence, in the base case scenario, all electricity is generated from oil and natural gas. However, it is possible to deploy renewable technology and reduce electricity generation from oil. The cost of this policy is explained in detail in Blazquez et al. (2017). In summary, for this policy we assume that the renewable technology is photovoltaic solar crystalline silicon cells with a cost of $1.34 million per megawatt and a capacity factor of 19 percent, as suggested by Bloomberg New Energy Finance (2015).

Policy 5. Increasing the administered price of domestic oil

This policy is probably the simplest way to reduce domestic consumption of oil. Moreover, it does not imply any direct additional cost to the government or any public company. The representative administered price of domestic oil used in this study is $18 per barrel. This price reproduces the main macroeconomic features of the Saudi economy in the long run (for a detailed explanation see Blazquez et al. 2017). The domestic price of oil and oil products are increased simultaneously and in the same proportion. The net increase in public revenues for all the policies is directly transferred to households to increase social welfare. This is particularly relevant for this policy.

Policy 6. Increasing the efficiency of electricity in the production of energy services

The same quantity of energy services (power, cooling, or lighting) can be produced using less electricity (and fewer inputs to produce the electricity) by investing in technologies that are more efficient.

The total cost of an electricity efficiency program includes, among others, direct rebates or incentives to customers, technical support, program administration, evaluation, verification and marketing. Molina (2014) analyzed 20 different U.S. state electricity programs from 2009 to 2011, finding that the average cost to reduce electricity consumption by one kilowatt is $0.028: the reference value we use as a benchmark.

Policy 7. Increasing the efficiency of oil and oil products in the production of energy services

In this case, the primary energy service is transportation. The policy would maintain the quantity of energy service provided, such as distance traveled, but with less oil and oil products used. To achieve this, we explore two possibilities: Policy 7a, a car-scrapping program and Policy 7b, a hybrid program, assuming that for both policies the average life of a vehicle is 10 years.

For Policy 7a, the Spanish scrapping program PIVE 8 (Instituto para la Diversificación y Ahorro de la Energía 2017) is used as a benchmark for implementing the scrapping program in the model. This program was used to scrap and replace over 290,000 old vehicles by new efficient vehicles with a budget of €225 million. To have access to public assistance, the new vehicle has to be at least 15 percent more efficient than the average new vehicle. In this paper and for the sake of simplicity, we assume that vehicles bought under the scrapping program are 15 percent more efficient than standard vehicles.

For Policy 7b, the hybrid program, conventional cars in the model are assumed to be replaced by hybrid cars, based on Liu's (2014) comparison of the cost and efficiency of a conventional car with a similar hybrid car. Note the assumption is that the hybrid cars do not include plug-in hybrids given this would be likely to increase electricity demand in Saudi Arabia significantly. According to Liu (2014), the hybrid car is, in terms of fuel consumption, 26 percent more efficient but 17 percent more expensive.

Table 1 shows a comparison of the estimated cost of the policies in dollars in 2016 to reduce oil consumption by one barrel.

Table 1. Direct cost of the policies to export one additional barrel.

Policy	Cost ($)
1. Production of oil	9.2
2. Natural gas imports	36.4
3. Efficiency of gas power plants	4.4
4. Renewable technology	16.3
5. Price of domestic oil	0
6. Efficiency of electricity	34.4
7a. Efficiency of oil (scrapping program)	15.3
7b. Efficiency of oil (hybrid program)	53.8

Source: KAPSARC.

Simulation Results

Saving one barrel of oil per day

We start our analysis for each of the policies assuming that only one additional barrel of oil is saved and sold on international markets. Policies may improve welfare through five different channels:

1. The positive impact of the gap between the domestic and international oil prices. This factor is common for all policies, as the increase in oil revenues is the same.

2. The negative effect on the international oil price, which is common for all the policies.

3. An increase in the productivity of the economy through energy efficiency programs that are more expensive but add an 'extra positive' impact. These include Policy 6, Policy 7a, and Policy 7b that aim to increase the efficiency of electricity, oil and oil products.

4. The different costs of the policies.

5. An increase in the domestic price of oil also causes an impact due to change in relative prices.

Table 2 shows the simulation from the model for gross welfare gain of each policy without a price reaction; net welfare gain without a price reaction but taking into account the cost of the policies; net welfare gain with price reaction; the ranking of the policies; and the estimated impact of all the policies on CO_2 emissions. In other words, we initially assume that the policy has no cost and the barrel of oil saved has no impact on international markets, which implies that the additional barrel exported is sold at the international market price ($53 per barrel in constant dollars of 2016). Using these assumptions, we run the model and estimate the gross welfare gains without a price reaction. We define welfare gains as the increase in expenditure in total private consumption, including energy services

Table 2. Welfare gains and CO_2 emissions of the policies per additional barrel exported (in dollars of 2016 and kilograms).

	Without price reaction		With price reaction		
Policy	Gross	Net	Net	Rank	CO_2
1. Production of oil	53.7	42.0	31.5	4	+10
2. Natural gas imports	53.7	15.9	5.6	8	-150
3. Efficiency of gas power plants	53.7	46.6	38.1	2	-368
4. Renewable technology	53.7	35.7	25.2	5	-368
5. Price of domestic oil	28.6	28.6	18.2	7	-368
6. Efficiency of electricity	86.6	48.1	37.6	3	-368
7a. Efficiency of oil (scrapping program)	86.6	66.7	56.3	1	-368
7b. Efficiency of oil (hybrid program)	86.6	29.0	18.7	6	-368

Source: KAPSARC.

consumption, that leaves the representative household indifferent between the new situation and the initial situation before any policy is implemented. In our simulations, we assume that the current account (or the foreign bond stock) is constant in absolute terms, while it changes in gross domestic product (GDP) terms. In most business cycle studies, the current account relative to GDP is constant, while it changes in absolute terms. Secondly, we run the model again, adding the cost for each policy and estimate the societal net welfare gains, assuming that Saudi Arabia is a marginal oil producer and a shift in Saudi exports does not impact the international oil price. Thirdly, we relax this assumption and run the model again but adding the international oil price response. To do so, we compute a long-run price elasticity of the residual demand for Saudi oil as explained in Pierru et al. (2018). Finally, we rank the policies according to the net welfare gains with price reaction and present an estimation of the reduction in Saudi CO_2 emissions in kilograms.

Table 2 allocates the total welfare increase generated for each policy, within the general equilibrium framework, to the additional barrel exported.

The gross welfare gain without policy cost and price reaction, in the case of an increase of domestic production, is not identical to the international price of oil as we are using a general equilibrium framework. Thus the results account for all the direct and indirect impacts. The government has to increase the production of oil by 1.04 barrels to increase the export of oil by one barrel, as the additional barrel exported implies higher revenues for the country. This leads to higher domestic demand for electricity and oil products from consumers and firms. This implies that one barrel is sold at the international price ($53) and 0.04 barrels are sold at an administered domestic price ($18). The sum of both is $53.7: the welfare gain of exporting one additional barrel of oil via an increase in oil production, which represents a a welfare gain of $51.6 = \frac{53.7}{1.04}$ dollars per barrel produced.

Regarding net welfare gains with price reaction, Policy 1 (an increase in oil production) is arguably the most intuitive way to increase oil exports. But as Table 2 shows, this does not produce the greatest estimated welfare gain, being ranked only fourth. Furthermore, Table 2 also shows Policy 1 is the only policy that leads to an increase in domestic carbon emissions, as no oil is actually ‘saved.’ Instead, the most attractive policy would appear to be Policy 7a: the car scrapping program. This policy has the highest estimated welfare gain and produces the highest estimated reduction in emissions, along with all other policies except Policy 1 and Policy 2. This is despite Policy 7a not being the cheapest. The reason for this result is that, in our model, private consumption of goods and energy services are the two drivers of welfare. A car scrapping program allows a simultaneous increase in non-energy consumption and energy services.

Policy 6 and Policy 7b have a direct impact on the efficiency of the energy services firm and have the greatest positive impact on gross welfare. However, as Table 2 shows, the cost of these programs is an important aspect when considering the policies. For example, Policy 7b (hybrid car program) is the second least attractive policy (ranked sixth in welfare gains) due to its high cost, thus negating the positive effects. Policy 6 (to increase the efficiency in the use of electricity) is ranked third in welfare gains.

Policy 2 (to increase the share of natural gas), Policy 3 (the improvement in the efficiency of gas power plants), and Policy 4 (the deployment of renewable technology) aim to reduce the consumption of oil and oil products in electricity generation. Table 3 shows that Policy 3 is the most attractive policy. The other two policies rank eighth and fifth respectively, due to their relatively high costs. And though shifting from oil to natural gas in electricity generation (Policy 2) has a positive impact on carbon emissions, it is meager compared to the other policies.

Policy 5 (an increase in the administered domestic prices of oil and oil products) also increases the electricity price, as oil is the most relevant input in electricity generation. This policy has no fiscal cost but has indirect negative implications for consumers, given the increase in the prices of energy services and the reduction in the production of final goods and services. This policy significantly increases public revenues and, thus, public transfers to households. Policy 5 is estimated to result in an overall societal welfare gain but is ranked seventh.

To sum up, policies aimed to curb oil consumption marginally have a positive impact on welfare and on carbon emissions.

The negative impact is due to the international price response. The gap between the net welfare gain with price reaction and net welfare gain without price reaction is around $11 per additional barrel of oil exported on average.

Table 2 also provides information that could be used to evaluate small projects aimed to save oil in Saudi Arabia. The welfare gain of any project aimed to reduce oil consumption in electricity generation should be valued as the sum of the gross welfare gain without price reaction ($53.7) minus the price reaction ($11.3) and minus the direct cost of that specific project. Similarly, the welfare gain of any project aimed to increase energy efficiency should be valued as the sum of the gross welfare gain without price reaction ($86.6), minus the price reaction ($11.3), minus the direct cost of that project.

Welfare analysis is the standard way to evaluate policies. Nevertheless, policymakers also find the impact on GDP and public budget relevant. Table 3 shows the impact of the policies on GDP and net public revenues once the cost of the policy is discounted.

Table 3. Impacts of the policies to export one additional barrel of oil in dollars of 2016.

Policy	GDP	Net public revenues
1. Production of oil	42.4	33.2
2. Natural gas imports	42.1	5.9
3. Efficiency of gas power plants	42.5	38.1
4. Renewable technology	42.3	26.2
5. Price of domestic oil	13.0	54.5
6 . Efficiency of electricity	82.3	-8.3
7a. Efficiency of oil (scrapping program)	83.2	10.6
7b. Efficiency of oil (hybrid program)	81.4	-27.5

Source: KAPSARC.

Table 3 shows that Policy 5 has the largest positive impact on public revenues but the smallest impact on GDP. This is because the increase in the domestic price of oil boosts public revenues but disincentivizes domestic production. Policy 6, Policy 7a and Policy 7b improve productivity and, as a result, significantly increase GDP. However, the high cost of these policies has a strong detrimental effect on public revenues.

Escalating policies from one barrel per day

Saudi policymakers are likely to want to consider the impact of saving and exporting significantly more than one barrel per day. It is therefore important to consider the technical possibilities of escalating the amount of oil saved and exported. We exclude Policy 1 (an increase in oil production) from this analysis as it is not a policy aimed to save oil.

There are no technical problems that would hinder the escalation of Policy 2 (importing natural gas). The limit of this policy would only be reached if it completely displaced oil and oil products from the electricity generation mix. For Policy 3 (an increase in the efficiency of gas power plants), the average technical efficiency of natural gas power plants would have to shift from 0.42 to a maximum of 0.54. In the case of Policy 4 (the deployment of renewable technology), a mix of different renewable sources could completely displace oil and oil products from the electricity generation mix, achieving a maximum penetration of 66 percent (renewable generation over total generation of electricity). In practice, this target is difficult to achieve in Saudi Arabia given the lack of hydro resources. The current policy target is 9.5 GW in 2023, but Saudi policymakers view it as a first step in the decarbonization of the electricity mix (Reuters August 24, 2017). For this reason, we opt for a target of 35 percent of penetration, identical to the target approved in January 2018 by the European Union Parliament for 2030.

In the case of Policy 6, aimed at increasing the efficiency of electricity, we set the maximum technical increase in productivity at 25 percent compared to the baseline scenario. This increase in productivity is based on Boogen (2017) which finds an average inefficiency of around 20 to 25 percent for Swiss households. This range captures the engineering inefficiency of the appliance stock and the inefficiency that household behavioral changes can help avoid. For Policy 7a (the scraping program), the Saudi fleet would have to increase energy efficiency by 15 percent. For Policy 7b (the hybrid program), there would be a 26 percent increase in the energy efficiency of the fleet.

The maximum impact on oil exports is achieved in Policy 5 (price increase) when the administered domestic price is increased to the international oil price. In practice, this large increase in prices would trigger additional energy efficiency policies. For this reason, we present two simulations for this policy: Policy 5a, where the price increase does not trigger additional energy efficiency policies, and Policy 5b, where there is also an increase in the efficiency of electricity (Policy 6), more efficient cars (Policy 7a) and the deployment of renewable energy (Policy 4).

We analyze the impact of the policies outlined above in a general equilibrium context in the long run. This implies that all the direct and indirect impacts are taken into consideration. The rebound effects due to changes in the national income, or changes in energy prices, are implicitly addressed in the model. Table 4 details the results from the analysis for barrels of oil saved and instead exported,

Table 4. Annual impacts of escalating the policies to their maximum (in thousand bbl/d, billion dollars and millions of tons).

Policy	Oil exports	Welfare	GDP	Public revenues	CO_2
2. Natural gas imports	696	1.2	1.3	1.3	-38
3. Efficiency of gas power plants	102	1.3	1.6	1.4	-14
4. Renewable technology	367	2.9	5.6	3.1	-49
5a. Price of domestic oil	1,237	0	-5.9	27.4	-166
5b. Price of domestic oil	1,495	3.8	2.5	26.3	-201
6. Productivity of electricity	96	1.1	2.9	-0.5	-10
7a. Productivity of oil (scrapping)	82	1.6	2.5	0.3	-11
7b. Productivity of oil (hybrids)	139	0.5	4.1	-1.8	-19

Source: KAPSARC.

welfare gains, GDP, net public revenues and the impact on CO_2 emissions. As mentioned above, the additional net public revenues from these policies are directly transferred to households to foster social welfare.

There are three insights for policymakers: first, Policy 5a has a very large impact on oil exports, net public revenues and carbon emissions. However, the impact on welfare is limited due to the increase in the domestic prices of energy and the contraction of GDP having a negative impact on households' welfare, also reducing the positive effect generated by an increase in public transfers to households. This simulation does not take into account that a large increase in energy prices will trigger additional energy efficiency measures.

This case is explored in Policy 5b, where we simulate a combination of policies aimed to reduce the consumption of electricity, oil and oil-related products. The simulation shows that this combination would boost oil exports and have a large, positive impact on households' welfare and domestic carbon emissions. Second, policies aimed to increase energy efficiency (Policy 6, Policy 7a and Policy 7b) have a mild impact on oil exports and carbon emissions and deliver poor results in terms of public revenues due to their high cost. Third, policies aimed to reduce the share of oil in power generation (Policy 2, Policy 3 and Policy 4) can reduce oil consumption significantly and have a positive impact on welfare and public revenues.

For the sake of completeness, Table 5 shows a comparison of the policies for the target of 75,000 bbl/d saved. The results do not change qualitatively from those for one barrel of oil saved and instead exported (Table 2). The main insight from Table 5 for Policies 3 to 7b is that saving 75,000 bbl/d can boost welfare in a range of between $0.4 billion and $1.5 billion and reduce carbon emissions by 10 million tons. Policy 2 (importing natural gas) also has a positive impact on welfare, but the positive impact on carbon emissions is mild.

Table 5. Annual impacts of the policies to increase oil exports by 75,000 bbl/d (in billion dollars and millions of tons).

Policy	Welfare	GDP	Public revenues	CO_2
2. Natural gas imports	0.2	0.2	0.2	-4.1
3. Efficiency of gas power plants	1.0	1.2	1.0	-10.1
4. Renewable technology	0.7	1.2	0.7	-10.1
5a. Price of domestic oil	0.5	0.3	1.5	-10.1
6. Productivity of electricity	0.9	2.2	-0.3	-10.1
7a. Productivity of oil (scrapping)	1.5	2.3	0.3	-10.1
7b. Productivity of oil (hybrids)	0.4	2.2	-0.9	-10.1

Source: KAPSARC.

Finally, we simulate the impact of the substantial increase in administered prices of gasoline and electricity in January 2018. This increase was accompanied by the Citizen's Account policy in December 2017: a direct public transfer of funds to medium income households. This combination of policies is similar to Policy 5. For this policy, we simulated an increase in the administered price of oil of 80 percent in the model, consistent with the average increase in electricity tariffs and the increase in gasoline 91-octane. The simulations show that this policy would increase oil exports by 724.000 bbl/d and welfare by $2.6 billion in the long run. It would also reduce CO_2 emissions by 97 million tons annually.

Conclusions

This study explores the possible long-run impacts of different policies aimed to curb oil consumption in Saudi Arabia and increase oil revenues from exports. The domestic price of oil in Saudi Arabia is administered and below the international price, creating an opportunity to generate economic value. To undertake the research, we used a general equilibrium model for a small open economy where the international price of oil depends on the level of Saudi exports. To the best of our knowledge, this is the first study to address this issue from a macroeconomic perspective.

We discussed seven policies aimed at reducing oil consumption and increasing oil exports in the long run. As outlined, to reduce oil use in electricity generation, Saudi Arabia could import LNG, deploy renewable energy, or increase the technical efficiency of natural gas plants. These policies benefit from the gap between domestic and international prices. An alternative way to reduce oil consumption could be to increase the efficiency of electricity and oil consumption, and the consumption of oil products. Finally, it could be possible to reduce oil consumption in Saudi Arabia and increase oil exports by increasing the domestic prices of oil. For the sake of completeness, we also considered a policy for increasing oil production, as this is a more obvious way to increase oil exports.

The analysis of these policies, using the bespoke general equilibrium model for the Saudi economy, leads to the following insights: first, policies designed to curb oil consumption have positive impacts in terms of welfare, GDP, and carbon emissions, although the cost of the policies and the impact on productivity plays a critical role. Second, we find policies aimed to increase energy efficiency have limited scalability, and, consequently, the potential positive impacts at macroeconomic scales are small. Third, the increase in administered oil prices has the largest impact on domestic demand of oil and, therefore, on oil exports. However, this policy also has negative impacts on welfare that can be mitigated using non-energy policies, such as the Citizen's Account implemented by the Saudi government in December 2017. Fourth, shifting oil power generation to natural gas has a positive impact on the Saudi economy even if the natural gas is imported. Fifth, welfare gains for all the policies studied range between a minimum of $6 and $56 per barrel of oil saved. Sixth, we find that these policies, excluding increasing the share of natural gas in the generation mix, reduce the level of domestic emissions by around 368 kg per barrel saved. However, the net direct impact on global emissions is nil given the oil saved in Saudi Arabia is exported and consumed abroad.

The research presented in this paper provides a useful tool to evaluate the potential individual energy efficiency projects. We find that the gross positive impact of one barrel of oil saved in electricity generation is estimated to be around $43. This impact is much larger for energy efficiency projects, at around $76. In both cases, the gross welfare gains have to be compared with the cost of the project to assess its net economic value. Energy efficiency projects are profitable at a lower oil price than those aimed at shifting from oil power generation to natural gas or renewables.

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Appendix

This appendix describes how the Saudi Arabian model introduced in Blazquez et al. (2017) has been extended and developed for the analysis undertaken in this paper.

First, oil production $(\bar{O}_t)$ and natural gas production $(\bar{G}_t)$ are policy variables which can be increased or reduced.

Second, the technical efficiency of the natural power plants *(β)* can be changed. The production of electricity is given by the following expression:

$$E_t = \alpha O_{E_t} + \beta \bar{G}_t + \bar{R}_t \tag{A1}$$

Third, the energy services production function has been changed in the following way:

$$S_t = \left[a(A_1 E_t)^\lambda + (1-a)\left(A_2 O_{S_t}\right)^\lambda\right]^{1/\lambda} \tag{A2}$$

In this study, these parameters are no longer fixed while in Blazquez et al (2017), A_1 and A_2 are constant and equal to 1, i.e., $A_1=A_2=1$.

Finally, we modified the production function for final goods and services as follows:

$$Y_t = A_3 n_t^\theta \left[(1-b)k_t^\nu + bS_{F_t}^\nu\right]^{\frac{1-\theta}{\nu}} \tag{A3}$$

Blazquez et al. (2017) assume A_3=1 is constant. We allow for changes in this variable. In this case, there is no cost associated with this policy.

The costs of these policies show up in the government budget according to the following expression:

$$P_{O_t}(\bar{O}_t - O_{E_t} - O_{S_t}) + \bar{P}_{O_t}(O_{E_t} + O_{S_t}) + \bar{P}_{R_t}\bar{R}_t + \bar{P}_{G_t}\bar{G}_t = i_{g_t} + TR_t + \varsigma_O(\bar{O}_t - \bar{O}_{SS}) + \varsigma_G(\bar{G}_t - \bar{G}_{SS}) + \varsigma_\beta(\beta - \beta_{SS}) + \varsigma_{A1}(A_1 - 1) - \varsigma_{A2}(A_2 - 1) \tag{A4}$$

This expression is similar to that of Blazquez et al (2017) but takes into account the costs of the policies. In particular, variables ς_O, ς_G, ς_β, ς_{A1}, ς_{A2} represent the cost of a unitary change in the production of oil, the production of natural gas, a change in the calorific efficiency of natural gas power plants, a change in the productivity of electricity and a change in the productivity of oil, respectively. The variables $\bar{O}_{SS}$, $\bar{G}_{SS}$ and $\bar{\beta}_{SS}$ are the variables in the initial steady state, prior to any policy change, and they are identical to those used by Blazquez et al (2017).

The model also has a new price reaction function that links Saudi exports and the international oil price. Saudi Arabia is a significant player in oil markets and, therefore, a change in its production or exports can have an impact on the international price. We assume that a change in oil exports, $\Delta X_t = \Delta(\bar{O}_t - O_{E_t} - O_{S_t})$, leads to change in oil revenues according to the standard expression:

$$\Delta\left(P_{O_t} X_t\right) \cong \left(1 + \frac{1}{\varepsilon}\right) P_{O_t} \Delta X_t \tag{A5}$$

As explained in Pierru et al. (2018), this expression can be rewritten as follows:

$$\varepsilon = \frac{\Delta X_t}{X_t} / \frac{\Delta P_{O_t}}{P_{O_t}} = [\varepsilon_D - (1-\rho)\varepsilon_R]/\rho \tag{A6}$$

where ε_D and ε_R represent the price elasticity of global demand and non-Saudi supplies, and ρ is the Saudi market share of global oil output.

We consider long-run elasticities since we compare steady-state solutions of the model. The two elasticity values ε_D and ε_S are not directly observable and, in addition, the literature offers no consensus on these values. Furthermore, as stressed by Hamilton (2009) these values have changed throughout time, with the recent light tight oil revolution increasing the elasticity of supply. For our purposes, we consider the values discussed and used by Pierru et al. (2017): ε_D=-0.3,ε_R=0.3, and ρ=11.7 percent. This means that increasing oil exports by one barrel in period t would generate an incremental revenue equal to 79 percent of the international market price.

Finally, in this study we focus on the value of “one barrel of oil saved per day”. Given that we use a macroeconomic model, we cannot technically reduce oil consumption (or increase oil production) by one barrel per day. The minimum amount oil saved in the model is 750 bbl/d, this is, 0.01 percent of oil exports. We ran the model for this amount of oil and the divided the results for 750.

Notes

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About the Project

Project: Shadow Pricing of Resources

Initiative: Public valuation of investment projects

Description: Saudi Arabia's economy is passing through a phase of transformation in which some resources will be freed from existing usages and allocated to new development opportunities. In a standard economics framework markets are considered to provide an efficient way of allocating resources. However, there are many goods and services for which there are no markets or the market price may not reflect the "real" value due to market failures such as externalities, resource scarcity or economic distortions. Making decisions based on the wrong opportunity costs or value of these resources could lead to over- or underinvestment in projects. This would deteriorate the welfare of the citizens and prevent the Kingdom from fully realizing its economic potential. The objective is to understand to what extent specificities of the Saudi economy influence how to assess projects from a public perspective.

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