Welfare Distortions of Climate Change Policies

by

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Submitted to the Engineering Systems Division
in Partial Fulfillment of the Requirements for the Degree of

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Abstract

The economic cost of reducing greenhouse gas (GHG) emission is an important policy consideration. As public awareness of climate change consequences increase, there is increased political support for greenhouse gas emission controls. However, there are disagreements over the intensity of controls as well as the implementation timeline. A major factor of consideration is the economic cost. Due to the complexity of the climate change issue, many people have chosen to focus on the carbon equivalent quota price as a proxy for the magnitude of cost. While the carbon price is a helpful guide, it provides an incomplete picture of all the distortions and their interactions. This thesis aims to break down the different components of welfare loss in computer general equilibrium (CGE) models, so as to further understand the issue.

The MIT Emissions Prediction and Policy Analysis (EPPA) model, a large-scale computable general equilibrium (CGE) model, simulates trends in global economics and greenhouse gas emissions. Utilizing the EPPA model, I examined the distortions resulting from carbon taxation, domestic taxation, changes in terms of trade, international oil market effect, and international capital flow.

This thesis focused on Japan and the European Union, showing that high carbon price does not always correlate with a proportional high percentage welfare loss. The distortion induced by interaction of non-carbon taxation dwarfs that of carbon taxation. As a result, some countries with a high carbon price may experience low national welfare loss relative to other countries with lower carbon price. Finally, I complete the thesis by examining the different policy implications for this detailed understanding of economic cost of climate change policies.

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1. INTRODUCTION

1.1 Thesis Motivations

The economic cost of reducing GHG emission is an important policy consideration. Globally businesses and politicians have often resisted any changes that will adversely affect the competitive advantage of their products on the international market. The current U.S. administration has consistently rejected the Kyoto Protocol of 1997 as too costly and flawed in its implementation. Similarly developing countries have fiercely refused to agree to any initiatives that may suggest progression into carbon dioxide constraints on their countries in the future, even though these initiatives may bring about short-term financial or technical benefits.

Due to the complexity of the climate change issue, many people have chosen to focus on the carbon equivalent quota price as a proxy for the magnitude of the costs. The economic cost is then estimated using the area under the marginal abatement cost (MAC) curve, with the area being half of the carbon price multiplied with the quantity of carbon emission reduction. As such, a high carbon price is commonly accepted as an indictor of high economic cost to the country, and a low carbon price is seen as an indicator of low economic cost. However, analyses with the MIT Emissions Prediction and Policy (EPPA) model have shown that a high carbon price does not always correlate with a proportional high percentage welfare loss for each individual country.

In order to fully understand this seemingly puzzling phenomenon of high carbon price and low percentage welfare loss from one country relative to another country, we need to break down the various components of welfare loss within a computable general equilibrium (CGE) model. Using the EPPA model, I decomposed the welfare loss components of Japan and Europe. I find that while the MAC curve can estimate the direct cost implementation of carbon reduction policies it fails to consider interaction effects from trade and taxation. These interaction effects include changes in terms of trade of a country, andtaxation of domestic goods and services (fuel, intermediate, consumption, and etc taxes). In countries with high levels of trade and domestic taxation, the non-carbon distortions are often many times higher than the direct carbon distortions. With this analysis, I show that the carbon price does not present a full picture of the economic situation and the welfare loss from carbon policies for each country is not directly correlated to its carbon price.

1.2 Overview of the Thesis

The objective of this thesis is to analyze the different aspects of economic loss in a country facing a carbon limiting policy. Using the MIT EPPA model to provide the analytical framework, I modified the model and extracted relevant economic data for analysis. Chapter 2 introduces the model as well as the different modeling scenarios. Following that, Chapter 3 traces the different sources of economic distortions within two EPPA regions, Japan and the European Union (E.U.). I present the theory behind each source and then go on to apply the EPPA model to confirm the theory. This exercise begins by looking at the commonly recognized marginal abatement curve (MAC) estimates of the carbon distortion, then goes on to examine the effects of domestic taxation distortions. Domestic taxation rates applied in the EPPA model are derived from the GTAP 5 database, and they include intermediate taxation and excise taxation. Changes in cost structure of the country's different industry sector can affect its competitiveness in the international market. This change in the country's terms of trade is also analyzed. A specific example of a terms of trade effect is changes in world oil markets. With a GHG limiting policy applied in the developed countries, we can expect a fall in the international demand for oil. This reduction in the price of oil provides a national benefit for oil importing countries that we call the oil market effect. Finally, the decomposition results are compared with the other measurement of cost.

Chapter 4 goes on to explore the limitations of the theories and simulation methods used in this thesis. Chapter 5 focuses on the policy implications of the new understanding on the different components of welfare loss in a country under carbon limiting policies. Understanding the components create opportunities for policy instruments to mitigate the magnitude of the distortions by targeting specific elements of the economy. However, even with these opportunities, I suggest how political resistance may prevent their implementation. The thesis is concluded in Chapter 6.

2. MODELING DISTORTIONS

2.1 The EPPA Model

In order to analyze the welfare distortion effects, I used the MIT Emissions Prediction and Policy Analysis (EPPA) model simulate the scenarios of interest. The EPPA model (Babiker et al., 2001) includes the capability to project emissions of CO_2, non- CO_2 greenhouse gases and range of other emissions that directly and indirectly affect the radiative properties of the atmosphere. This model also simulates the world economy to produce anthropogenic greenhouse gas emission scenarios, thus allowing the analysis of the economic impacts of different climate policies. EPPA is a recursive dynamic multi-regional general equilibrium model. It is built on a comprehensive energy-economy data set from GTAP that accommodates a consistent representation of energy markets in physical units as well as detailed accounts of regional production and bilateral trade flows. The base year for the model is 1997, and it is solved recursively at 5-year intervals through 2100. The analysis in this thesis is performed with EPPA version 4, which incorporates sixteen regions and eight sectors (see Table 1). Not only does EPPA version 4 incorporate new GTAP 5 economic data, it also incorporates new and improved estimat7es of the non-CO_2 greenhouse gases and other pollutants.

Within CGE models, the circular flow of goods and services is simulated as shown in Figure 1. In the products market, the firms (production sector) provide goods and services to the households (consumers) while the households provide factor inputs (labor and capital) back to the firms. In the flow of payments, the households make payment to the firms for the goods and services while the payment to labor and capital are transferred to the households. Taxes (or subsidies) levied by government affect consumer and producer choices even with tax revenue returned to the household. The effect of taxes or subsidies on consumer and producer decisions are referred to as distortions because the marginal value of consumption differs from the marginal cost of producing the good by the tax or subsidy level. Additional details about the structure of taxes within the EPPA model are present in Chapter 3.

Table 1: Countries, Regions, and Sectors in the EPPA Model

Country or Region	Sectors
Annex B	**Non-Energy**
United States (USA)	Agriculture (AGRI)
Canada (CAN)	Services (SERV)
Japan (JPN)	Energy Intensive products (EINT)
European Union+[1] (EUR)	Other Industries products (OTHR)
Australia/New Zealand (ANZ)	Transportation (TRAN)
Former Soviet Union[2] (FSU)	**Energy**
Eastern Europe[3] (EET)	Coal (COAL)
Non-Annex B	Crude Oil (OIL)
India (IND)	Refined Oil (ROIL)
China (CHN)	Natural Gas (GAS)
Indonesia (IDZ)	Electric: Fossil (ELEC)
Higher Income East Asia[4] (ASI)	Electric: Hydro (HYDR)
Mexico (MEX)	Electric: Nuclear (NUCL)
Central and South America (LAM)	Electric: Solar and Wind (SOLW)
Middle East (MES)	Electric: Biomass (BIOM)
Africa (AFR)	Electric: Natural Gas Comb.Cycle
Rest of World[5] (ROW)	Electric: NGCC w/ Sequestration
	Electric: Integrated Gasification w/ Combined Cycle and Sequestration (IGCC)
	Oil from Shale (SYNO)
	Synthetic Gas (SYNG)
	Household
	Own-Supplied Transport (OTS)
	Purchased Transport Supply (PTS)

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[1] The European Union (EU-15) plus countries of the European Free Trade Area (Norway, Switzerland, Iceland).

[2] Russia and Ukraine, Latvia, Lithuania and Estonia (which are included in Annex B) and Azerbaijan, Armenia, Belarus, Georgia, Kyrgyzstan, Kazakhstan, Moldova, Tajikistan, Turkmenistan, and Uzbekistan which are not. The total carbon-equivalent emissions of these excluded regions were about 20% of those of the FSU in 1995. At COP-7 Kazakhstan, which makes up 5-10% of the FSU total joined Annex I and indicated its intention to assume an Annex B target.

[3] ᶜIncludes a number of former Yugoslav republics and Albania not Part of Annex B, which contribute only a small percentage of the overall emissions of the Region.

[4] South Korea, Malaysia, Phillipines, Singapore, Taiwan, Thailand

[5] All countries not included elsewhere: Turkey, and mostly Asian countries.]

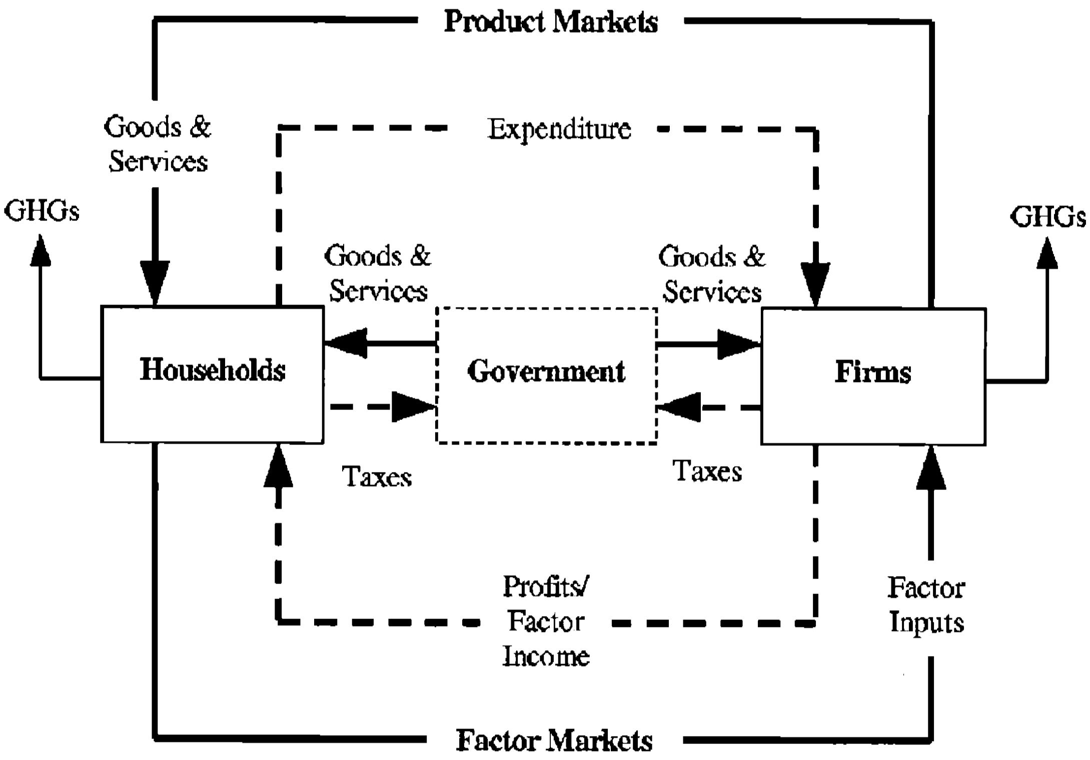

Figure 1: Circular Flow of Goods and Services in an Economy

3.2 Modeling Scenarios

In order to analyze the effects of the welfare distortions, results from two EPPA model scenarios are compared. The first is the reference scenario, where the country under analysis is not constrained by any carbon limiting policy, while the other countries fulfill the requirements of the Kyoto Protocol. The second is a policy scenario where carbon limiting policies are applied according to the Kyoto Protocol agreements. A summary of the policies applied in each scenario is presented in Table 2.

Table 2: Regional Targets in Scenarios

	Scenarios	
Regions	**Reference**	**Policy**
US	Intensity Targets	Intensity Targets
Japan / E.U.	No constraints	Kyoto

Other Annex B countries	Kyoto	Kyoto
Developing Countries	No constraints	No constraints

Except for the U.S., each Annex B country agrees to reduce their GHG emissions to levels agreed upon as part of the Kyoto Protocol, by the year 2010. For the timeframe of consideration, the developing countries and the country under analysis will not have any policy constrains placed on them. I assumed that the USA meets an intensity target as proposed by the current Administration (See Figure 2) This intensity reduction aims to achieve an 18% reduction in CO2 emissions per GDP over the next decade. With the increase in GDP, the corresponding absolute quantity of CO2 emissions is allowed to increase. This is contrasted to the fixed Kyoto constraints, which gets progressively much tighter as economy grows with time.

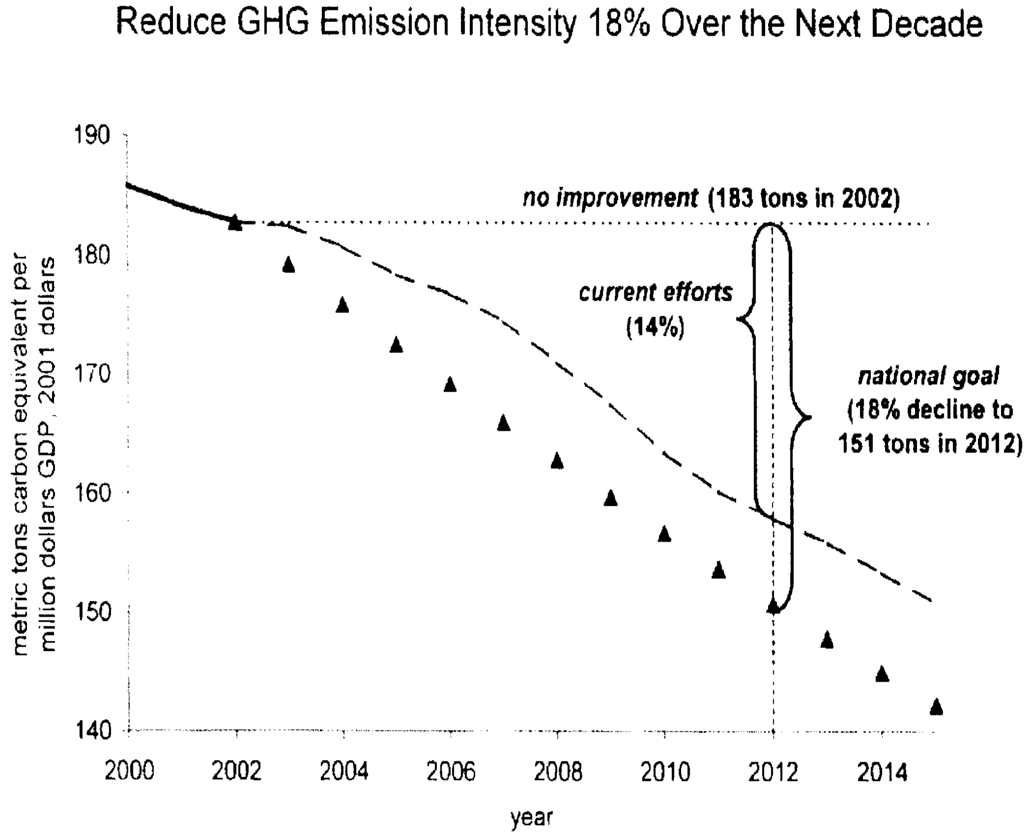

Figure 2: Bush Administration Intensity Target for the US (White House, 2002)

An international GHG trading system where countries can exchange emission permits is commonly accepted as the ideal long-term system to equalize marginal cost of GHG abatement between countries. The Kyoto Protocol includes provisions for international permit trading. However, it is unclear whether parties will be in the position to make use of this provision. Studies with full trading across all Kyoto Protocol remaining parties suggest that the cap may not be binding (Babiker et al, 2002). Such a scenario would have no cost, and not therefore provided an interesting case to evaluate for my purpose.

3. DECOMPOSITION OF WELFARE LOSS

3.1 Marginal Abatement Curve

The marginal abatement curve (MAC) traces the cost of the carbon policy across different levels of carbon abatement. In the year 2010, a range of twenty abatement levels from the reference emission level is simulated in the EPPA model. The carbon prices from the simulation are plotted, and the plotted line is the marginal abatement curve. It is the marginal abatement curve because the carbon price is the unit cost of the least, i.e. the marginal, ton abated. The marginal abatement curves for Japan and the European Union are presented in Figures 3 and 4 respectively.

As readily available solutions to carbon emissions are exhausted, countries are forced to reduce emissions at progressively higher carbon price. This is shown in the exponential form of the MAC. Each additional quantity of carbon emission abatement corresponds with a higher carbon price. By adding each of these small increases in abatement quantity, multiplied with each corresponding carbon price, the marginal economic cost to the society is obtained. The sum of all the small increments gives the total economic cost to the economy. It is important to note that this economic cost only represents one component of the total welfare loss that the households face.

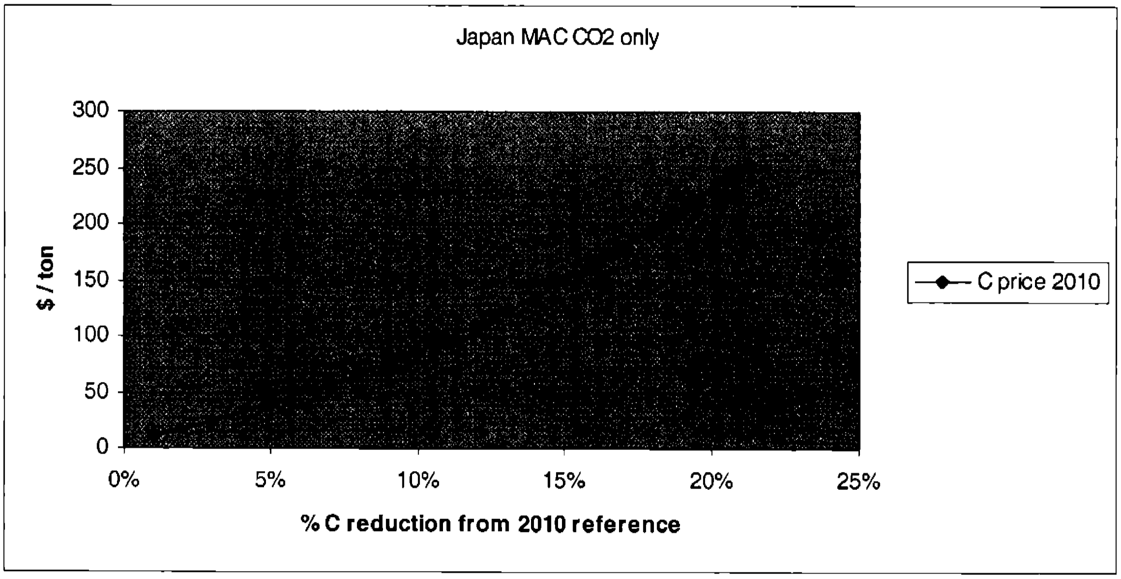

Figure 3: MAC for Japan in 2010

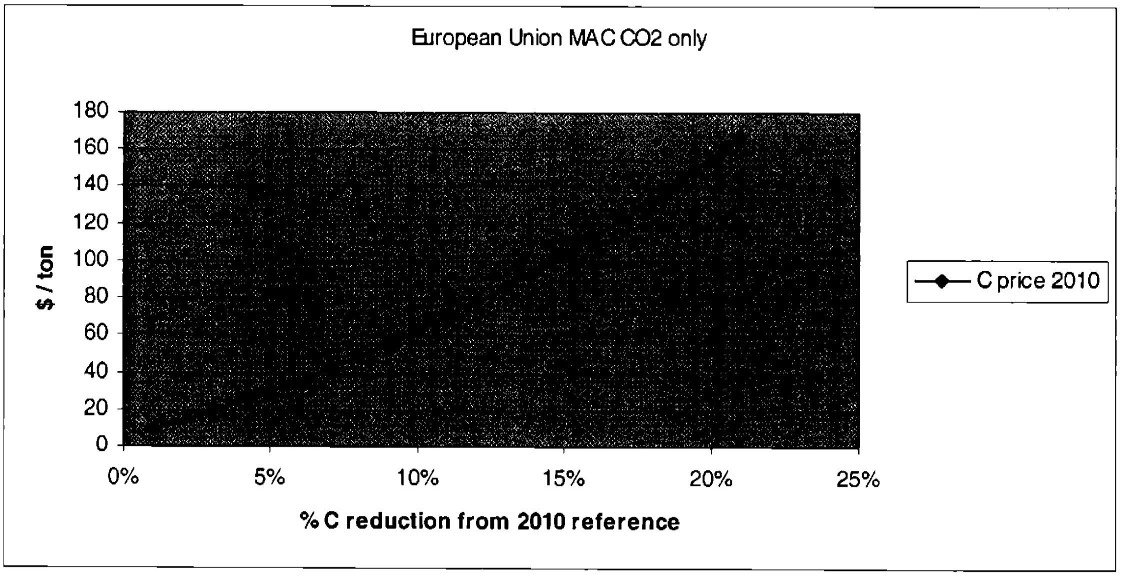

Figure 4: MAC for the E.U. in 2010

3.2 Welfare Loss from domestic taxation

The GTAP 5 database is provides the key economic data for version 4 of the EPPA model. GTAP data includes five types of taxes within an economy, namely intermediate, excise, export, import and consumption taxes. In general these taxes vary by economic sector and good. For example, the intermediate tax on refined oil products is different in transportation than in energy intensive industries.

Taxes are applied to consumption of intermediate goods in each country. This intermediate level taxation affects the cost of resources to downstream industries and correspondingly the quantity supplied of goods and services by the upstream industries. As the carbon quota is likely to have the most impact on increasing the cost of intermediate fuel use, I will look specifically at the intermediate energy demand for each industry sector in this paper. The taxation on other non-energy intermediate goods and services are assumed to have small or no impact on the welfare loss.

Just as intermediate taxes are applied to goods and services to the downstream industries, goods and services to households (final demand) are also taxed. In this paper, I will focus on the taxation on household consumption of fuels. In Japan there is no coal use by households, a small level of natural gas consumption, and a larger proportion of refined oil usage. In certain sectors of the economy, the government collects excise taxes for transactions. This is often applied to the sale of alcohol, cigarettes, used cars or jewelry.

Within an economy, it is possible to examine the specific distortion for each individual sector and fuel type. Gardner (1983) showed how effects of a policy decision are distributed through an economy. I follow a similar approach to decompose the direct cost of a carbon tax, distortion and trade effects, broken down by sector and by fuel. To check this decomposition I sum these to get the total economic loss, and compare that to the total consumption loss reported directly in the EPPA model. The subsequent paragraphs go in detail on how the carbon and domestic taxation induced distortion for each fuel and in each sector are calculated.

The market demand and supply curves are shown in Figure 5. For a small and open economy importing most of its fossil fuels, the supply is assumed to be perfectly elastic, as it does not affect the international supply of the fuel. This is especially true for a Japan, and the similar assumption is applied to the E.U. In Figure 5, Q2 is the policy quantity that is obtained from the model when a carbon limiting policy is applied to the country. On the vertical axis, Q2 corresponds to the final price that includes the domestic taxation as well as the carbon taxation. Applying the same elasticity equation above, I multiplied the percentage change in price in the policy scenario with the individual fuel elasticity. This allows us to extract the quantity demanded of each fuel (Q1 to Q2). This estimate is used with the assumption that the demand curve is linear and downward sloping. With this Q1 figure, I can now estimate the distortion for each sector and fuel. The distortion from carbon taxation is the area within the shaded triangle, while the domestic tax distortion is the area within the shaded rectangle.

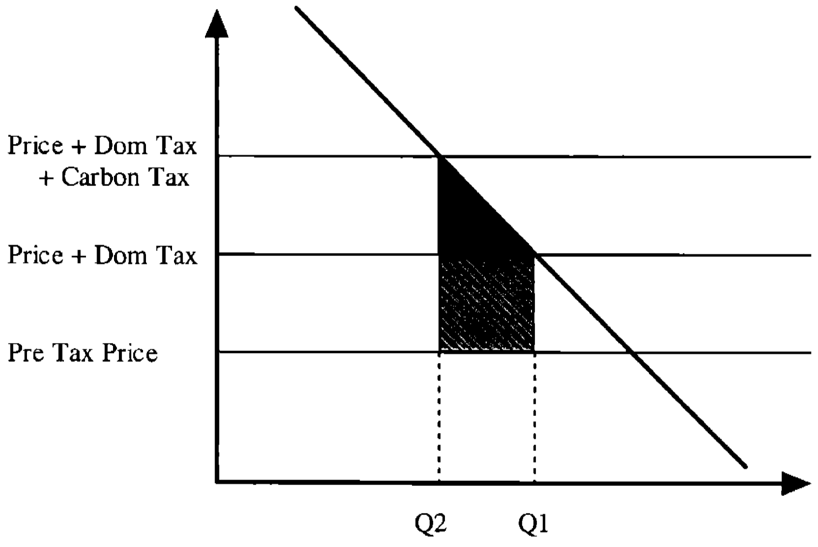

Figure 5: **Effects of Existing Fuel Taxes on the Cost of a Carbon Policy**

However, based on EPPA simulation results, the reality is more complicated. With the implementation of a carbon policy, not only do I see a movement along a demand curve as shown in Figure 5, but also a shift because the prices of other fuels are simultaneously changing. For certain sector and fuel combinations, there is an increase in demand, while in other combinations there is a fall in demand. An example is illustrated in Figure 6, with the demand curve shifting inwards from D1 to D2. In this case I observe from the model the pre-policy point (a) and the post policy point (b). If I interpreted this as a movement along the demand curve, it would appear that the demand curve was the dashed line D3. If so, I would have overestimated the triangle area as ½ * carbon price * (Q1-Q2). Instead I need an estimate of Q1'.

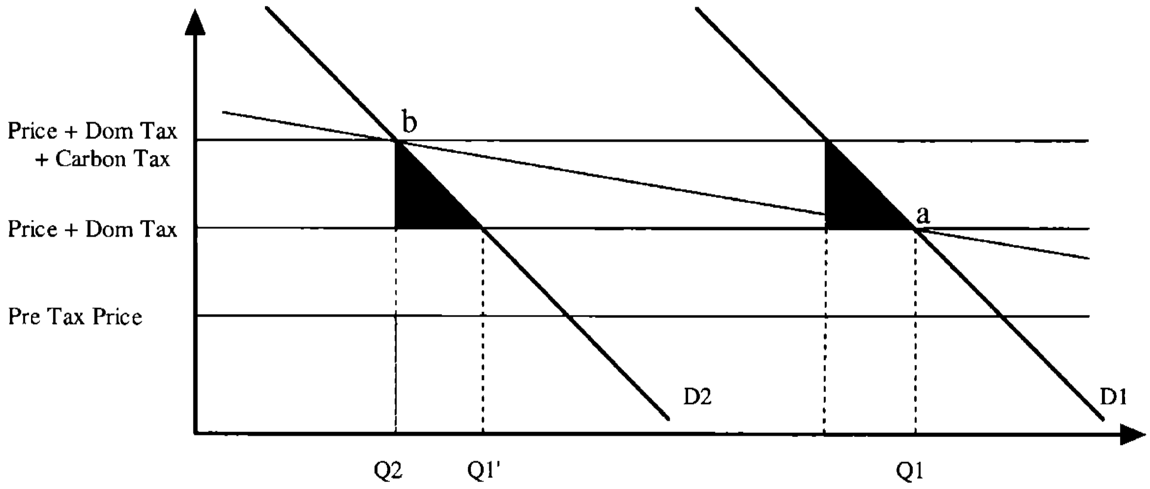

Figure 6: Effects of Existing Fuel Taxes on the Cost of a Carbon Policy under Shifting Demand

In order to estimate Q1' and subsequently the fuel use distortions, I will need to obtain the demand elasticity of substitution for the fuel use within each sector. This fuel use elasticity can be estimated in two ways. One way is a numerical method, changing the fuel price by a specific percentage, simulating the model, and finding the percentage change in quantity of fuel used. The second way is to analytically solve the expression for the elasticity from the CES production function used in the EPPA model.

The numerical method of estimating the demand elasticity involves changing the overall cost of fuel type in each industry sector. The elasticity of demand (ε_d) for each fuel and sector can be calculated using the following equation.

$$\varepsilon_d = \frac{\%\ Change\ in\ Q}{\%\ Change\ in\ P}$$

This method obtains the fuel response of the economy to a change in the fuel price in that sector, including downstream substitution among goods because the prices have changed due to the change in the price of fuel.

To get a comparable analytical estimate, I needed to estimate unit demand elasticity from the CES nest that contains this fuel. I then need to trace the follow on output effects.

The analytical method involves tracing unit demand of the nested constant elasticity of The EPPA model utilizes constant elasticity of substitution (CES) function, which exists under a specific form expressed as:

$$P_0 = \left(\theta\,[P_1]^{\sigma-1} + (1-\theta)\,[P_2]^{\sigma-1}\right)^{\frac{1}{1-\sigma}}$$

Where

P_0 is the price of the output of the emitting sector
P_1 is the unit price of the fuel input
P_2 is the unit price of the other input in the fuel nest
θ and (1- θ) are the shares of P_1 and P_2 in factor payments
σ is the elasticity of substitution between the two inputs

Differentiating P0 with respect to P1, the unit demand function X_1 is obtained.

$$X_1 = \theta\,[\frac{P_0}{P_1}]^{\sigma}$$

The price elasticity of demand can be obtained by taking the derivative of X_1 with respect to P_1.

$$\varepsilon = -\frac{\theta\,\sigma}{P_1}(\frac{P_0}{P_1})^{\sigma} + \frac{\theta\,\sigma}{P_0}(\frac{P_0}{P_1})^{\sigma}$$

Multiplying the price elasticity of demand with P_1 / X_1, the elasticity of demand is obtained as follows.

$$\varepsilon_d = -\sigma\left(1 - \frac{P_1}{p_0}\right)$$

Within the EPPA model, nested CES functions are used to model the change in demand within the economy. Thus the same calculations can be applied to a three level nested CES function to derive the final demand elasticity of demand for each fuel and each sector. Differentiating across the entire nest structure of the model will be a large task given the complex production structure in EPPA. Thus this analytical method was not utilized.

With the data on the demand elasticity, I can now estimate the actual change in quantity demanded of each fuel from the application of the carbon taxation in the policy scenario. Correspondingly, I obtain the individual carbon and domestic tax distortion by fuel and sector.

In the electricity generation sector, while there may not be any carbon taxation applied so as to avoid double taxation, the domestic taxation distortion still exists. The same derivation of elasticity is applied and the domestic taxation distortion is computed. In Japan, the government taxation on fuel use in the electricity generation sector is small, thus this distortion forms a considerably small share of the overall domestic distortion.

According to Rosen (1998), the overall excess burden of a set of taxes can be calculated with the following equation.

$$Burden = -\frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} t_i P_i t_j P_j S_{ij}$$

Where P_i = before-tax price of the *i*th commodity

t_i = ad valorem tax on the *i*th commodity

S_{ij} = compensated response in the demand of the *i*th good with respect to a change in the price of the *j*th good.

This form does not require estimates of the price elasticities, using only the pre and post-policy quantities and prices.

Applying the above equation to the taxes within the EPPA model, I obtained a very close match with estimates of the area in the triangle formed by the MAC. This result supported the other method that utilizes the elasticity of demand. However, to gain greater accuracy, I chose to focus solely on calculating the distortion using the elasticity of demand from the market to market analysis.

3.4 Terms of Trade

According to Krugman & Obstfeld (1997), the terms of trade is the price of the good a country initially exports divided by the price of the good it initially imports. The index that measures terms of trade is as:

$$TOT\ index = \frac{\sum_i p_{i,e} Q_{i,e}}{\sum_i p_{i,m} Q_{i,m}}$$

Where $p_{i,e}$ = export prices of good *i*
$P_{i,m}$ = import prices of good *i*
$Q_{i,e}$ = export quantity of good *i*
$Q_{i,m}$ = import quantity of good *i*

An increase in the export prices relative to the import prices intuitively means that the country can now enjoy greater amount of imported goods and services for the same level of exports. Conversely an increase of import prices relative to export prices means that the country's competitiveness has decreased and lower levels of imports are now consumed for the same level of exports. Thus changes in terms of trade plays an important impact on the country's welfare.

In order to obtain the magnitude of influence of trade on a country, not only do I need to know the export and import prices, I also need to know the volume of trade. This volume of trade, excluding trading of oil (that has been taken into consideration under the oil market effects), is derived from the model. The welfare gain from terms of trade changes is calculated with the following equation:

$$TOT\ Gain = \sum_i (p_{i,e,pol} - p_{i,e,ref}) Q_{i,e} - \sum_i (p_{i,m,pol} - p_{i,m,ref}) Q_{i,m}$$

Where the subscripts 'pol' and 'ref' refer to the value of these variables in the policy and reference scenarios respectively.

The international trade in oil is an important source of energy for many countries around the world. This is especially true for countries like Japan, which do not produce sufficient domestic fuels. As such, any change in the demand for oil internationally will have a significant impact on Japan. The international oil market is an important component of the terms of trade. In order to examine this effect in detail, analysis is performed for the terms of trade effect without the oil market, as well as the oil market effect independently.

With a carbon policy applied globally, the global demand for fossil fuels is reduced. This lowers the international price of refined oil and provides an exogenous source of import savings. While this price reduction is moderated by the increase in consumption by the developing countries that are not under the Kyoto quotas, the effects of the fall in demand from developed countries dominates. Japan relies on fuel imports for much of the domestic energy demand, with nuclear power covering the additional demand.

I derived the international crude oil price and the level of domestic oil demand for both the reference as well as the policy scenario. The change in level of domestic oil demand is calculated with the production in the policy scenario minus the oil export plus the oil imports. Subsequently the estimate of the oil market effect is then calculated with the change in level of price multiplied with the new policy scenario international oil price.

3.6 Analysis of results

Within the MIT EPPA model, welfare loss is calculated based on the change in household consumption levels from the reference scenario. Comparing the consumption loss figures with the sum of all the different distortions analyzed, a good match is obtained. The results of the calculations are summarized in Table 3 and 4.

This calculation provided me with a very close approximation of the carbon distortion from the EPPA model. For the purpose of comparing the total economic distortions, I integrated the area under the MAC, producing an accurate carbon loss figure that matched the elasticity estimates. The gains from the terms of trade as well as oil market effect are small relative to the economic loss from the carbon and domestic taxation induced distortion. With the high level of taxes within the two countries, this is not surprising. Finally, to equalize international capital movements within the EPPA model, the model corrects for capital flows. This correction ranges from 10% to 18% of the overall welfare cost, and it varies according to the specific closure of the foreign sector in EPPA.

The close match between the MAC and the carbon distortion provided me the confidence that the various distortions explained in previous chapters are comprehensive. The assumptions that I made to calculate of the various distortions underestimate the true magnitude of the total economic loss. This is reflected in the total distortion figures being lower relative to the welfare loss reported in the EPPA model.

Table 3: Summary for Japan

	Cost[6] (billions of $)
MAC (exact)	7.94
Carbon Distortion	7.68
Domestic Distortion	23.6
Oil Market Effect	-0.37
Terms of Trade Effect	-2.06
Capital Markets	4.42
Total	**33.73**
EPPA Consumption Loss	**38.73**

Table 4: Summary for the E.U.

	Cost (billions of $)
MAC (exact)	16.4
Carbon Distortion	13.4
Domestic Distortion	92.02
Oil Market Effect	-1.13
Terms of Trade Effect	-7.22
Capital Markets	16.3
Total	**114.6**
EPPA Consumption Loss	**131.29**

---

[6] Negative numbers as gain to economy

3.5 Limitations of analysis

The market by market approached used in this thesis is based on the concept of partial equilibrium. However, the EPPA model is a general equilibrium model, and thus we can only approximate the welfare loss that is reported in the model. In addition, within this version of the EPPA model, there is no consideration of labor and capital taxation. At the same time, labor and capital stocks are modeled in fixed supply. Thus there are no distortionary effects calculated in these markets. In reality, this is a potential source of economic loss but no loses occurs in EPPA because these distortionary effects are not represented. Much work on revenue recycling has shown interactions of capital and labor taxes with carbon tax depending on how revenues from a carbon tax are distributed (Babiker el et, 2002).

In the calculation of carbon and domestic taxation distortions, the demand curve for each fuel is assumed to be linear across the small change in price and our elasticity estimates an approximation. We see this in comparing the direct cost estimate from markets to an exact measure from MAC.

Finally it is also important to remember that the EPPA model only considers the economic costs of certain climate change policies. It does not consider the economic consequences of ecological changes as well as the efforts to mitigate the impact of these ecological changes. For instance, with increased frequency of weather related natural disasters, the economic cost of rebuilding the damage as well as the cost of prevention should be taken into consideration. Climate change may also dramatically affect land use options and disrupt the agricultural sector. Thus from a policy perspective, the true cost of inaction may be significantly higher as the available options for emission controls narrow even with improved technologies.

4. POLICY IMPLICATIONS

The natural carbon cycle involves approximately 700 billion tons of carbon being exchanged each year, with equal amounts of carbon being produced and absorbed by nature. Over the past hundred year, the atmospheric carbon concentrations increased by more than 30%. This increase beyond the carrying capacity of the natural processes is now commonly accepted in the scientific community as anthropogenic. The bulk of this increased carbon is attributed to fossil fuel combustion and there is global agreement on the importance of stabilizing the trend of increasing atmospheric carbon concentration. Unfortunately, the challenge today lies in coming to agreement how much needs to be done and when the corrective measures should be implemented. The uncertainty in predicting the long term changes in global climate has given unrealistic hopes that the problem may be small and insignificant relative to the natural cycle. The situation is further compounded by the optimism in technological change to facilitate a significantly more efficient solution in the future. A large part of the challenge is motivated by concerns about economic cost to a country, relating to the impacts on employment levels, domestic business competitiveness as well as economic growth rates. The numerical analysis performed in this thesis has showed that the actual welfare loss is linked to carbon taxation distortion is small relative to the other sources of distortions. This suggests that with creative policy making it may be possible to reduce the economic cost of carbon limiting policies, overcoming the resistance to implementation. This chapter aims to trace some of the policy challenges and possible solutions.

The straightforward answer to reducing the magnitude of the economic distortions is to drastically reduce intermediate taxation. While this is clearly a source of immediate welfare and financial gain to the consumers, alternative solutions must be found to answer to the motivations for the taxation. These taxes are a main source of government revenue and a replacement for this revenue is needed. One solution is to auction permits and use the auction revenue to replace the lost energy tax revenue. At a minimum, one might exempt highly taxed fuel sectors from the carbon policies to avoid aggravating the distortions. To continue to achieve these goals even with a reduction of domestic taxation, alternatives include tax system reform, reduction of current energy consumption and technological solutions. Looking deeper into each of the above pathways, specific options include higher carbon taxation improving energy efficiency, greater reliance on renewable energy and higher research and development funding.

I have assumed the energy taxes are purely distortions. If they are correcting other externalities then this assumption is not correct. For example, taxes may be implemented to correct pollution problems. Alternatively a gasoline tax levied to provide revenue for road construction and thus it is in part a user fee. Babiker el et (2002) reviewed evidence for fuel taxes on the E.U. and concluded that they are did not appear to be related to specific externalities. This probably is true for Japan as well.

5. CONCLUSION

Many policy studies focus solely on the level of carbon price and the area under the MAC as a measure of economic cost. While this is helpful as a guide, it provides an incomplete picture of all the distortions. The carbon price may be high, and correspondingly result in a high carbon related distortion. However, as shown in this paper, the distortion induced by interaction of non carbon taxation related activities dwarves that of carbon taxation. As a result, some countries with a high carbon price may experience low national welfare loss relative to other countries with lower carbon price.

In all, for policy considerations it is important to look beyond the carbon price to discern the factor that induces the largest welfare loss to the country. With this information, policy makers and businesses can better focus on the destination, applying market driven environmental initiatives that are meaningful and cost effective at the same time.

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