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EE489: Seminar in Industrial Economics

Electric vehicles and fuel vehicles

: An empirical analysis

Presents

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By

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"This paper analyse the damage of both fuel vehicles and electric vehicles across 6 states in the US by focusing on the cost that they create from emission, demographic factors, and location of power plants. Where data sets were collected during 2010 to 2014 and use OLS models as analysis tool. The result shows that overall electric vehicles are more beneficial, since they create less cost than fuel vehicles, and can have more positive impact in the urban areas where there are more damage created by fuel vehicles."

Introduction

18th century, Europe, steam powered engine was invented and replaced the horses for moving carriages. However, it was restricted on public road and most of their duty was on the private rail, even their initial purpose was to use on public road. More than half of the century after steam power engine introduced, the first internal combustion engine that run by fuel was invented and later developed into the engine that we use modern automobiles.

Internal combustion engines (ICE) are the engines that powered by petroleum, diesel, LPG or kerosene (Michaelis, 1995). One of the reasons that make this kind of engine become more successful than other is because availability to access petroleum during the period of 19th century, also it has been using in various kind of transportation. For instance, cars, planes and boats. Across the same period, electric vehicles (EV) are invented as an alternative for internal combustion engines and with better technology development they get more attention in the market and increase in demand, especially in urban areas. There are some main features that can be found only in electric vehicles, for instance, they are quiet, easy to drive and not emit pollution. However, with cheap price of gasoline caused electric vehicles to fall short and internal combustion engines dominated the market.

In the late 20th century, electric vehicles got their attention back again, since there was a shortage in gasoline and surged in price, but most importantly the environmental concern. Motor vehicles caused pollution and other forms of environmental damage (Delucchi, 2000), government started to implement regulation that would prevent engines to create more pollution by subsidizing on electric vehicle purchase and imposing vehicle miles traveled tax (Holland, 2016).

This paper examines emission from driving fuel vehicles and charging electric vehicles in the United State of America by using econometric model to analyse the effects of each kind of vehicles from the cost that it creates. Also, this paper is going to answer two

questions. First, can electric vehicles be the replacement of fuel vehicles in term of emission cost that it creates, since people have belief that electric vehicles are emission free, but in reality emission is already created from the power plants that produce electricity to run those vehicles. Second, will electric vehicles be more effective in urban areas than rural areas, hence in the urban areas with higher congestion of both people and fuel vehicles should create more emission and electric vehicles can solve the problems.

The first part of the seminar paper consists of literature review from other research paper, which has similar ideas across this topic. Then, it is followed up by methodology, where it discusses on the data that use in this paper and explain the econometric model that uses to analyse the data. After that, the result from regression is explained in detail, where the result is analysed in the conclusion.

Literature review

Motor vehicles are the cause of pollutions and environmental damages which consider as externalities to private decisions. Since, the cost that motor vehicles create is high, alternative fuels and electric vehicles are suggested applications. From the result (Delucchi, 2000), it shows that electric vehicles create less external cost, however the cost use for introduce electric vehicles might exceed health benefits from reduce air pollution. On the other hand, fossil fuel provides substantial economic benefits, but rises with environmental cost. Technology breakthrough is required for transportation sector to use battery for power generation, and compare operating cost of electric vehicle to a combustion engine. As a result, oil price needs to be higher for electric vehicle to be cost competitive, meaning that in short and middle-term electric vehicle cannot replace fueled combustion engines (Covert, 2016).

Several governments believed that there are cheaper alternatives to oil, in which alternative fuel vehicles (AFV) and electric vehicles (EV) gain their attention due to possibilities that can reduce pollution and emission. Author (Michaelis, 1995) believes that in long term those alternative vehicles will replace internal combustion engines (ICE), and focuses on roles of alternatives on pollution, also effectiveness and cost on emission policy. As a government, there is range of subsidies from them for purchasing an electric vehicle depends on each state. Also, they focus on environmental benefits by examining air pollution damages from gasoline vehicles and electric vehicles. Authors (Holland, 2016) use theoretical model to illustrate environmental benefits by calculating from emission per mile of electric vehicle and gasoline vehicles in each state. Then, they use econometric model to determine emission form electricity the use to charge electric vehicles. As a result, metropolitan areas create benefits, while outside metropolitan areas create negative benefits, and air pollution tends to export to other states with more gasoline vehicles.

In term of tax policies, both carbon tax and energy tax are the most cost-efficient for reduce emission and energy consumption, since they internalize the carbon cost and minimize it, which is better than setting standard where it is least efficient way due to lower energy price that will not make incentive for creating carbon-free technology and cause sector with high energy usage become more energy-intensive which make the result worse in the long-run. Therefore, standard policy cannot cover all the sectors which make overall reduction in consumption small compare to tax policies (Yuan, 2011).

While other research papers mainly focus on effects from government intervention, which come as a tax and subsidy, or look at the usage and price of the fuel. In this seminar paper, the result is going to reflect the effects from various variables that come from both vehicles and demographic information, which have uniqueness and different way of analysis. Since, there are 4 econometric models that use to analyse in different situations.

Methodology

The data that use in this seminar paper will be taken from one of the research paper from American Economic Review (Holland, 2016). In the research paper, the authors have a concern about environmental issue, since car manufacturers develop new electric vehicle models into the market, which influenced by various reasons. For instance, technology advancement, production cost, different in price between electricity and oil, and subsidy from government. They observation is whether there is a short-term benefit from using electric vehicle or not. First, they are looking at damage from charging depend on time of charging. Second, the environmental benefits of each kind of car models corresponding to subsidy from government in each area. Third, amount of pollution that transfer across the state and causation of the pollution movement, which is connected with government subsidy in each areas, since United State of America has federal system that creates local government which implement their own subsidy programs. Their analysis is derived from two models, econometric model that focuses on emission from power plants that create electricity that use to charge those electric vehicles, and AP2 model that covers damage from local pollution (Holland, 2016).

The data sets were collected during 2010 to 2014, which includes record of different models of vehicles in every state in USA with a total of 31 models, 20 models from fuel vehicles and 11 from electric vehicles. Also, amount of emission that vehicles create and their damage in term of cent per mile. In this paper, where 6 variables are collected, 5 variables are categorized as damage from fuel vehicles; consist of damage from carbon dioxide, particulate matter less than 2.5 micrometers, sulfur dioxide, nitrogen oxide, volatile organic compound, and 1 variable categorized as damage from electric vehicle.

In the seminar paper, data is used in a form of cross sectional data, and choose only 6 states as a sample size for whole country. The chosen states are California, Florida, New

York, Georgia, Kansas, and Montana, the identification is made by United State Census Bureau by using specified criteria to identify urban areas from rural areas. The United State Census Bureau identifies 2 type of urban areas, urbanized areas where population reaches 50,000 people or more, and urban clusters where population is more than 2,500 people, but less than 50,000 people. Also, there are other factors to be considered, which include density, land use, and distance. First, the area needs to have a density of 1,000 people per square mile, if density is not reached minimum threshold, then it must be a combination of residential and non-residential area. Second, land cover needs to be used for non-residential landscape. For instance, parking lots and airport. Third, some residential areas are still considered as urban areas, even if the areas are separated by a large regional park, shopping center, or other commercial development.

Also, all the demographic data is taken from United State Census Bureau, where the data was collected and estimated from American Community Survey (ACS), and then official data was released through the Census Bureau's Population Estimates Program. Income per household, percentage of people graduated in high school, and number of population in each city data sets are selected to use in this paper to analyses and see the effect of income, education, and population.

The locations of power plants are taken from the website called Global Energy Observatory (GEO), where it is a database for global energy information. One of features is generating a map and locating all the power plants in the world, also identifies the type of power plants. So, location data in this paper is collected by searching the map of each state, which includes 8 kinds of power plant, consist of *coal*, *gas*, *geothermal*, *hydro*, *nuclear*, *oil*, *waste*, and *water*.

Across 6 states, there are 507 cities which are going to be our observation in the model. Since, the data set has separated in the detail, it covers all of the damage for each

models of cars in each cities of the state. Therefore, the data set that use in this paper is rearranged to average of damages across all models, both fuel and electric vehicles, in term of cent per mile in each cities and use those data in the regression. Then, the result will show how significant those emissions that both vehicles create impact the overall marginal damage. I choose to analyse difference of damage between fuel vehicle and electric vehicle, because from the source that I take data set from includes every factors that can possibly create damage and classified as marginal damage, in the case where marginal damage is increasing the reason is either from increasing in fuel vehicle damage or decreasing in electric vehicle damage, however in the case where marginal damage is decreasing the reason is either from decreasing in fuel vehicle damage or increasing in electric vehicle damage. Moreover, average income per house hold data set is divided by 10,000 and number of population in each city data set is divided by 1,000,000 in order to make whole data set have same digit value at one's place.

Econometric Model

In this seminar paper consists of 4 econometric models where first model illustrates the relationship between difference in the damage in each city of the states in USA and damage that is created by both fuel vehicles and electric vehicles. Where the marginal damage is the difference between damage from fuel vehicles subtracted by damage from electric vehicles, which also includes all the damage that is already existed. Second model has damage that is created by fuel vehicle as dependent variable, and finds relationship between dependent variables and other independent variables except marginal damage. Model 3 is similar to model 2 excepts it uses electric vehicle damage as dependent variable and fuel vehicle damage becomes one of the independent variables. Lastly, model 4 shows

the relationship between total damage the created by both fuel and electric vehicles, and demographic information and power plant location.

Regression Formula:

Model 1:

$$Y = \beta_0 + \beta_1\, fuelcost + \beta_2\, evcost + \beta_3\, urban + \beta_4\, income + \beta_5\, edu + \beta_6\, population + \beta_7\, coal + \beta_8\, gas + \beta_9\, geo + \beta_{10}\, hydro + \beta_{11}\, nuc + \beta_{12}\, oil + \beta_{13}\, waste + \beta_{14}\, wind + \mathcal{E}$$

To determine whether fuel vehicles or electric vehicles create more damage to environment and which factors have more impact to overall damage that is created. The dependent variable in the model is marginal damage (Marginaldmg), the difference in total damage in a city created by of fuel vehicles and electric vehicles. The model consists of 5 quantitative variables and 9 dummy variables. For qualitative variables, *fuelcost* is a combination of all damages that created by fuel vehicles, consist of carbon dioxide, particulate matter less than 2.5 micrometers, sulfur dioxide, nitrogen oxide, and volatile organic compound. Also, *evcost* represents damage that created by electric vehicles in term of cent per mile. Income per household and percentage of people graduated in high school is represented by *income* and *edu* respectively. Lastly, *population* represents number of population in each city.

Variable *urban* is a dummy variable represents area that classified as urban area by United State Census Bureau, so urban areas are given the value of 1 and rural areas are given the value of 0. Other dummy variables are under the same category, consist of *coal*, *gas*, *geo*, *hydro*, *nuc*, *oil*, *waste*, and *wind*, it represents the type of power plants that located in cities in each state. Where *coal* represents coal power plant, *gas* represents gas power plant, *geo*

represents geothermal power plant, *hydro* represents hydro power plant, *nuc* represents nuclear power plant, *oil* represents oil power plant, *waste* represents waste power plant, and *wind* represents wind power plant. So, the areas that have power plant are given the value of 1 depend on what kind of power plants they have in the areas and value of 0 are given to the areas that do not have power plant, and also depend on what kind of power plants they do not have.

Model 2:

$$Y = \beta_0 + \beta_1\, evcost + \beta_2\, urban + \beta_3\, income + \beta_4\, edu + \beta_5\, population + \beta_6\, coal + \beta_7\, gas + \beta_8\, geo + \beta_9\, hydro + \beta_{10}\, nuc + \beta_{11}\, oil + \beta_{12}\, waste + \beta_{13}\, wind + \mathcal{E}$$

Model 3:

$$Y = \beta_0 + \beta_1\, fuelcost + \beta_2\, urban + \beta_3\, income + \beta_4\, edu + \beta_5\, population + \beta_6\, coal + \beta_7\, gas + \beta_8\, geo + \beta_9\, hydro + \beta_{10}\, nuc + \beta_{11}\, oil + \beta_{12}\, waste + \beta_{13}\, wind + \mathcal{E}$$

Model 2 has *fuelcost* as dependent variable and model 3 has *evcost* as dependent variable, both of model consists of 13 variables, which the purpose of both models is to find how of each independent variables in the models explain their dependent variable, since the result may different in each case.

Model 4:

$$Y = \beta_0 + \beta_1\, urban + \beta_2\, income + \beta_3\, edu + \beta_4\, population + \beta_5\, coal + \beta_6\, gas + \beta_7\, geo + \beta_8\, hydro + \beta_9\, nuc + \beta_{10}\, oil + \beta_{11}\, waste + \beta_{12}\, wind + \mathcal{E}$$

Model 4 has *totaldmg* as dependent variable, that represents as total damage that come from the combination fuel vehicle damage and electric vehicle damage, consists of 12

independent variables, which shows how can those independent variables explain total damage that is created by both fuel and electric vehicles.

Result

The damage can be caused by many factors, either from emission that is created by vehicles or demographic factors. Ordinary Least Squares (OLS) is used in the analysis, since more than one variable uses to predict value of one dependent variable. From Table 1, we can see summary of the data that use in this regression analysis, where it shows all variables that use in the equation and indicates their observation, mean, standard deviation, minimum value, and maximum value. According to Table 2, with 95 percent confidence interval there are 8 significant variables. First, across 507 observations and 14 variables that use in this regression, R-square is at 95.59% meaning that independent variables are well-explained the dependent variable.

The main purpose of this first model regression is to test whether these factors have any impact on marginal damage or not by looking at both vehicles and demographic factors and there are 8 factors that are significant include *fuelcost, evcost, population, income, edu, hydro, nuc, and oil*.

First, the dependent variable is marginal damage where it is the difference between fuel vehicle damage and electric vehicle damage, meaning that electric vehicle cost is negative from the data collection. The outcome shows that both vehicles cost have statistically significant relationship with marginal damage; fuel vehicles can increase marginal damage by 103.9%, while electric vehicles can decrease marginal damage by 89%.

Table1: Data Summary

Variable	Observations	Mean	Std. dev	Min	Max
Marginaldmg	507	-0.872	0.916	-3.337	3.161
fuelcost	507	1.526	0.236	1.33	1.84
evcost	507	2.464	0.875	0.031	4.807
population	507	0.175	0.576	0.001	9.818
urban	507	0.453	0.498	0	1
income	507	58.9	14.321	0	1
edu	507	85.518	6.914	0	1
coal	507	0.094	0.293	0	1
gas	507	0.272	0.445	0	1
geo	507	0.001	0.044	0	1
hydro	507	0.153	0.361	0	1
nuc	507	0.019	0.139	0	1
oil	507	0.122	0.327	0	1
waste	507	0.108	0.311	0	1
wind	507	0.015	0.124	0	1

Second, in terms of demographic factors, it includes income per household in each city, percentage of population that graduated in high school and population in each city. Income is a significant factor, but not highly impact marginal damage which can be increased at 6.4%. However, education has negative impact on marginal damage and can decrease the dependent variable by -0.7%. Also, population has a positive impact on marginal damage, which can increase dependent variable by 30.8%.

Third, electric vehicles create their damage from electricity power plants, since it generates source of energy that power those vehicles. There are many types of power plants located around the areas in the states. So, power plants are variables that need to be considered and only one the significant variable is the areas with hydro power plant, nuclear power plant, and oil power plant located in, which can increase marginal damage by -6%, -22.4%, and 5.7% respectively.

Table 2: Regression Result

	(1) Marginaldmg	(2) fuelcost	(3) evcost	(4) totaldmg
fuelcost	1.039***		0.713***	
	(21.86)		(3.59)	
evcost	-0.893***	0.0358***		
	(-83.86)	(3.59)		
urban	0.0258	0.160***	-0.186*	0.0835
	(1.21)	(8.49)	(-2.08)	(0.93)
edu	-0.00715***	-0.00571***	-0.00559	-0.0160*
	(-4.52)	(-3.87)	(-0.84)	(-2.27)
income	0.0638***	0.0584***	-0.0874*	0.00969
	(7.43)	(7.58)	(-2.42)	(0.26)
population	0.308***	0.0553**	-0.236**	-0.154
	(17.25)	(3.31)	(-3.16)	(-1.94)
coal	-0.0468	0.0914**	0.192	0.365**
	(-1.52)	(3.16)	(1.48)	(2.65)
gas	-0.0108	-0.00723	0.0840	0.0766
	(-0.51)	(-0.36)	(0.93)	(0.79)
geo	-0.0986	-0.230	-1.423	-1.917*
	(-0.50)	(-1.23)	(-1.71)	(-2.16)
hydro	-0.0593*	0.0319	-0.326**	-0.291**
	(-2.38)	(1.35)	(-3.13)	(-2.60)
nuc	-0.224***	0.00531	0.0463	0.0586
	(-3.36)	(0.08)	(0.16)	(0.19)
oil	0.0572*	-0.000220	0.296*	0.314*
	(2.01)	(-0.01)	(2.48)	(2.45)
waste	-0.0492	0.0649*	-0.262*	-0.164
	(-1.66)	(2.32)	(-2.10)	(-1.24)
wind	-0.0280	0.0165	-0.671*	-0.684*
	(-0.40)	(0.25)	(-2.25)	(-2.14)
_cons	-0.0681	1.482***	2.509***	5.272***
	(-0.49)	(13.08)	(4.35)	(10.27)
N	507	507	507	507

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

For model 2 where fuel vehicle cost is dependent variable, R-square is at 40.40% with 7 significant independent variables. There are 3 variables that significant and different from the main model, includes *urban, coal,* and *waste*, which affect the dependent variable by 16%, 9.1%, and 6.5% respectively. Also, *evcost*, *income* and *population* have positive impact on fuel vehicle cost. However, *edu* has a negative impact on dependent variable.

Electric vehicle cost is dependent variable in the model 3, with R-square of 13.39% and 8 significant variables, includes *fuelcost, urban, income, population, hydro, oil, waste,* and *wind*. From the result, almost all of the significant variables have negative impact on electric vehicle cost except *fuelcost*, and *oil*, where they can increase dependent variable by 71.3% and 29.6% respectively.

In the model 4 where total damage is dependent variable, with R- square of 8.14% and 6 significant variables, includes *edu, coal, geo, hydro, oil*, and *wind*. Only *coal* and *oil* can create positive impact on total damage by 36.5% and 31.4%, while other significant variables have negative impact on dependent variables.

Conclusion

Technology is always developing and innovation is going faster than ever, people try to find a new ways of doing thing that has been doing in the same way for decades. Vehicle is one of products that people try to push it into another level by making it works more effectively, since there are many concerns occurred from issues that it can create. Until now, where electric vehicle is introduced as an alternative for ordinary fuel vehicle, and there are beliefs that this is the solution for the problems that are existed.

According to hypothesis, this paper wants to find out that can electric vehicle be an alternative vehicle choice or it is already good enough by using fuel vehicle. From the result,

the increase of fuel vehicle damage has caused marginal damage to increase by 103.9%, while the increase of electric vehicle damage has caused marginal damage to decrease by 89%, so as an overall economy we can see that electric vehicle creates less environmental damage than fuel vehicles by 14.6%, it implies that electric vehicle is a better choice for people to choose from since it creates more benefit to society, even they have positive relationship in model 2, when the number of cars increase in the same proportion, but the actual number of cars is different, since there are more fuel vehicles than electric vehicles, meaning that there is also different in term of pollution created, which make electric vehicle has low impact in model 2. Also, electric vehicle is beneficial in the area with oil power plants located in the area, since the marginal damage can increased by 5.7%. Even though, overall marginal damage is increasing, but the reason behind is due to electric vehicle that create less cost which is better off if the area has more electric vehicles. However, electric vehicle can cause more damage if the area has hydro power plant or nuclear power plant located in the area. Moreover, if we look at the total damage, location with coal power plant or oil power plant are going to increase the overall damage, while geothermal power plant, hydro power plant or wind power plant are going to decrease the overall damage.

In term of demographic result, we can answer another question in this paper that urban areas are going to be better with more electric vehicles. Even though, urban area is not significant in the first model, but model 2 and model 3 are able to explain, we can see that urban areas are going to increase fuel vehicle damage, while decreasing the damage for electric vehicle, meaning that electric vehicle could be more beneficial in urban areas, due to the fact that being in the urban areas, there are more electric vehicles than fuel vehicles in the areas. Moreover, both income per household and education of people have lower impact to marginal damage compare to other variables due to the unit of measurement where income has positive impact, while education has negative impact on marginal damage. We can see

that people tend to create more emission through fuel vehicles when they obtain more income, which is directly proportional to marginal damage. However, it is different case with education where it is inversely proportional to marginal damage; more than 80% of American citizens have graduated high school, meaning that people with higher education have more environmental concern, which can reduce the marginal damage even if their impact is small. Also, population does increase both marginal damage and fuel vehicle damage, but decrease electric vehicle damage, by comparing the effect of population in model 1 and model 2, we can see that the higher population in the area, the higher marginal damage it creates, but fuel vehicle damage that is affected by population is lower than the marginal damage, and have negative effect with electric vehicle, meaning that population creates small portion of damage through both kinds of vehicles compare to the damage that population can create by itself.

To conclude, with all the factors combine we can see that electric vehicle is better than fuel vehicle in many ways and potentially become the next people choices of vehicles in the future.

Limitation

There is also a limitation in this seminar paper, since all the observations in this paper are the cities in United State of America; some variable is not viable in this analysis due to insufficient data. For instance, income per capita were intended to use in the analysis, however there is not enough detailed data to be collected. Only data for income per household is recorded in each city and fit with my data set. Also, there are no data that specified the actual number of fuel vehicles and electric vehicles in each city.

Reference

Beresteanu, A., & Li, S. (2011). GASOLINE PRICES, GOVERNMENT SUPPORT, AND THE DEMAND FOR HYBRID VEHICLES IN THE UNITED STATES. *International Economic Review, 52*(1), 161-182. Retrieved from http://www.jstor.org/stable/23016626

Branch, G. P. (2012, September 01). [Data file]. Urban and Rural. Retrieved from https://www.census.gov/geo/reference/urban-rural.html

Carlsson, F., & Johansson-Stenman, O. (2003). Costs and Benefits of Electric Vehicles: A 2010 Perspective. *Journal of Transport Economics and Policy, 37*(1), 1-28. Retrieved from http://www.jstor.org/stable/20053920

Covert, T., Greenstone, M., & Knittel, C. (2016). Will We Ever Stop Using Fossil Fuels? *The Journal of Economic Perspectives, 30*(1), 117-137. Retrieved from http://www.jstor.org/stable/43710013

Data Access and Dissemination Systems (DADS). (2010, October 05). [Data file] Retrieved from https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml

Delucchi, M. (2000). Environmental Externalities of Motor-Vehicle Use in the US. *Journal of Transport Economics and Policy, 34*(2), 135-168. Retrieved from http://www.jstor.org/stable/20053837

Fullerton, D., & Gan, L. (2005). Cost-Effective Policies to Reduce Vehicle Emissions. *The American Economic Review, 95*(2), 300-304. Retrieved from http://www.jstor.org/stable/4132836

Holland, S., Mansur, E., Muller, N., & Yates, A. (2016). Are There Environmental Benefits from Driving Electric Vehicles? The Importance of Local Factors. *American Economic Review*, 106 (12): 3700-3729. [Data file]. DOI: 10.1257/aer.20150897

Knittel, C. (2012). Reducing Petroleum Consumption from Transportation. *The Journal of Economic Perspectives, 26*(1), 93-118. Retrieved from http://www.jstor.org/stable/41348808

Liu, C., Greene, D., & Bunch, D. (2014). Vehicle Manufacturer Technology Adoption and Pricing Strategies under Fuel Economy/Emissions Standards and Feebates. *The Energy Journal, 35*(3), 71-89. Retrieved from http://www.jstor.org/stable/24694919

Map Data in GEO - GEO Systems. (n.d.). [Interactive map that shows power plant locations]. Retrieved from http://globalenergyobservatory.org/constructNetworkIndex.php

Sioshansi, R. (2012). OR Forum—Modeling the Impacts of Electricity Tariffs on Plug-In Hybrid Electric Vehicle Charging, Costs, and Emissions. *Operations Research, 60*(3), 506-516. Retrieved from http://www.jstor.org/stable/23260149

Yuan, M., Tuladhar, S., Bernstein, P., & Lane, L. (2011). Policy Effectiveness in Energy Conservation and Emission Reduction. *The Energy Journal, 32*, 153-172. Retrieved from http://www.jstor.org/stable/41323313