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Environmental and welfare assessment of fossil-fuels subsidies removal: A computable general equilibrium analysis for Ghana

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ABSTRACT

One of the motivations for the removal of subsidies on fossil fuels is that these subsidies lead to the over-consumption of energy, and as a result, undermine environmental quality. Despite the huge opportunities that removal of subsidies on fossil fuels may bring for climate change mitigation, empirical studies for Ghana have failed to appropriately test these links. For this reason, this study employs a multi-region computable general equilibrium (CGE) model to evaluate the welfare and environmental impacts from imported refined oil subsidies removal in Ghana. The simulation experiment shows evidence of welfare losses even if environmental benefits are accounted for. Although the rate of CO_2 emissions appears to increase, there is an overall 1.9% improvement in environmental quality due to the removal of fuel subsidies. The results provided in this study imply that the removal of subsidies on energy should be implemented along with policies aimed at stimulating economic activities. In addition, the study has implications for the so-called 'green paradox'.

1. Introduction

Even though Ghana produces oil in commercial quantity, it is still a net importer of the commodity and depends strongly on refined oil products for satisfying its energy needs [49]. The Energy Commission of Ghana (GEC), in its 2015 energy supply and demand outlook, writes: "for 2015, we estimate that the total crude oil and imported products required should increase to about 3.65 million tons from about 3.34 million tons in 2014, in order to maintain the economic growth at 4.2% and also to meet optimal refinery operations as well as refined products for local consumption" [19]. Despite the fact that Ghana produces oil in commercial quantities and owns its own refinery, the country spends relatively large amount to pay for imported oil than it gets from export of the commodity.[1] For instance, Dogbevi [14]; referencing the Bank of Ghana writes: "… as at May 2015 Ghana spent $ 195.5 million importing oil, but earns $ 188.1 million from its oil exports." Fig. 1, based on data from GEC, presents information on refined oil imports in Ghana as a share of total refined oil consumption for the period 2000 to 2012. As may be observed from Fig. 1, refined oil imports in Ghana constituted between 32 and 77% of the total refined oil consumption in the country during the period 2000–2012. This trend, as demonstrated for various petroleum products (during the period 2000–2013), is shown more clearly in Fig. 2.

From the above discussion and data from GEC, one may see that imported refined oil constitutes a very significant fraction of the total refined oil consumption in Ghana; and as such, a consideration of the imported refined oil sub-sector, in particular, could present significant implications for Ghanaian energy policy.

Indeed, the huge pressure which calls for countries to reduce their consumption of fossil fuels while at the same time improving wealth and income distribution has increased the need for poverty-alleviating mitigation strategies in developing countries. The so-called 'green growth' can be made possible in either two ways: first a massive deployment of renewable energy technologies; and second, improvement in the level of energy efficiency [73]. Notwithstanding, subsidies on fossil fuels are apt to cripple development strategies geared towards promoting green growth by reducing the attractiveness of investment in renewable energy and

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[1] One reason for this is the fact that the country's current refinery, given its capacity and state of engineering, cannot meet up with growing demand.

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Symbols and description

AfDB	African Development Bank
ATK	Aviation Turbine Kerosene
CDE	Constant Differences in Elasticities
CES	Constant Elasticity of Substitution
CGE	Computable General Equilibrium
CO_2	Carbon Dioxide
DPK	Dual Purpose Kerosene
GDP	Gross Domestic Product
GE	General Equilibrium
GEC	Ghana Energy Commission
GSI	Global Subsidies Initiative
GTAP	Global Trade Analysis Project
IMF	International Monetary Fund
IEA	International Energy Agency
LPG	Liquefied Petroleum Gas
NPA	National Petroleum Authority
OECD	Organization of Economic Cooperation and Development
PE	Partial Equilibrium
SAM	Social Accounting Matrix
TOR	Tema Oil Refinery
WB	World Bank

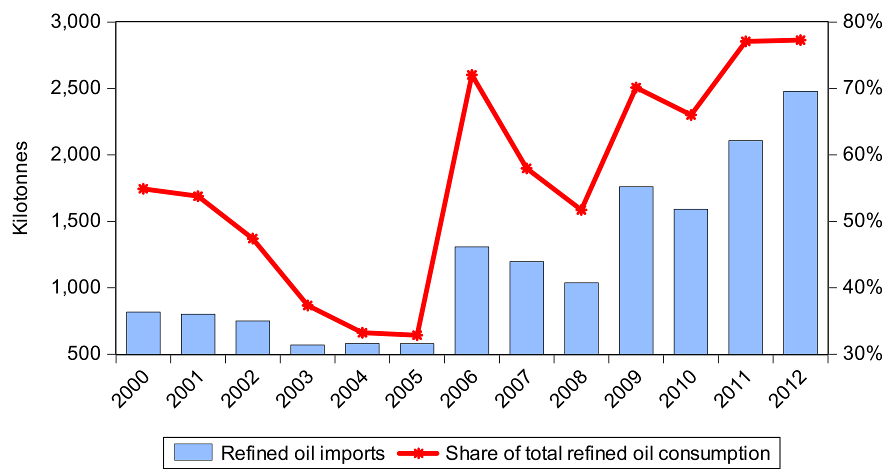

Fig. 1. Refined oil imports in Ghana.
Source: GEC [17].

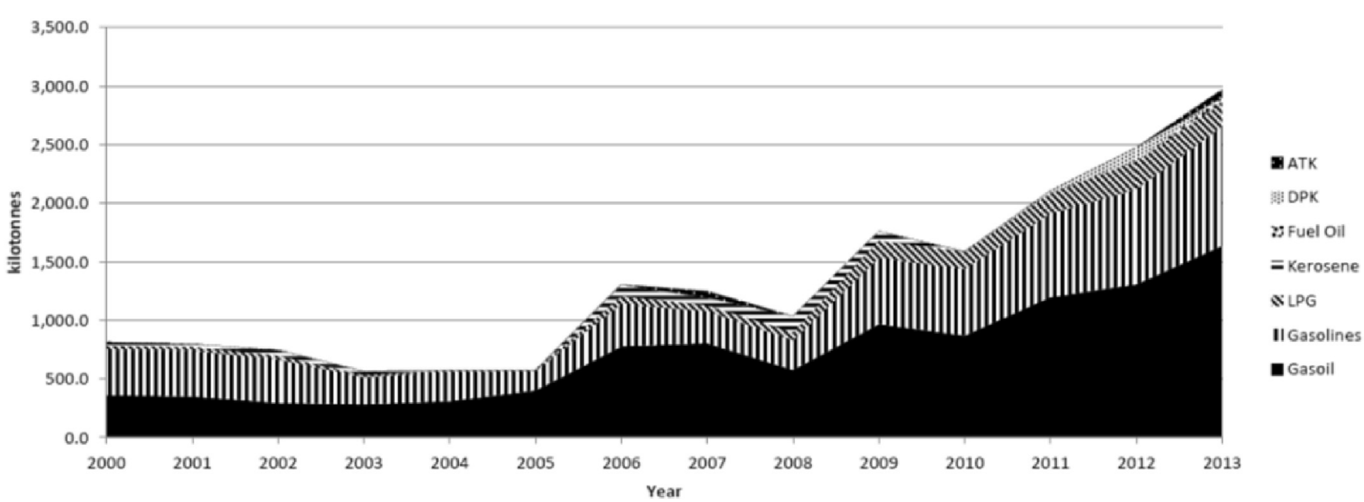

Fig. 2. Trend in refined oil imports in Ghana.
Source: GEC [18].

limiting the need to improve energy efficiency [74]. It has been estimated that the removal of all fossil fuel subsidies globally has the potential of cutting the level of carbon dioxide (CO_2) emissions driven by the production and utilization of energy by 6.9% by 2020 [33]. Meanwhile, a number of scholars have already agreed that subsidies on fossil fuels fail to address the needs of the poor. As a result, reforming these mechanisms would present opportunities for developing more pragmatic policies that would effectively address the issue of poverty. Considering the case of most African countries, it is estimated that 44.2% of subsidies on fossil fuels go to the richest 20% while the poorest 20%, on the other hand, stand to benefit only 7.8% of these subsidies [1].

The main purpose of this study is to examine the environmental and welfare benefits stemming from Ghanaian fossil fuels pricing reform.[2] This is done by utilizing computable general equilibrium (CGE) modeling technique. Bhattacharyya [4] provides a review of CGE studies of energy and environmental issues. Few other publications that have recently applied CGE models to issues of energy and environment as a means of either quantifying and evaluating economic and environmental impacts of fossil fuel subsidies removal on the one hand or environmental policy modeling on the other hand include: Lin and Jiang [43]; Lin and Li [44]; Siddig et al. [61]; Wesseh and Lin [75]; Wesseh and Lin [76] and Wesseh and Lin [77].

The originality and scientific contribution of this study adds value to the literature. It is certainly among few academic publications on the controversial subject of fuel subsidies – largely dominated by institutional studies. For the Ghanaian case in particular, Wesseh and Lin [75] recently evaluated the economic benefits of fossil fuels subsidies removal. Notwithstanding, these authors did not touch on one of the most important incentives for fossil fuel subsidies removal, that is, a quantitative analysis of the environmental benefits [2]. Furthermore, the general welfare implication from fossil fuels subsidies removal through the application of general equilibrium theory was ignored by Wesseh and Lin [75]. For these reasons, the present study comes in handy as it serves to bridge an inherent gap.

The remainder of the article is organized as follows. Section 2 reviews the relevant literature. Section 3 discusses the methods and data used. Simulation results are documented and discussed in section 4. Section 5 draws the conclusions and provides limitations and directions for further research.

2. Relevant literature

The most popular approach employed in the literature to study the impacts of fossil-fuel subsidy reform has been the use of partial-equilibrium and general-equilibrium techniques. On the one hand, partial-equilibrium models look exclusively at the product market where the subsidy reform is happening, in this case, the energy market. Based on simple-supply-and-demand curves and economic assumptions, price, demand and production changes in fossil fuels as a result of subsidy removal are estimated. Computable general-equilibrium (CGE) models, on the other hand, employ sets of equations that specify supply-and-demand behavior across a multitude of markets to simulate markets for production factors and goods [67].

Several studies for developed countries now exist, ranging from multi-region and multi-fuel modeling to single-country and multi-fuel modeling, which quantify the economic, environmental as well as social impacts of subsidy reform. Among the most prominent of these studies include Larsen and Shah [42]; Burniaux et al. [7]; Steenblik and Coroyannakis [78]; Anderson and McKibben [2]; IEA [28,56,60]; Freund and Wallich [36]; World Bank [79] and Burniaux et al. [8].

The general conclusions from the above studies can be categorized as economic, environmental or social. On the economic impacts of fossil-fuel subsidies reform, the general conclusions are that subsidies: increase energy consumption and reduce incentives for energy efficiency (e.g. Ref. [52]; reduce foreign exchange revenue and poses a drain on government finances (e.g. Refs. [5,12,36,69]; increase dependence on imports and undermine investment in alternative energy sources (e.g. Ref. [65]; promote energy-intensive production at the expense of labor (e.g. Ref. [5]; encourage shortages or costly rationing systems (e.g. Ref. [52]; and encourage corruption. In terms of the environmental impacts, the overall conclusions are that subsidies: contribute to global GHG emissions, local air and water pollution (e.g. Refs. [2,56,60,65]); landscape destruction (e.g. Ref. [2]; and depletion of non-renewable fossil-fuel stocks (e.g. Ref. [12]. With regards to major potential social impacts, subsidies may: benefit the rich more than the poor (e.g. Refs. [79,80]); reduce energy available to the poor [80]; not target types of energy that would be more beneficial to the poor (e.g. Ref. [28]; divert government money from more effective social programs; and increase the health vulnerability of the poor (e.g. Ref. [67].

Few studies have focused exclusively on developing countries. The main empirical assessment and earliest of these studies is found in Hope and Singh [27] who, using survey data on household spending patterns, estimated the impacts of energy prices on spending in six developing countries including Ghana. Results from the assessment show that the pricing reform led to income and welfare losses. Following similar line of research, Coady and Newhouse [11] studied both the direct and indirect effects of fossil-fuel subsidy reform in five developing countries including Ghana. The authors found that, overall, a 50% increase in fuel prices leads to an average 4.6% decrease in real income. Almost similar conclusions are reached in Global Subsidies Initiative [22]. Burniaux and Chateau [81], based on previous global studies, show that subsidies removal yields both economic and environmental benefits. Highlighting recent country-specific studies, Lin and Jiang [43] show that subsidy reforms in China, although reduce energy consumption and CO_2 emissions, produce a negative effect on the Chinese macro-economy. Other studies conducted for China with similar conclusions include: Lin and Li [44]; Jiang and Lin [37]. For an African country in particular, Siddig et al. [61] investigated the impact of removing fossil fuel subsidy on the Nigerian economy and found that accompanying a subsidy reduction with a transfer of income to poor households alleviates some of the negative impacts on households. More recently, Wesseh and Lin [75] evaluated the impacts of refined oil subsidies removal in Ghana and found that the removal of subsidies raises prices and reduces households' demand.

Even though general conclusions have been implied from the empirical literature, the impacts of pricing reforms may vary substantially from region to region. Hence, robust empirical analyses directed to specific regions become inevitable. From the review of studies presented above, one would notice that the only available research on subsidies removal in Ghana are institutional studies conducted within a multi-region framework and recent work by Wesseh and Lin [75]. The present study is different from Wesseh and Lin [75] in that it provides a more robust analysis on the environmental impacts of the removal of fossil fuel subsidies and highlights the general welfare implications.

In light of the above, one may find that the present study adds value to the literature both in terms of Ghanaian energy policy and computable general equilibrium (CGE) modeling.

3. Methods and data

Using relevant social accounting matrix (SAM) for Ghana, this study applies CGE modeling techniques.

3.1. What is CGE modeling?

Computable general equilibrium or CGE models are complete

[2] Such an investigation is also driven by the strong connections existing between the use of energy and economic growth [48,71].

mathematical representations of an economy, comprising the actions of households (or consumers), producers (or industries/firms), government, investors and exporters. Each of these agents participates in markets for supplying and demanding commodities and factors, and has an underlying behavior that determines their decisions. For a comprehensive review of CGE models and their applications, interested readers are referred to: Bhattacharyya [4]; Dixon and Parmenter [13]; Ginsburg and Keyzer [20] and Partridge and Rickman [58].

3.2. Brief description of the applied model

In this study, the Global Trade Analysis Project (GTAP) model, a static, multi-sector, multi-regional CGE model, developed by the Global Trade Analysis Project at Purdue University is applied to analyze the impacts of fossil fuel subsidy removal in Ghana. Since the changes in energy policy would have economy-wide effects, it is necessary to utilize models which take into account the activities of all agents and sectors in the economy; thus, the CGE model comes in handy in this case.

The GTAP model has been widely used for policy analyses such as evaluating the impacts of subsidies, quotas, tariffs and in land-use analysis [6]. In order to preserve space and given that the applied model has been fully documented, interested readers are referred to Hertel [26] for full mathematical details of the GTAP model. This model has a competitive economic environment, as well as a utility and profit maximizing behavior of consumers and producers. Perfect competition in all markets and constant returns to scale technology are assumed. Two set of equations, namely: accounting relationships and behavioral equations, characterize the GTAP model.

The basic structure of the model includes: households, industrial sectors, governments, and global sectors across countries. In each region (e.g. Ghana), there is a representative “regional household” and “firms”. All countries and regions in the world economy are connected through trade. International trade is linked through Armington substitution in which goods are differentiated by country of origin [6]. This implies that, based on the factor endowments (land, skilled and unskilled labor, capital and natural resources), a constant elasticity of substitution (CES)[3] composite of imported intermediate and domestically produced goods is used in fixed proportions with a value-added CES composite. Households receive income and spend it on three types of expenditures: private (consumer), government and savings. Firms use primary and intermediate inputs to produce final goods. They can either buy inputs from other firms or import intermediate inputs from other regions. Firms pay wages to households in return for employing land, labor, capital and natural resources. Firms can sell output to other firms, private households, government and investment, and can also export their goods.

On the production side of the model, a CES production function is assumed when firms decide on the percentage of primary factors of production and intermediate inputs to purchase from other firms. In this study, the CES value of zero, which is standard in GTAP, is used to determine the degree of substitution between primary production factors and intermediate inputs.

The demand side of the model allows total income to be allocated based on fixed value shares across household, savings expenditure and government. The optimization problem then becomes one in which the representative household tries to maximize a CDE objective function (see Ref. [25]. For each region, the model is then calibrated to differing price and income elasticities of demand. In this way, a richer description of final demand is guaranteed and consumption becomes a CES composite of imported and domestically produced goods.

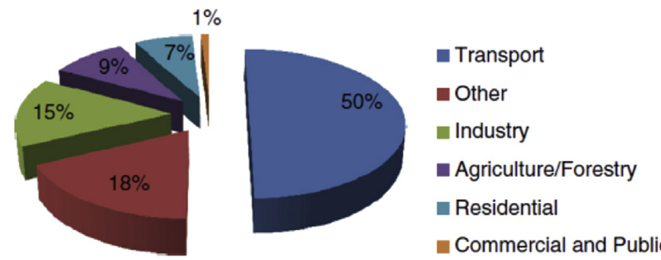

Fig. 3. Ghanaian oil consumption by sectors for 2006.
Source: Lin et al. [49]

3.3. Applying the GTAP model to Ghana

As indicated in Wesseh and Lin [75]; total subsidies were 17%, 49%, 67%, 50% and 108% for petrol, kerosene, diesel, fuel oil and liquefied petroleum gas (LPG) respectively. Because the Ghanaian government has planned to continue its policy of cross-subsidization of LPG and kerosene, only ratios for petrol, diesel and fuel oil are included with the calculation for total subsidies for refined oil imports. Sectorial oil mix in Ghana for the year 2006 is presented in Fig. 3.[4] Utilizing Fig. 3, and given that kerosene and LPG are mainly consumed by the residential sector, it is possible to estimate the scale of subsidies on imported refined oil (excluding kerosene and LPG) utilizing weighted averages. Hence, the total amount of subsidies on imported refined oil can be approximated as follows:

Refined oil subsidies $= \left(\frac{(0.17+0.67+0.50)}{3}\right) \times (0.93) \approx 42\%$. In the modeling exercise, a 42% shock to tax on imports of refined oil would therefore be implemented as a means of simulating the removal of subsidies on refined oil imports in Ghana.[5]

To implement the GTAP model, a closure that fixes government savings is applied in order to prevent the subsidy removal from translating into increased government savings. The rationale for adopting such a closure is to reduce the vulnerability of Ghanaian households to the negative consequences of subsidy removal; and hence, represents an important innovation. We implement the GTAP model using ‘RunGTAP’, the program for interactively solving the GTAP model. In order to investigate the welfare and environmental impacts of imported refined oil subsidy removal in Ghana, the GTAP variable ‘tm’ is shocked; i.e., the change in tax on imports of refined oil from the rest of the world to Ghana. This shock is represented in ‘RunGTAP’ as: *Shock tm(“oil”,“gha”)* $= +42$. Therefore, with information on the scale of subsidies, the analysis in this study can be easily replicated. ‘

The model applied in this study is more sophisticated and adds considerable complexity. For instance, the basic structure of CGE

[3] For details on the CES function, interested readers are referred to Arrow et al. [3]; Jorgensen and Dale [38]; Klump et al. [40].

[4] As in Lin et al. [49]; this study is constrained to reference 2006 sectoral oil consumption data due to the unavailability of more updated data. Notwithstanding, the authors argue that the 2006 sectorial oil consumption mix is still a reasonable representation of Ghana's current sectorial oil mix given the low scale of alternative energy sources and their inability to replace oil in most of the sectors considered.

[5] In the equation, 0.17 is the total subsidies on petrol which is given to be 17%, 0.67 represents the 67% subsidies on diesel, 0.50 represents the 50% subsidies on fuel oil, 0.93 represents the total sectorial share obtained from Fig. 3 and 3 represents the three different fuel types.

models has been modified to include intermediate inputs in production. Another advantage of our applied model over other CGE models is the fact that final demand in the GTAP model is able to distinguish between households, trade, capital creation and government. A diagram showing physical flows which summarizes the GTAP model is given in Fig. 4.

3.4. Data

The GTAP version 8 database with base year 2007 for 129 regions and 57 sectors provides the data for analysis in this study. Based on the 2005 SAM for Ghana [23], we aggregate the database into 9 sectors and 14 regions; corresponding to sectors and regions of particular relevance to the Ghanaian economy. The regional aggregation represents countries neighboring Ghana and major trading partners. The GTAP database was also used in Wesseh and Lin [77].

4. Simulation results

In this section, changes in welfare and environmental quality due to refined oil subsidies removal are presented. All of the variables are endogenous in the GTAP model except environmental quality.

4.1. Welfare impacts of subsidy removal

Results of welfare changes or equivalent variation (measured in $ US million) due to imported refined oil subsidy removal in Ghana are presented in Table 1. Since the removal of subsidy represent a distortion in the market, this should lead to welfare losses especially where the benefits accruing from environmental cleanup are not considered and the subsidy removal does not offset other preexisting distortions. As expected, the results reported in the first column of Table 1 show that the removal of imported refined oil subsidy in Ghana leads to a $ 935.24 million welfare loss in Ghana.

In order to calculate welfare measure which takes utility gains due to environmental benefits into account, a CES utility function defined over the standard utility aggregate in addition to environmental quality, is assumed for each consumer and given by

$$\widehat{U} = F(U, Q) \tag{1}$$

In the above expression, F has the CES functional form, U represents the estimated equivalent variation from the GTAP model, and Q is the environmental quality, defined as

$$Q = \overline{Q} - D \tag{2}$$

Where: $\overline{Q}$ represents the "endowment" of environmental quality

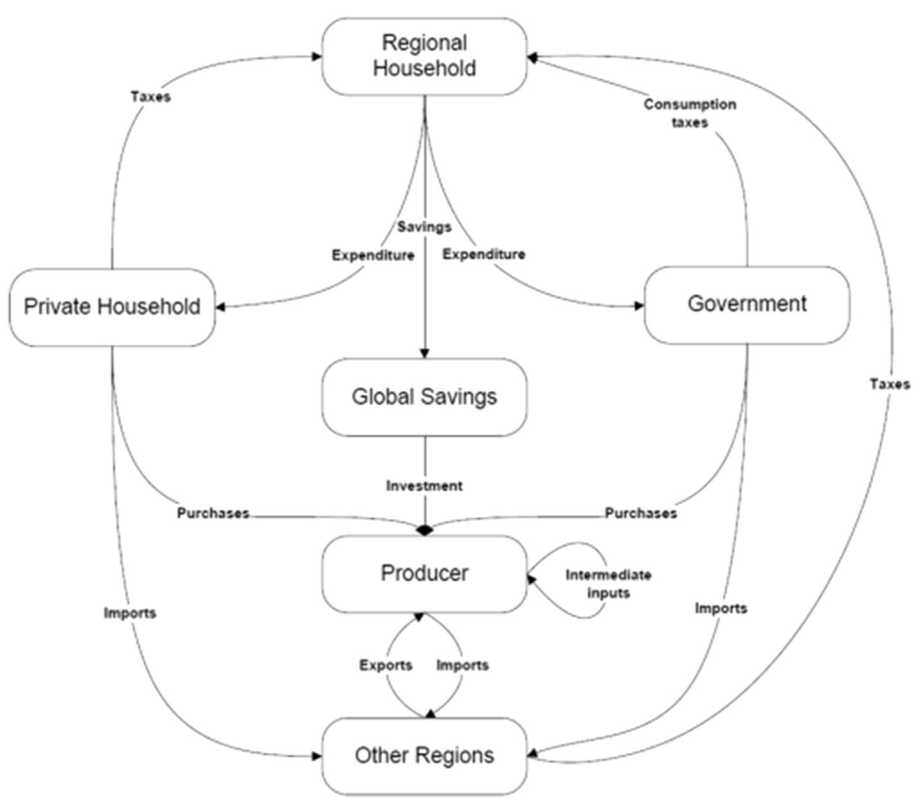

Fig. 4. The GTAP CGE model.
Source: King [39].

Table 1
Changes in welfare due to imported refined oil subsidies removal in Ghana (2007 $ US million).

Country/Region	Without environmental benefits	With environmental benefits
Ghana	−935.24	−337.8

and D symbolizes damages from emissions (Section 5.6 provides information on how damages are quantified). Given the emissions per unit output and the assumption that the marginal damage from emissions is constant, it is possible to calculate the dollar value of damages. For this reason, two parameters are assumed namely: the share of initial damages in total endowments of environmental quality ($D/\overline{Q}$) is assumed to be 0.25 in all regions and the elasticity of substitution in the CES utility function is assumed to be 0.5. With these, the share of environmental quality in utility can be determined, from which welfare values are computed.

The results in the second column show that, as opposed to a $ 935.24 million welfare loss in Ghana when environmental benefits are left unaccounted for, accounting for environmental benefits would still result in welfare losses, but by a lesser value, that is, $ 337.8 million. All other regions namely: Ivory Coast, Nigeria and the rest of Sub-Saharan Africa benefit from the improvement in environmental quality.

4.2. Impact on environmental quality

Since the applied model does not directly shed light on how the level of CO_2 emissions co-move with the removal of subsidies, the impact of subsidies removal on CO_2 emissions in Ghana is first assessed qualitatively using the data. Fig. 5 summarizes different periods in Ghanaian fuel subsidy reform. For instance, Fig. 5 shows that the reform was implemented in 2001, 2003, 2005–2008 and then 2009–2010. Therefore, in order to set the stage for properly evaluating how the removal of fuel subsidies influences the level of CO_2 emissions in Ghana, this paper compares periods and subsequent periods of reform with the total amount of CO_2 emissions from energy utilization shown in Fig. 6.

Observing from Fig. 6, one would notice that total CO_2 emissions from the utilization of energy in Ghana fell by 2.7% the year before the reform. However, after the removal of imported refined oil subsidies in 2001, total CO_2 emissions increased by 5.4% in 2002

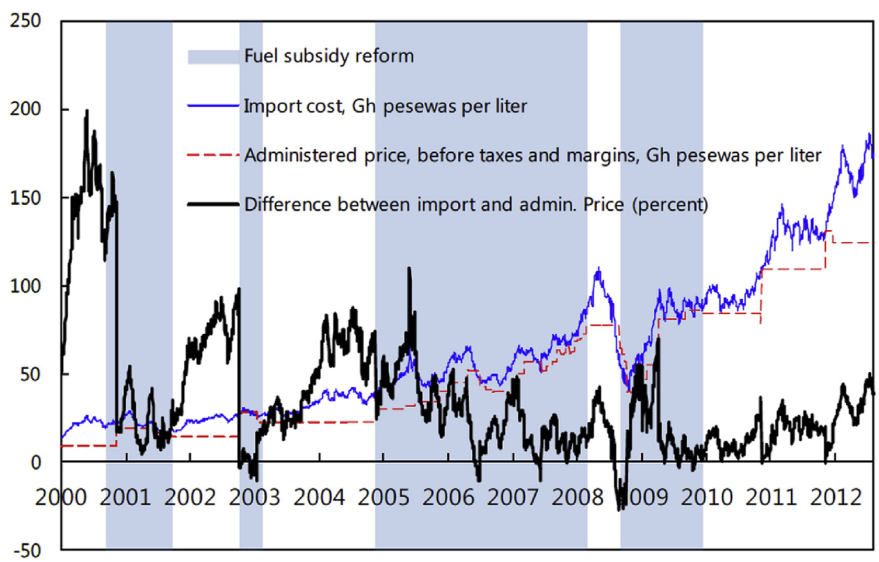

Fig. 5. Ghanaian fuel subsidy reform and price developments (2000–2012).
Source: Lin and Wesseh [51].

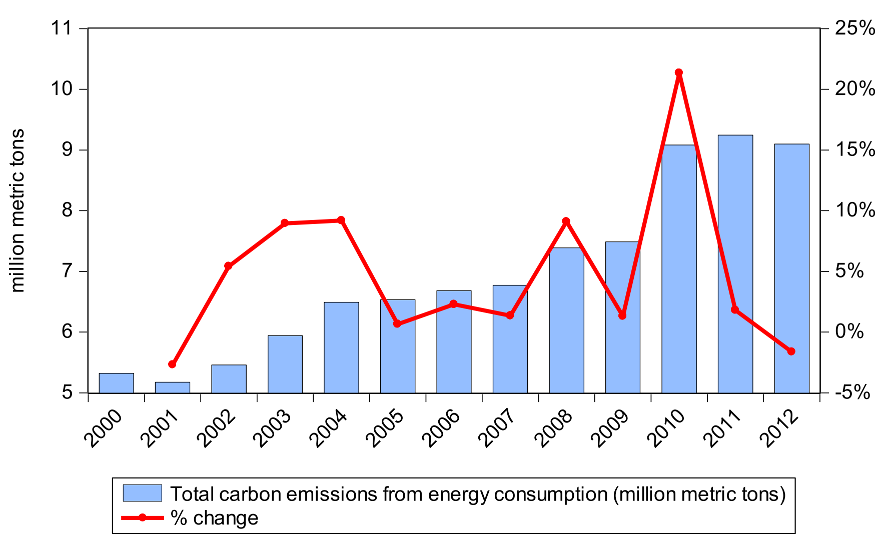

Fig. 6. Total carbon emissions from the consumption of energy.
Source: Wesseh and Lin [75].

Table 2
Environmental damages before and after the subsidy removal in Ghana (2007 $ US million).

Region	Before policy Shock	After policy shock	Reduction in environmental damage (%)
Ghana	1879.6	1842.7	1.9

and 9% from 2002 to 2003. In the same way, implementation of the reform again in 2003 saw a 9.2% rise in total emissions in 2004 and a 0.7% increase from 2004 to 2005. The periods spanning 2005–2008 and 2009–2010, all witnessed positive changes in the level of CO_2 emissions with the highest happening in 2010 – a 21.3% increase in total emissions. As a matter of fact, throughout the periods of reform profiled in our sample, the level of CO_2 emissions has always increased despite a fall in real GDP [75]. A notable exception is the year 2012 in which CO_2 emissions fall by 1.6%. Therefore, it is difficult to conclude that the removal of fossil fuel subsidies in Ghana was actually able to reach the goal of CO_2 emissions reduction.

In order to make the analysis on how fossil fuels subsidy removal affect environmental quality more satisfactory, data on damages and abatement per dollar output as well as benchmark pollution taxes provided in Wesseh and Lin [77] are employed to calculate environmental damages by region before and after the policy shock. The equation used to calculate environmental damages before the removal of subsidy is given by:

$$DE_{ij} = \left(\frac{1}{n}\sum_{i=1}^{10} X_{ij}\right)(T*) \tag{3}$$

where, DE_{ij} represents the damage-equivalent emissions for GTAP sector i in GTAP region$j$, X_{ij} is the ith GTAP commodity mapping in the jth region, n indicates all sectors that belong to GTAP sector i and $T^*_{ij} = \frac{T_{ij}}{\pi^*_i}$ is the optimal emissions tax of the ith sector in region j and π^*_i is the ith sector optimal internalization of externalities. On the other hand, damages after the subsidy removal are computed by multiplying the old value of GTAP-output (Q) by the 'after policy' output (qo) in order to obtain the new output. Multiplying by per unit emissions and summing over all goods aggregates yields new value of damage per region.

Environmental damages before and after the subsidy removal in Ghana are documented in Table 2. As shown in Table 2, the removal of subsidy on imported refined oil in Ghana reduces Ghanaian environmental damages by 1.9%.

5. Conclusions, policy implications and limitation of the study

In this study, a multi-region computable general equilibrium model was estimated to evaluate the environmental and welfare impacts of refined oil subsidies removal in Ghana. The closure which we apply is one that fixes government savings to ensure that spending of additional government income from subsidies removal is guaranteed. The results show that removal of subsidies on refined oil imports in Ghana would lead to increased rate of CO_2 emissions in Ghana; hence, demonstrating evidence of the 'green paradox'. Notwithstanding, there is an overall 1.9% improvement in environmental quality due to the subsidies removal. Despite the applied closure, welfare declines in general as a result of the subsidies removal. The decline in welfare in Ghana also affects neighboring countries, albeit marginally. In general, the present study agrees with other studies for Ghana on the point that subsidies removal leads to decline in the level of economic activities. In addition, removal of refined oil subsidies in Ghana is likely to reduce the government's financial burden provided the income from subsidies removal is not entirely redistributed.

The results reported in this study have two major implications for policy making. First, removal of subsidy on energy should be implemented along with policies aimed at stimulating economic activities and reducing the level of CO_2 emissions, especially where there is evidence of the 'green paradox'. Second, the study provides insights that governments' environmental policies could be effective by not just focusing on the level of CO_2 emissions, but as well as other pollutants.

Despite the contribution of this paper, there are few shortcomings that must be pointed out. In the first place, the study has failed to distinguish between household and refined oil types. Since subsidies removal would affect different income groups differently, for policy purposes, it would be necessary to split households and treat different refined oil products separately. Finally, the present study simulates only one scenario. Hence, splitting households and fuel types while simulating a number of policy options, is left as a valuable avenue for future research and model specification.

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