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The Economic Implications of Eliminating Coal Subsidies in G7 Countries

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The Economic Implications of Eliminating Coal Subsidies in G7 Countries

Abstract

This paper analyzes the economic implications of eliminating coal subsidies in G7 countries (Canada, France, Germany, Italy, Japan, United Kingdom, United States) in light of the Paris Agreement and the 2009 commitment to addressing climate change. The study uses a computable general equilibrium (CGE) model and contains three different simulations: production subsidy removal, consumption subsidy removal, and both consumption and production subsidy removal in G7 nations. Three variables were analyzed: economic welfare, market price, and output quantity. The results obtained using the Global Trade Analysis Project (GTAP) indicate that coal price increases and output quantity decreases, while economic welfare varies.

Keywords

CGE Model, Macroeconomics, The Group of Seven, Fossil Fuels, Subsidies, International Economics, Paris Agreement, Environmental Sustainability

Cover Page Footnote

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1. Introduction

The Paris Agreement, one of the most notable global commitments to address and combat climate change, was created on December 12, 2015 in Paris by the Parties to the United Nations Framework Convention on Climate Change (UNFCCC, 2019). On April 22, 2016 (Earth Day), the Agreement was opened for signature at the UN Headquarters in New York. It entered into force on November 4, 2016, and has been ratified by a total of 185 Parties out of 197 Parties to the Convention to this date (UNFCCC, 2019). Most notably, the Paris Agreement includes a commitment to keep the increase of global temperature under 1.5 degrees Celsius. One of the requirements in place to achieve this goal is for all Parties of the Agreement to meet their nationally determined contributions (NDCs), which are outlined in the Agreement. The commencement of the Paris Agreement has led to increased speculation and attention toward the implications of fossil fuel subsidies in nations that are Party to the UNFCCC, as fossil fuel emissions are a key contributor to climate change. Thus, it is crucial to investigate the economic implications of reducing and even eradicating fossil fuel subsidies, particularly in wealthy nations. For this reason, this paper investigates the economic implications of eliminating fossil fuels in Group of 7 nations.

The Group of 7 is a forum that consists of the world's major industrialized countries: Canada, France, Germany, Italy, the United Kingdom, and the United States. Since the G7 summit in 2009, the Group has agreed to eliminate fossil fuel subsidies by 2025. As of June 2019, the largest contributor to fossil fuel production is the United States, contributing just under 20% of the world's fossil fuels. Canada, another G7 member nation, is the number 4 global producer of fossil fuels, contributing under 5% (Glacier Media Group, 2019). These statistics indicate the importance of analyzing the impacts of reducing fossil fuel subsidies in G7 nations.

In light of the Paris Agreement and the G7 commitment to gradual reduction of subsidies, this paper analyzes the economic implications of fossil fuel elimination in G7 countries. The basis of this study is the Growth Trade Analysis Project (GTAP) database and software, which were used to model the elimination of coal subsidies. The GTAP database describes global "bilateral trade patterns, production, consumption and intermediate use of commodities and services" (GTAP). This Computable General Equilibrium (CGE) multi-region, multi-sector model is optimal for simulating the economic impacts of eliminating coal subsidies. Further explanation of the model, including the aggregation used in this study, is found in Section 4: The Model.

The novelty of this paper lies in the subject matter as well as in the research methods. First, few if any other research papers analyze the specific economic implications of eliminating coal subsidies solely in G7 nations.

Furthermore, the use of the Global Trade Analysis Project CGE model and database Version 7 lends itself to the accuracy of data and its credibility. Most notably, due to the recent nature of both the G7 commitment as well as the Paris Agreement, this study is timely and relevant to policymakers and economists worldwide.

This paper is organized as follows: Section 2 is comprised of a review of related literature pertaining to the Paris Agreement, global fossil fuel production, and fossil fuel subsidies. Section 3 describes the use of the GTAP CGE model as a quantitative framework. Section 4: Descriptive Statistics explains the relevant aspects of the baseline economy, particularly the calculations involved in determining the present fossil fuel subsidy percentages of all G7 nations. The experimental design of the study is presented and justified in Sections 5, and the results are shown and analyzed in Section 6 of the paper. The final sections consist of a conclusion, appendix, and references for sources used in this study.

2. Literature Review

Since the commencement of the Paris Agreement on November 4, 2016, multiple reports have been published regarding actions and suggestions for mitigating, addressing, and combating climate change. Of these numerous sources, a portion elaborate on the nature of fossil fuel subsidies on a global scale (although extremely few specifically study G7 nation fossil fuel subsidy reduction), providing insight into both the advantages and disadvantages of national fossil fuel subsidies as well as their effects on domestic and foreign economies. The majority of these sources are in consensus that the removal of coal subsidies would potentially aid in the mitigation of climate change, by means of discouraging inefficient energy consumption as well as allowing greater opportunity for the use of renewable energy sources. Interestingly, some sources argue that the reduction or eradication of fossil fuel subsidies could additionally have indirectly positive effects in climate change mitigation: removing fossil fuel subsidies poses the possibility of energy users making an effort to reduce energy use due to higher energy costs (Parry, 2018).

One of these such sources is Limited Emission Reductions From Fuel Subsidy Removal Except in Energy-Exporting Regions, published in *Nature*. The authors compared fuel use and CO_2 emissions with and without subsidy reform by country using five different models, and found that the removal of subsidies would decrease global energy demand, albeit only by a few percent by 2030 (Jewell, McCollum, Emmerling, Bertram, Gernaat, Krey, 2018). One of the reasons for the small decrease is that coal subsidies are already relatively minimal (Parry, 2018). In contrast to the study of this paper however, the researchers used

Integrated Assessment Models as well as projections for fossil fuel subsidy percentages in the near future.

Other sources published after the commencement of the Paris Agreement include Monasterolo and Raberto (2019). This study makes use of the EIRIN Stock-Flow Consistent Model to conclude that the gradual reduction of fossil fuel subsidies in high-income countries (defined in the study) is advantageous to the green economy (Monasterolo & Raberto, 2018). This study is similar in that it analyzes the economic implications phasing out of fossil fuel subsidies; However, it differs from the research presented in this paper as it reduces fossil fuel subsidies in all high-income countries, not the Group of 7 countries.

One notable research report on fossil fuel subsidies in regards to the United Nations Framework Convention on Climate Change is Seizing the Opportunity: Tackling Fossil Fuel Subsidies Under the UNFCCC, published in 2017. In particular, this report suggests new opportunities for the consideration of fossil fuel subsidies under the UNFCCC. Some of these suggestions include improved reporting on the subsidies themselves to ensure the awareness of policy makers, as well as the reduction of financial support for high-emission investments (van Asselt & Kulovesi, 2017). While these suggestions do not correspond directly to G7 countries, they both apply to countries including the G7 and other similar nations.

Finally, Embodied Carbon Dioxide Emission at Supra-National Scale by Z. M. Chen and G. Q. Chen presents an empirical analysis of fossil fuel induced carbon dioxide emissions on a global scale, aggregated into three regions: G7, BRIC (Brazil, Russia, India, and China), and the rest of the world (also referred to as RoW in tables) (Chen & Chen, 2011). However, it is important to note that this study was completed well before the commencement of the Paris Agreement in 2016. The overall results indicate that G7 obtained a considerable CO_2 trade surplus while BRIC had a CO2 trade deficit. While this study is similar to the one in this paper as they both regionally aggregate to isolate the G7 nations, the results are significantly different considering that this study was published in advance of the creation of the Paris Agreement.

Unlike the large majority of literature on the subject of fossil fuel subsidies and climate change mitigation in light of the 2016 UNFCCC Paris Agreement, this paper specifically presents and analyzes the economic implications of fossil fuel subsidy reduction in Group of 7 countries on an international scale, all the while referencing the Agreement itself.

3. The Model

This paper makes use of the static version of the computable general equilibrium (CGE) model Growth Trade Analysis Project (GTAP) to analyze the economic

implications of reducing the coal subsidies of G7 nations. The GTAP model was coordinated by the Center for Global Trade Analysis in Purdue University's Department of Agricultural Economics. This model informs a wealth of research, through its flagship database (released every few years).

The GTAP database is a multi-region multi-sector model that has its basis in the system of national accounts. It is important to note that the Armington assumption (based on imperfect substitutability of products in consumer behavior) is used when handling bilateral trade within the model. In this paper, the database version GTAP 7 data set (data for 2011) is used for modeling simulations. The use of this computable general equilibrium model framework to analyze the economic implications of fossil fuel subsidy reduction in the G7 countries is explained in the following paragraphs.

3.1 The Computable General Equilibrium (CGE) Model

Computable general equilibrium (CGE) models are simplified representations of the global economy that account for interactions between various notable parties including governments, producers, and consumers. CGE models rely on numerous assumptions to predict and analyze the impact of internal and external shocks such as new tariffs or policy changes on the economy. The notable assumptions made in this particular CGE model include average-cost pricing and that producers exhibit cost-minimizing behavior. Neo-classical equations are used to model these assumptions within the economic system. The CGE model database consists of various elements that allow it to be used in prediction of the economy's response to internal and external shocks: a database of transaction values, elasticity parameters and economic data of most nations.

The model has the capability to analyze purchases and sales between consumers, producers, the government and the foreign sector, and represents these relationships in the database results. Consumers for example, purchase goods and services from both domestic producers and international foreign producers. The government, notably, significantly impacts the economy by taxing or subsidizing individuals and corporations, as well implementing tariffs and subsidies on imports and exports. This paper focuses on government subsidies on fossil fuels in particular.

3.2 The GTAP Framework

As previously mentioned, the GTAP framework relies on various assumptions to provide results on the impacts of inputted economic shocks. In particular, GTAP CGE assumes perfect competition and constant returns to scale, across all the industries and trade relationships made in the database. GTAP is a multiregion, multisector model. The version of the GTAP model used in this paper, GTAP

Version 7 released in 2011, uses data on a total of 140 countries and 57 categories of goods. This feature of GTAP allows it to be used effectively when analyzing economic shocks and their impacts on different countries and industries. The other notable assumption made in GTAP 7 is the Armington assumption, which is used when handling shocks to bilateral trade relationships.

3.3 Aggregations and Variables

The GTAP software allows users to aggregate variables to isolate and analyze specific sectors, factors, or regions within the database. This section states and explains the aggregations chosen to study the economic implications of eliminating coal subsidies in G7 nations.

The geographic aggregation used in this study comprises the United States of America, United Kingdom, France, Japan, Canada, Italy, Germany, the European Union, and the Rest of the World. The United States, United Kingdom, France, Japan, Canada, Italy, and Germany are the seven members of the Group of 7, the largest advanced economies in the world, according to the International Monetary Fund. The European Union holds the responsibilities and opportunities of G7 membership, although it does not have the right to host or chair any of the G7 summits. This geographic aggregation was chosen to isolate the G7 countries from the rest of the world. This allowed the study to experiment with individual shocks to the coal subsidies of the G7 nations, but also experiment with shocking all G7 countries at once. This aggregation provided for interesting results which are presented and analyzed in Section 6, Simulation Results.

The factors were left in the 5 categories in the default standard aggregation in GTAP: land, unskilled labor, skilled labor, natural resources, and capital. As this paper studies the impacts of reducing coal subsidies, the aggregation was left as such in anticipation of a minimal impact on all five factors. This hypothesis was confirmed after running the experiments, and can also be seen in Section 6: Simulation Results.

For the purpose of this study, the 57 sectors were aggregated into 9 categories: natural resources, industrial, transport, commercial, electricity, capital goods, coal, oil, and gas. First, coal, oil, and gas were isolated as this study focuses on reducing subsidies on those three resources. The 6 other categories were aggregated based on their industries, so as to analyze the impact of fossil fuel subsidy reduction on each individual industry.

This study simulates and predicts the impacts of reductions to both consumption and production subsidies on *fossil fuels* in G7 nations individually, and all G7 nations at once. The *coal subsidies* were reduced to 0 subsidies, the methods of which are described in the following section: Descriptive Statistics.

4. Descriptive Statistics

4.1 Coal Production Subsidies

In order to remove the coal production subsidies on GTAP, it was necessary to find the percentage of the total output of coal that is subsidized in a particular nation. To derive this, this study uses 2019 data for the monetary value of each of the G7 nations' coal subsidies, in each country's national currency. These data included subsidies to budget transfers and tax exemptions, but excluded public financing subsidies. Using exchange rates as of July 9, 2019 (as reported on the XE converter website), these monetary values were converted into US Dollars, the currency used by GTAP. These values were then divided by the total sales of domestic products, found using the TVOM metric on the GTAP software. Table 1a and table 1b show the calculations that were performed to obtain the final percentage of coal production subsidies in each of the G7 countries.

Table 1a: Raw Coal Production Subsidies in the G7 Nations.

Country	Production Subsidy (Millions of National Currency)	Production Subsidy (Millions of USD)
United States	1057 USD	1057
United Kingdom		
France	0.457 EUR	0.51221474
Japan	6423 YEN	59.0434275
Canada	19.773106 CAD	15.06694859
Italy		
Germany	96 EUR	107.59872

Source: Overseas Development Institute (ODI)

Table 1b: Coal Production Subsidies as Percentages

Country	Production Subsidy (Millions of USD)	TVOM	Production Subsidy (%)
United States	1057	78368	1.348764802
United Kingdom		2223	
France	0.51221474	37.1	1.380632722
Japan	59.0434275	107	55.18077336
Canada	15.06694859	7410	0.2033326395
Italy		16.7	
Germany	107.59872	10524	1.022412771

Sources: Overseas Development Institute (ODI), Own Aggregation of the GTAP Model

The data is evidently incomplete as the United Kingdom and Italy do not have accurate reports of their annual coal production subsidies. Furthermore, Japan subsidizes coal production at a drastically high percentage of around 55%. This result, however, is consistent with the fact that Japan is the second-worst at keeping its pledges to end fossil fuel subsidies out of the G7 nations and invests substantially in fossil fuel exploration and coal mining (ODI, 2018).

When using this data on GTAP, the percentage value of the subsidy was added to the initial net tax or subsidy that was present. The initial ad valorem taxes were derived using the GTAP Model. Table 2 summarizes the results that were obtained.

Table 2: Initial Ad Valorem Tax Rates on Coal Production

Country	Initial Ad Valorem Tax Rate (%)
United States	-8.72
United Kingdom	-2.47
France	-5.39
Japan	-7.08
Canada	-2.15
Italy	-0.088
Germany	90.3

Source: Own Aggregation of the GTAP Model

4.2 Coal Consumption Subsidies

Fossil fuels' consumers can be divided into three different groups: industries, private consumers, and the government. The total national subsidies provided to consumers was found using the ODI's database. The consumption subsidies were found by adding subsidies to coal-fired power and coal consumption, which were converted into US Dollars using July 9, 2019 exchange rates as reported by the XE converter. Additionally, in order to measure total consumption in a country, the disposition of domestic sales and imports were found using DOMSALESDISP and IMPSALESDISP on the GTAP. The sum of these was found for each G7 nation. Finally, to derive a percentage, the total monetary value of the coal consumption subsidies was divided by the sum of the disposition of domestic sales and imports, using the formula $\frac{Coal\ Consumption\ Subsidies}{Domestic\ Sales + Imports}$. The results of these calculations can be seen in tables 3a, 3b, and 3c below.

Table 3a: Raw Coal Consumption Subsidies

Country	Coal-Fired Power Subsidies (Millions of National Currency)	Coal Consumption Subsidies (Millions of National Currency)	Total Coal Consumption Subsidies (Millions of National Currency)	Total Coal Consumption Subsidies (Millions of USD)
United States	173 USD	718 USD	891 USD	891
United Kingdom	127 GBP	538 GBP	665 GBP	828.62325
France	14 EUR	72.877754 EUR	86.877754 EUR	97.37432424
Japan	1261 YEN		1261 YEN	11.5917425
Canada		23.382390 CAD	23.38239 CAD	17.81719412
Italy	30.9 EUR	813.042349 EUR	843.942349 EUR	945.9074636
Germany	1963 EUR	172 EUR	2135 EUR	2392.9507

Source: Overseas Development Institute (ODI)

Table 3b: Disposition of Domestic Sales and Imports

Country	DOMSALES DISP (Millions of USD)	IMPSALES DISP (Millions of USD)	Sum of DOMSALESDISP and IMPSALESDISP (Millions of USD)
United States	65744	1219	66963
United Kingdom	2204	4260	6464
France	36.5	1902	1938.5
Japan	107	24789	24896
Canada	2153	776	2929
Italy	16.6	3205	3221.6
Germany	10421	7089	17510

Source: Own Aggregation of the GTAP Model

Table 3c: Coal Production Subsidies as a Percentage

Country	Total Coal Consumption Subsidies (Millions of USD)	Sum of DOMSALESDISP and IMPSALESDISP (Millions of USD)	Consumption Subsidy (Percentage)
United States	891	66963	1.330585547
United Kingdom	828.62325	6464	12.8190478
France	97.37432424	1938.5	5.023178965
Japan	11.5917425	24896	0.04656066236
Canada	17.81719412	2929	0.6083029744
Italy	945.9074636	3221.6	29.36141866
Germany	2392.9507	17510	13.66619475

Source: Overseas Development Institute (ODI), Own Aggregation of the GTAP Model

Again, there is some missing data, namely for coal-fired power subsidies in Canada and for coal consumption subsidies in Japan.

5. Experimental Design

Three distinct experiments were performed in this study to observe the impacts of removing coal subsidies in G7 countries. First, the coal production subsidies were removed in the G7 nations. Second, the coal consumption subsidies were removed in the G7 nations. Finally, both coal production and consumption subsidies were removed from the G7 nations. Each of these experiments was run in each of the G7 nations individually, then collectively to assess the impacts of removing coal subsidies from all G7 countries as was initially proposed in 2009.

To simulate the removal of production subsidies, the GTAP variable TO, output or income tax in region r, was shocked. This variable was shocked as it reports the net value of the output or production taxes and subsidies. In order to find the appropriate magnitudes for the shocks, data from the Overseas Development Institute (ODI) was used and the production subsidies were found as a percentage, as indicated in the Descriptive Statistics section. These subsidies were subtracted from the initial value of TO as this is representative of the

removal of subsidies. The value of TO before and after the implementation of the shock are reported in Table X.

Table 4: Implementation of Coal Production Subsidies

Country	TO Before Shock	TO After Shock
United States	-8.72	-10.0688648
United Kingdom	-2.47	
France	-5.39	-6.767032722
Japan	-7.08	-62.25707336
Canada	-2.15	-2.35023264
Italy	-0.088	
Germany	90.3	89.22878723

Source: Overseas Development Institute (ODI), Own Aggregation of the GTAP Model

It is important to note that Germany has a significantly larger TO value than any of the other G7 nations. This can be accounted for by the fact that in 2011 (GTAP Version 7 uses data from 2011), coal was the largest source of electricity in Germany, and since then, they have begun to take substantial measures in phasing out their coal production subsidies (Climate Scorecard, 2018). One example of this is the passing of the Hard Coal Funding Act in 2011 (Climate Scorecard, 2018).

To simulate the removal of consumption subsidies, six different GTAP variables were shocked. Consumers groups are divided as follows: firms, the government, and private consumers. Thus, taxes on each of these three consumers, for both domestic and imported coal, were shocked. Specifically, the variables were TFD (tax on domestic i purchased by j in r), TFM (tax on imported i purchased by j in r), TGD (tax on domestic i purchased by government household in r), TGM (tax on imported i purchased by government household in r), TPD (commodity, source-specific shift in tax on private consumption of the domestic), and TPM (commodity, source-specific shift in tax on private consumption of imports).

The percentage changes for each of these variables were determined using data from the ODI, using the calculations in the Descriptive Statistics section of

the paper. The same consumption subsidy percentage was removed from each of the six GTAP variables being shocked.

Table 5: Implementation of Coal Consumption Subsidies

Country	Consumption Subsidies After Shock
United States	-1.330585547
United Kingdom	-12.8190478
France	-5.023178965
Japan	-0.04656066236
Canada	-0.6083029744
Italy	-29.36141866
Germany	-13.66619475

Source: Overseas Development Institute (ODI), Own Aggregation of the GTAP Model

6. Simulation Results

Three main experiments were run and analyzed: the removal of coal production subsidies, the removal of coal consumption subsidies, and the removal of both coal production and consumption subsidies. In all three experiments, the effect on three different GTAP variables was measured. The first is EV, or equivalent variation, a measure of economic welfare, . The second is PM, the changes in market prices. The third variable is QO, the change in the output quantity per country.

6.1 Removal of G7 Coal Production Subsidies Only

The overall trend for the removal of coal production subsidies in G7 nations displayed a very strong effect on Japan, with the EV increasing, PM decreasing, and QO increasing. The results were likely counterintuitive due to the large shock that was implemented in Japan compared to the other G7 nations, which could possibly have not been compatible with the GTAP model. The results from the GTAP model are below:

Table 6a: Change in Equivalent Variation with Removal of G7 Coal Production Subsidies

G7 Country	EV
US	-155.37
UK	1.03
France	-0.15
Japan	540.95
Canada	-1.17
Italy	-1.6
Germany	-8.02
EU	2.7
RoW	-65.73

Source: Own Aggregation of the GTAP Model

Table 6b: Change in Market Price with Removal of G7 Coal Production Subsidies

pm	US	UK	France	Japan	Canada	Italy	Germany	EU	RoW
Land	-0.01	0	0	0.02	0	0	0	0	0
UnSkLab	-0.01	0	0	0.03	0	0	0	0	0
SkLab	-0.01	0	0	0.03	0	0	0	0	0
Capital	-0.01	0	0	0.03	0	0	0	0	0
NatRes	-0.83	0	-0.01	-3.88	-0.06	0	-0.89	0.01	-0.03
Coal	0.49	-0.02	0.22	-528.52	-0.1	0.01	0.24	0.01	-0.1
Oil	0	0	0	0	0	0	0	0	0
Gas	0	0	0	0	0	0	0	0	0
Industrial	0	0	0	0.02	0	0	0	0	0
Transport	0	0	0	0.03	0	0	0	0	0
Commercial	-0.01	0	0	0.03	0	0	0	0	0
Electricity	0.07	0	0	-0.01	0	0	0.03	0	-0.01
CGDS	0	0	0	0.02	0	0	0	0	0

Source: Own Aggregation of the GTAP Model

Table 6c: Change in Output Quantity with Removal of G7 Coal Production Subsidies

qo	US	UK	France	Japan	Canada	Italy	Germany	EU	RoW
Land	0	0	0	0	0	0	0	0	0
UnSkLab	0	0	0	0	0	0	0	0	0
SkLab	0	0	0	0	0	0	0	0	0
Capital	0	0	0	0	0	0	0	0	0
NatRes	0	0	0	0	0	0	0	0	0
Coal	-0.51	-0.01	-0.65	408.98	-0.15	0.01	-0.15	0.01	-0.05
Oil	0.01	0	0	-0.01	0	0	0	0	0
Gas	0	0	0	-0.01	0	0	0	0	0
Industrial	0	0	0	-0.01	0	0	0	0	0
Transport	0	0	0	0	0	0	0	0	0
Commercial	0	0	0	0.01	0	0	0	0	0
Electricity	-0.03	0	0	0.01	0.01	0	-0.02	0	0
CGDS	-0.02	0	0	0.05	0	0	-0.01	0	0

Source: Own Aggregation of the GTAP Model

The results for Japan are very counterintuitive and drastic. This is because of a GTAP error: many different solutions were tried and each produced a similar error.

Another notable country is the United States. Their EV decreased, which can be explained by the fact that the US is a net exporter of coal. Due to the lack of subsidies, we can see that the price of coal in the US increased and the quantity output decreased, as expected. Due to coal's large contribution to the economy in the US, it is understandable that the economic welfare of the country was affected.

Aside from the specific impacts in the US and Japan, there are other general trends in this experiment. For one, we see that apart from the US and Japan, most countries coal prices experienced relatively minimal change despite the removal of production subsidies, as those countries are not large coal producers. The same goes for output quantity, where the quantity stays around the same in all countries except for the US, France, and Japan.

6.2 Removal of Only G7 Coal Consumption Subsidies

Overall, the removal of coal consumption subsidies encourages G7 nations to utilize their domestic resources of coal, which can benefit certain nations by decreasing the price of other related resources. Most prevalent in the following tables is the benefit that Germany experiences through the decrease in the price of electricity.

Table 7a: Change in Equivalent Variation with Removal of G7 Coal Consumption Subsidies

G7 Country	EV
US	55.72
UK	87.83
France	-38.61
Japan	15.14
Canada	-31.11
Italy	349.35
Germany	573.15
EU	-108.92
RoW	-407.74

Source: Own Aggregation of the GTAP Model

A notable change is that Germany had the greatest increase in economic welfare. The change in Germany can be accounted for by the fact that Germany begins to produce more coal domestically as importing becomes more expensive and Germany has the natural resources to do so. This has the effect of making the price of electricity cheaper since coal facilitates the production of electricity. This can also be seen in Table 7b. The cheaper price of electricity allows Germany to consume more with the same income, which results in an increase in welfare.

Additionally, the Rest of the World faces the greatest decrease in welfare. A large reason for this trend is that China and India, both countries that are encompassed by the RestOfWorld GTAP aggregation, are the world's two greatest producers of coal (Enerdata, 2019). The removal of consumption subsidies from other nations decreases the amount of coal imported in those nations, which decreases the exports of coal from China and India. This forces

these two countries to decrease their production of coal, which can cause people to lose jobs and earn less income, accounting for the decrease in EV.

Table 7b: Change in Market Price with Removal of G7 Coal Consumption Subsidies

pm	US	UK	France	Japan	Canada	Italy	Germany	EU	RoW
Land	-0.01	0.05	0	0	-0.02	0.13	0.11	-0.01	-0.02
UnSkLab	-0.01	0.04	-0.01	0	-0.02	0.12	0.11	-0.01	-0.02
SkLab	-0.01	0.03	-0.01	0	-0.02	0.11	0.1	-0.01	-0.02
Capital	0	0.04	-0.01	0	-0.02	0.11	0.1	-0.01	-0.02
NatRes	0.13	0.07	0.01	0.13	0.03	0.02	2.94	0.05	0.03
Coal	0.15	0.89	0.77	6.49	0.09	1.59	0.98	0.04	0.06
Oil	-0.01	-0.01	-0.01	-0.01	-0.01	0	-0.01	-0.02	-0.01
Gas	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Industrial	-0.01	-0.01	-0.01	-0.01	-0.02	0.02	0	-0.01	-0.01
Transport	-0.01	0	-0.01	0	-0.02	0.02	0.02	-0.01	-0.01
Commercial	-0.01	0.02	-0.01	0	-0.02	0.08	0.06	-0.01	-0.01
Electricity	-0.21	-1.05	-0.07	-0.09	0.06	-0.84	-1.81	-0.01	0
CGDS	-0.01	-0.01	-0.01	-0.01	-0.02	0.02	0	-0.01	-0.01

Source: Own Aggregation of the GTAP Model

Overall, coal prices in all parts of the world increase, which is consistent with the expected results when a subsidy is removed. It can be noted that Japan's prices increase the most. This can be attributed to the fact that Japan is heavily reliant on coal, which accounts for 27% of its energy production (EIA, 2017). Furthermore, Japan imports most of the coal that it uses, and thus its net coal imports are very high, ranking the third-highest globally (Enerdata, 2019). Out of the total 189 metric tons (Mt) of coal that Japan used in 2018, 184.4 Mt was imported (Enerdata, 2018). Removing coal consumption subsidies would evidently affect Japan substantially, as the effects of Japan's high usage of coal and high dependency of imports are combined. Without the subsidies, Japanese consumers would have to pay a higher price for the coal that they use. Italy also experiences a high increase in price, which can also be attributed to the fact that it relies highly on imports of coal.

Furthermore, the price of natural resources in Germany increased while the price of electricity in Germany decreased. It is crucial to note in this instance that both of these sectors are heavily related to coal. Since importing becomes less desirable due to the removal of consumption subsidies, the demand for domestic natural resources grows. Germany has substantial amounts of coal and thus begins to produce more coal domestically. This has the effect of making electricity less expensive in the nation, as a large portion of electricity is produced using coal.

Table 7c: Change in Output Quantity with Removal of G7 Coal Consumption Subsidies

qo	US	UK	France	Japan	Canada	Italy	Germany	EU	RoW
Land	0	0	0	0	0	0	0	0	0
UnSkLab	0	0	0	0	0	0	0	0	0
SkLab	0	0	0	0	0	0	0	0	0
Capital	0	0	0	0	0	0	0	0	0
NatRes	0	0	0	0	0	0	0	0	0
Coal	0.08	0.47	0.41	2.81	0.05	0.99	0.47	0.03	0.04
Oil	0	-0.02	0	-0.01	0	-0.04	-0.02	0	0
Gas	0.01	-0.01	0.02	0.01	0.02	-0.04	0.01	0.02	0.02
Industrial	0	0.01	0.01	0	0	0.02	0	0	0
Transport	0	-0.01	0.01	0	0.01	-0.02	-0.02	0.01	0
Commercial	0	-0.02	0	0	0	-0.02	-0.03	0	0
Electricity	0.07	0.34	-0.16	0.02	-0.09	0.29	1.2	-0.18	-0.03
CGDS	-0.01	0.09	-0.03	0.01	-0.04	0.34	0.23	-0.04	-0.03

Source: Own Aggregation of the GTAP Model

In the above table, Japan increases its coal output. As imports become more costly due to the shocks implemented, Japan begins to produce more coal domestically, which increases the output quantity in this nation. Germany's quantity of electrical output increases as well. The reasoning for this is the same as the reasoning behind the decreased market price for electricity in Table Xb: electricity becomes less expensive to produce, allowing more of it to be produced with the same amount of money.

6.3 Removal of G7 Coal Consumption and Production Subsidies

The changes that can be observed here are mostly a combination of the changes that occurred in the removals of coal production and consumption subsidies separately. However, it is important to note that the effects on price had a greater magnitude than the effects on the quantity of output.

Table 8a: Change in Equivalent Variation with Removal of G7 Coal Production and Consumption Subsidies

G7 Country	EV
US	3.96
UK	79.52
France	-34.94
Japan	-124.19
Canada	-6.08
Italy	348.32
Germany	539.47
EU	-115.82
RoW	-296.85

Source: Own Aggregation of the GTAP Model

The main trends that can be observed here are that Italy and Germany have the most substantial increases in welfare. This is likely due to the fact that electricity becomes less expensive. Electricity is a necessity for most people in the two aforementioned countries, so the decrease in its price caused by the increased domestic production of coal likely benefits numerous people and allows them to consume more electricity with the same amount of income. This trend is demonstrated in table 7c above.

The Rest of the World has the most substantial decrease in welfare, with Japan and the EU also experiencing decreases in welfare. The effect of the Rest of the World is likely due to the fact that China and India are large coal producers and the effect on Japan is mostly due to the removal of its large production subsidies.

Table 8b: Change in Market Price with Removal of G7 Coal Production and Consumption Subsidies

pm	US	UK	France	Japan	Canada	Italy	Germany	EU	RoW
Land	-0.01	0.05	0	0	-0.02	0.13	0.11	-0.01	-0.02
UnSkLab	-0.01	0.04	0	0	-0.02	0.12	0.11	-0.01	-0.01
SkLab	-0.01	0.04	0	0	-0.02	0.12	0.1	-0.01	-0.01
Capital	-0.01	0.04	-0.01	0	-0.02	0.12	0.1	-0.01	-0.01
NatRes	-0.54	0.1	0	-0.35	0.04	0.02	2.54	0.22	0.11
Coal	0.85	1.09	1.22	77.33	0.38	1.84	1.4	0.26	0.29
Oil	-0.01	-0.01	-0.01	-0.01	-0.01	0	-0.01	-0.01	-0.01
Gas	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02
Industrial	-0.01	-0.01	-0.01	-0.01	-0.01	0.02	0	-0.01	-0.01
Transport	-0.01	0.01	-0.01	-0.01	-0.01	0.03	0.02	-0.01	-0.01
Commercial	-0.01	0.02	-0.01	-0.01	-0.01	0.09	0.06	-0.01	-0.01
Electricity	-0.1	-1.03	-0.06	-0.08	0.08	-0.83	-1.76	0.01	0.04
CGDS	-0.01	0	-0.01	-0.01	-0.01	0.02	0.01	-0.01	-0.01

Source: Own Aggregation of the GTAP Model

Generally, coal prices rise all over the world. This is a logical happening since both the production and consumption of coal has stopped being subsidized in the G7 nations, allowing the market for coal to return to its natural equilibrium. Additionally, there is also a higher demand for natural gas, a common alternative to coal, so the prices of natural gas increase in all parts of the world. However, this increase is not very large.

The price of coal in Japan increases greatly, likely due to their large, pre-existing coal production subsidies. Prices in Italy increase as well due to the significant coal consumption subsidy that was in place. Germany's prices of natural resources increased, and prices of electricity fell, consistent with the results from removing only the consumption subsidies.

Table 8c: Change in Output Quantity with Removal of G7 Coal Production and Consumption Subsidies

qo	US	UK	France	Japan	Canada	Italy	Germany	EU	RoW
Land	0	0	0	0	0	0	0	0	0
UnSkLab	0	0	0	0	0	0	0	0	0
SkLab	0	0	0	0	0	0	0	0	0
Capital	0	0	0	0	0	0	0	0	0
NatRes	0	0	0	0	0	0	0	0	0
Coal	-0.32	0.57	-0.1	-98.33	0.09	1.08	0.4	0.14	0.15
Oil	0	-0.02	0	0	0	-0.04	-0.02	0	0
Gas	0.01	-0.01	0.01	0.01	0.01	-0.04	0	0.01	0.01
Industrial	0	0.01	0.01	0	0	0.02	0	0	0
Transport	0	-0.01	0	0	0.01	-0.02	-0.02	0.01	0
Commercial	0	-0.02	0	0	0	-0.02	-0.03	0	0
Electricity	0.03	0.34	-0.16	0.02	-0.08	0.29	1.17	-0.18	-0.03
CGDS	-0.02	0.1	-0.02	0	-0.03	0.35	0.23	-0.04	-0.02

Source: Own Aggregation of the GTAP Model

Notable changes present are the substantial decrease in the output of coal from Japan, due to its large production subsidies. Overall, however, the changes in the output of coal are much less than the changes in price, due to the fact that the G7 nations are not the main producers of coal.

7. Conclusion

This paper presents and evaluates the economic implications of the elimination of coal subsidies in G7 nations both individually, and all at once. In particular, this study draws attention to the impacts of such changes on economic welfare, market prices, and quantity output per country. These three metrics allow policymakers and economists alike to comprehend the economic results of eliminating coal subsidies (production, consumption, and both) in G7 nations.

The notable use of the GTAP CGE model lends to the novelty of this study, as well as the accuracy and credibility of the results presented.

In the first study, removal of solely G7 coal production subsidies causes the welfare metric of large coal producers to rise. As well, in the same study, it is evident that the output quantity of coal dropped in most G7 countries, as well as in the rest of the world.

The second study, removal of solely G7 coal consumption subsidies was notable due to the increased coal prices worldwide, which is consistent with expectations following subsidy removal of any product.

Finally, in the last study, the removal of both G7 subsidies, US, UK, Italy and Germany saw an increase in welfare, while the remaining G7 countries did not. This likely lends itself to the cost of electricity in the member nations. Similarly to the second study, coal prices rise globally, and coal output levels decrease.

In Relation to the Paris Agreement this study indicates that reduction of coal subsidies in largely industrialized and prosperous nations would likely lead to a lower output of coal, contributing to the goal of mitigating and addressing climate change. As well, these results indicate that policymakers should consider both the economic as well as environmental implications of fossil fuel subsidies when it comes time to gradually eliminate them in accordance with the 2009 G7 commitment and the 2016 Paris Agreement.

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