# MIT Joint Program on the Science and Policy of Global Change

## Effects of Differentiating Climate Policy by Sector: A United States Example

*Mustafa H. Babiker, Melanie E. Bautista, Henry D. Jacoby and John M. Reilly*

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To inform processes of policy development and implementation, climate change research needs to focus on improving the prediction of those variables that are most relevant to economic, social, and environmental effects. In turn, the greenhouse gas and atmospheric aerosol assumptions underlying climate analysis need to be related to the economic, technological, and political forces that drive emissions, and to the results of international agreements and mitigation. Further, assessments of possible societal and ecosystem impacts, and analysis of mitigation strategies, need to be based on realistic evaluation of the uncertainties of climate science.

This report is one of a series intended to communicate research results and improve public understanding of climate issues, thereby contributing to informed debate about the climate issue, the uncertainties, and the economic and social implications of policy alternatives. Titles in the Report Series to date are listed on the inside back cover.

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# Effects of Differentiating Climate Policy by Sector: A U.S. Example

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**Abstract**

The experience of other environmental problems suggests that policies yielding uniform marginal costs across sectors, as most analyses assume, are not likely to be realized in practice. Some sectors will be favored over others, yielding different levels of control. Using the MIT Emissions Prediction and Policy Analysis Model, the national cost of such differentiation across sectors is shown to be very high. Moreover, because of interactions and feedbacks in the economy, measures that differentiate in this way may not even aid the sectors they are intended to protect.

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## 1. ISSUES IN DIFFERENTIATION OF POLICY BY SECTOR

Most economic analyses of greenhouse gas control agreements assume that targets are achieved by means of an efficient carbon cap-and-trade system or carbon tax, or by taxes on fuels at rates that reflect their carbon content. This assumption is common in part because policies yielding an equal carbon price across sources are presumed to achieve emissions reductions at least cost, and in part because more complex systems of controls are hard to analyze in economic models. Unfortunately for the analysis task, the history of attempts by governments to limit greenhouse emissions (and indeed of environmental regulation more generally) reveals that policy mechanisms rarely approach this ideal. A common carbon price may lead to shifts in international competitiveness among sectors and to variations in burden among sub-national regions. Fear of these effects, and of impacts on specific consumer groups which may erode political support for the control regime, lead to the granting of concessions to one sector or another. Uniform policies may also face ideological opposition. The use of price

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incentives, through the purchase of emissions permits or payment of emissions taxes, is viewed as unethical by some who believe people shouldn't be able to purchase a "right to pollute." They thus oppose the very instruments that can best achieve least-cost implementation. The interest in sectoral impacts shown by the IPCC's Working Group III is one indication of these concerns, and of the pressure for policies that protect particular sectors.

Here we address two questions regarding the design of emissions controls incorporating such differentiation: What do they cost? And do they work? First, what does it cost, in national terms, to impose policies intended to protect particular sectors or consumer interests? As a standard for exploring this question we use an "ideal" implementation that yields a common carbon price across sectors, and we compare this case with several alternatives that represent forms of differentiation frequently encountered in climate policy discussions. For our cases under climate policy we apply the emissions targets in the proposed Kyoto Protocol, and the analysis of economic effects uses the United States as an example.

Second, do these policies work as intended for the protected sector? And what are the consequences for those sectors not so favored? Partial-equilibrium analyses of such concessions (*e.g.*, exempting export-oriented industries from emissions restrictions) normally find that the special treatment is helpful to the target sector. In a general equilibrium analysis, however, which accounts for adjustments these concessions may trigger in other sectors, the picture can look very different. The benefit to the target sector may not be the same as that expected on the basis of a one-sector-only analysis, and there may be spillovers onto other sectors that the partial analysis misses. By analyzing sample policies in a general equilibrium economic model we hope to give an impression of the national costs and other consequences of such sectoral differentiation, and call attention to this aspect of emissions policy design.

We carry out the analysis using the MIT Emissions Prediction and Policy Analysis (EPPA) model. In Section 2 we provide a brief description of this model, including the addition of a household and industry transportation sector, which was needed for this study. In Section 3 we describe the reference and policy cases and how we have implemented them in the EPPA framework. Section 4 describes key results and Section 5 draws conclusions from our findings.

## 2. ANALYSIS METHOD

### 2.1 The EPPA-GTAP Model

The Emissions Prediction and Policy Analysis (EPPA) model is a recursive dynamic multi-regional general equilibrium model of the world economy which has been developed for analysis of climate change policy. Previous versions of the model have been used extensively for this purpose (Jacoby *et al.*, 1997; Jacoby and Sue Wing, 1999; Prinn *et al.*, 1999; Reilly *et al.*, 1999). The current version of the model is built on a comprehensive energy-economy data set (GTAP-E[1]) that accommodates a consistent representation of energy markets in physical units as

[1] This special database is provided by the Global Trade Analysis Project (GTAP) along with Release 4 of their economy-trade database. For further information on GTAP see Hertel (1997).

well as detailed accounts of regional production and bilateral trade flows. This EPPA-GTAP version of the model also has been applied to several studies of climate policy issues (*e.g.*, Babiker, Reilly, and Jacoby, 1999; Babiker, Reilly, and Ellerman, 1999). The base year for the model is 1995 and it is solved recursively at 5-year intervals. The model keeps track of multiple vintages of capital, a feature that will show up in the results presented below.

**Table 1** shows the regional and sectoral structure of the model as applied in this study. The world economy is aggregated into 12 regions, listed in the left-hand column. Although the focus of this analysis is on the United States, the results reflect the influence of international trade in all energy and non-energy goods (but not in emissions permits: the scenarios we run assume there is no international emissions trading). The economy of each region is aggregated to nine output sectors and a household sector, as shown in the right-hand column of the table. (The EPPA model also includes future or Òbackstop Ó sources of fuels and electricity, but they do not play a significant role in this analysis which looks only out to 2030.) Also shown are the shorthand sector names that are needed for discussion later.

Eight of the production sectors follow the standard GTAP definitions. The ninth, Transportation (denoted TRAN) has been added for purposes of this study. We use the United States as an example for study of policy effects, and its transportation sector is both a big source of emissions and politically important. The GTAP data set does not include a separate transportation sector within industry, nor does it contain a separate category for private automobile services in the household sector. GTAP does, however, contain a trade and transport sector that combines transport with trade margins. We use data from the 1992 U.S. Input-Output Accounts produced by the Bureau of Economic Analysis (Lawson, 1997a, b) as a basis for extracting transportation from the combined GTAP sector to create the EPPA transportation industry. We then aggregate the residual, trade margins, with EPPAÕs Other Industry Products (OIND).

**Table 1**. *Countries, Regions, and Sectors in the EPPA-GTAP Model*

| **Country or Region** | **Sectors** | |
|---|---|---|
| ***Annex B*** | ***Non-Energy Sectors*** | ***Name*** |
| United States | Agriculture | **AG** |
| Europe | Energy Intensive Industries | **EINT** |
| Japan | Other Industry Products | **OIND** |
| Other OECD | Transportation | **TRAN** |
| Former Soviet Union | ***Energy Supply Sectors*** | |
| East European Associates | Coal | |
| ***Non-Annex B*** | Oil | **OIL** |
| Brazil | Gas | |
| China | Refined Oil | |
| India | Electricity | **ELEC** |
| Energy Exporting Countries | | |
| Dynamic Asian Economies | ***Household (Consumer) Sector*** | **H** |
| Rest of World | | |

We also made adjustments to the Household (H) sector. Households produce transportation services for their own consumption using inputs from the Other Industry Products (OIND) and Refined Oil sectors. Personal consumption expenditures reported by the BEA (1997) were used to separate the fraction of purchases from these two sources that are used for purposes other than transportation.

This breakout yields a sector of own-supplied personal transportation (private automobiles) separate from other household activities, and a separate transportation sector in industry that supplies transport services to both industry (*e.g*., freight transportation) and households (purchased transportation service such as air and rail passenger service). This procedure for correcting the data, along with the details of the formulation of the production structure of the new sector, are described by Bautista (2000).

### 2.2 Capabilities and Limitations

Once one moves away from very simple policies, such as a uniform tax or a carbon permit system, there are many ways to construct a set of measures that achieve a particular national emissions target. While it is nearly impossible to predict the result of the political bargaining that gives rise to a specific policy, we consider several canonical types of sectorally-differentiated policies under the common restriction that they meet the U.S. Kyoto Protocol target. These policies include exclusion of a sector, or set of sectors, and sector-specific hard targets (without domestic permit trade among industries). With the EPPA-GTAP model we can then show the effects of these policies in a general equilibrium context. First, we calculate the effect on national welfare cost, as compared to implementation of the Kyoto constraint using a cap-and-trade system (or equivalent uniform national carbon tax). Also, we show how the adjustments in price and quantity, that are triggered by these sector-specific policies can combine to influence the level of activity in particular sectors (as indicated by value added) and their trade balance.

With these calculations we can explore many of the mechanisms that lead to increased costs and unintended effects under policies that differentiate among sectors. However, the use of the EPPA model does place some limits on our ability to fully capture these phenomena. For example, because of its general equilibrium structure the EPPA model implicitly assumes full employment of resources in each period. Thus it cannot reflect frictions in the labor market and possible unemployment during periods of transition. Also, although the capital vintaging incorporated in the model can represent some of the effects of rigidity in the capital stock, the model cannot fully reflect possible costs of stranded assets, which could appear in some sectors. To the degree that these frictions are more important under sectorally-differentiated policies, our estimates will understate their negative consequences.

Further, given the current structure of the EPPA model we are not able to explore highly detailed policies that might involve efficiency standards on energy-using equipment, such as controls of corporate average fuel economy (CAFE), or the prescription of reductions on a plant-by-plant or firm-by-firm basis. At our level of aggregation, for example, a requirement that the energy-intensive sector or the electricity sector meet a hard reduction target, with no trading across the economy, still implies that reductions are made in a cost-effective manner *within* the sector. We expect that technology standards or hard targets prescribed on a plant-by-plant or firm-by-firm basis, without inter-sector trade, would lead to greater inefficiency and higher economic cost than we estimate.

Our cost estimates must be qualified if there are pre-existing economic distortions that are “corrected” by the carbon policy, even though the policy itself may appear to be inefficient. Examples of such a pre-existing distortions include high excise taxes on electricity (Babiker, Reilly, and Ellerman, 1999), or on refined fuels (Babiker, Reilly and Jacoby, 2000). Also, our estimates do not account for possible benefits, such as equity concerns, aid for depressed areas, or ancillary environmental benefits that may help justify the choice of these sector-specific measures. However, even taking these qualifying factors into account, we believe that, given the level of aggregation applied in this study, our results will tend to understate the welfare effects of differentiating emissions controls by sector, and may miss some of the shifts of activity among sectors and unintended effects on sector trade balances.[2]

## 3. CASES FOR ANALYSIS

### 3.1 The Reference Case and Definition of a Kyoto-Type Commitment

The reference and policy cases used in this analysis are summarized in **Table 2**. Our reference case (REF), which presumes no climate policy, is similar to that used in previous analyses using the EPPA model (*e.g.*, Babiker, Reilly and Jacoby, 2000). Over the period 1995 to 2030 studied here, the U.S. GNP grows at an average annual rate of 2.3%. The welfare index used here is Equivalent Variation (roughly, the change in real consumption) and it increases by 2.4% per

**Table 2**. *Reference Case and Policy Cases (No International Permit Trade)*

| **Case** | **Definition** |
|---|---|
| **REF** | Reference Case, no climate policy |
| ***Cases under Kyoto target, with no exemption of sectors*** | |
| **FT** | Full Trading Domestically: |
| **NT** | No Trading among US sectors: Each industrial sector and households capped at the U.S. target. |
| ***Cases under Kyoto target, with exemptions of some sectors (E/…). Permit trade among sectors under cap.*** | |
| **E/TRG** | Exempt Tradable Goods. Tradable goods include other industry, energy intensive industry, agriculture, and the fuel sectors (coal, oil, gas and refoil). |
| **E/H&AG** | Exempt Households and Agriculture |
| **E/EINT** | Exempt Energy Intensive Industry |
| **E/TRAN** | Exempt Transportation |
| **E/ELEC** | Exempt Electric Utilities |

[2] We also do not consider ways that particular injured parties within a sector might be protected by direct compensation (*e.g.*, through the permit issuing process). Bovenberg and Goulder (1999) show that the owners of capital assets (but not labor in their analysis) could be protected at costs far below those shown here.

year. Carbon emissions grow at 1.5% per year. To make short-term economic growth as realistic as possible, labor productivity growth rates were set for 1995 to 2005 to produce overall economic growth rates that equal those actually experienced through 1998, and that follow preliminary estimates and short-term projections by the International Monetary Fund (IMF, 1999). The Reference case is meant to be a plausible scenario of future economic and emissions growth in the United States, but obviously wide uncertainty attends any such projections.

All of our policy cases apply the emissions targets in the proposed Kyoto Protocol, which for the United States require a reduction of average annual emissions, for the five-year commitment period of 2008 to 2012, to 93% of the 1990 level. Since the EPPA model solves at five-year intervals, we require 2010 emissions to meet this target. The level of emissions restraint is held at this same level to the end of the analysis period, 2030. The assumption of an unchanging emission target allows us to show how differential growth among sectors can change costs of the policies we consider.

Currently, only $CO_2$ emissions are modeled endogenously in EPPA, and thus in this paper we treat the Kyoto constraint as if it applied only to $CO_2$. Other work, evaluating the non-$CO_2$ other Kyoto gases, shows that their inclusion in the base period and in the control options can lower the cost of a Kyoto style commitment (Reilly *et al.*, 1999). However, the relative increase in costs resulting from a sectorally differentiated policy in a more complete, multi-gas analysis is likely to be similar to that found in the $CO_2$-only analysis conducted here. Further, we do not consider emissions permit trading among countries, which also can lower costs by substituting cheaper foreign credits for the domestic reductions. How a Kyoto-type system with international permit trading would actually work in a system of differentiated control policies, within countries or among them, is a complicated question awaiting further analysis (Hahn and Stavins, 1999).

Without international permit trading, the details of Kyoto implementation in countries outside the United States are not central to our analysis. As we have shown elsewhere, however, changes in the terms of trade can affect countries other than those imposing the constraints (Babiker, Reilly and Jacoby, 2000). We therefore impose the Kyoto constraint on all Annex B countries in order to capture any effects on goods trade that emissions restriction outside the United States would have on its domestic economy. We do not, however, impose sectorally differentiated policies outside the United States, but simply assume that economy-wide cap-and-trade controls exist in all other Annex B countries. Imposition of similarly differentiated policies outside the United States would have some small effect on the U.S. economy, through the effects on the terms of trade and trade in goods, but the insights gained about costs of U.S. implementation would not change significantly.

Our basic Kyoto policy case for the United States assumes an economy-wide cap-and-trade system (or equivalently a uniform carbon tax) which yields a common price of carbon emissions across all sectors. Because we compare this system with others that exempt some sectors from the restrictions of a carbon tax, and within a regime with no trade in permits among domestic sectors, we refer to this case as one with Full Trading (FT). This case provides a standard for comparison with the many studies that have been conducted with a simple, economy-wide cap and trade system. In the absence of other distortions in the economy it would also be the most efficient policy, achieving the target with the least overall cost to the economy.

One feature of the GTAP data set is that it includes energy taxes that, unless they are correcting another market externality, are distortionary. We considered a case for the United States in which these taxes were removed. The welfare costs of the policy differed very little, and we do not report them here. This result is not surprising, because fuel taxes are relatively low in the United States. If the same comparison were made for Europe, the effects of dropping the distortionary fuels taxes would be more significant, as suggested by Babiker, Reilly and Jacoby (2000).

### 3.2 Proportional Cap by Sector, with No Permit Trading

One alternative to the full trading case is a constraint imposed sector-by-sector, with No Trading (NT) among sectors. In this case, we require that each U.S. sector reduce its emissions to 93% of the 1990 level. This procedure is obviously only one of many ways to divide the reduction target. It provides an informative comparison with the full trading case, however, because it shows how a reduction that might appear to be ÒequitableÓacross sectors may raise costs above those from a trading solution. Permit trading has been applied to U.S. sulfur emissions, and the U.S. negotiators have fought hard for international permit trading in greenhouse gases. Nevertheless, this case is interesting because there remains resistance in the United States to the idea of pollution trading, and a general recognition that a permit system for carbon will be much more difficult to implement than that for sulfur.

### 3.3 Emissions Caps Exempting Particular Sectors

Domestic economic and political considerations may yield an implementation scheme that is neither universal, as with the FT case, nor rigidly applied sector-by-sector as under the NT assumption. Selected sectors may gain special consideration. These outcomes are approximated by a set of cases where various combinations of sectors, including both industry and consumers, are exempted from the system of emissions caps. In these cases we denote the exempt sectors by the prefix ÒE/ÓIt assumed that all sectors not so exempted are allowed to trade emission permits among themselves.

**Tradable Goods Sectors**. A major issue in the ratification of the Kyoto Protocol has been its possible effect on international competitiveness. This concern has contributed to a call for participation by developing countries, to create a level playing field (U.S. Senate, 1997). The prospects for significant developing-country participation seem dim in the near term, and an obvious political solution to the competitiveness threat would be the exemption of sectors that are heavily involved in international trade. To study this prospect we create a scenario where Tradable Goods (E/TRG) sectors are exempt from any cap. The exempted sectors include Agriculture (AG), Energy Intensive Industry (EINT), Other Industry Products (OIND), and the fuel sectors (Coal, Oil, Gas and Refined Oil). By far the most important exclusions are of Energy Intensive Industry and Other Industry Products. Energy Intensive Industry is a large emitter of $CO_2$, by virtue of its energy intensiveness, and under the aggregation used here Other Industry Products is the largest sector in the economy. Agriculture is a small sector. Exclusion of the fuel producing sectors has a small effect because the Kyoto constraint is imposed on fuel consumption rather than production, and relatively little energy is consumed directly in these production sectors. Thus Households (H), Electricity (ELEC), and Transportation (TRAN) bear the brunt of required emissions reductions in this policy scenario.

**Households and Agriculture**. At the other extreme, a populist political solution might focus on consumers and farmers, forcing the reductions onto industry. We evaluate this prospect in a scenario where Households and Agriculture are exempt (E/H&AG). Importantly, household-supplied transportation (*i.e*., the personal automobile) is exempt. The fact that many farms are family enterprises and that agriculture has been treated differently in the past with regard to environmental policy, leads us to exempt agriculture in this case as well. Another potential motivation for this case is that a permit trading scheme where emitters were monitored, and required to have emissions permits, could well exempt widely dispersed and small emitters simply on the basis of the high cost of enforcement.

**Energy Intensive Sectors**. Another set of policies might exempt the energy intensive sectorsÑEnergy Intensive Industry (EINT), Transportation in households and industry (TRAN), and Electricity (ELEC)Ñon the assumption that those sectors most severely affected by the policy would lobby hardest for exemptions. It turns out that exempting all of these sectors simultaneously would make it impossible to meet the U.S. Kyoto target under our reference growth assumptions, because in 2010 the emissions of these sectors alone exceed the target. We thus considered cases where each of these sectors was exempted from the cap individually.

We considered a number of other combinations, but those listed in Table 2 provide the best illustration of the impact on costs. These cases do not necessarily reflect particular proposals or positions that are currently on the negotiating table in the United States or elsewhere in Annex B, but they do contain the rough outlines of possible outcomes of political bargaining. If past environmental policy formulation is any guide, real policies that started down such a path would ultimately include far greater sectoral and technology specificity. Thus, as noted earlier, our estimate could well underestimate the cost penalty of policies that could be seen in practice.

## 4. EFFECTS OF ALTERNATIVE POLICIES

### 4.1 National Welfare Cost

**Table 3** presents the aggregate impacts on the U.S. economy for each of the policy cases discussed above, stated in terms of percent reductions in economic welfare as compared to the Reference case. Under the economy-wide cap-and-trade system with full trading (FT), the welfare losses are on the order of 1% of welfare in 2010. The welfare loss is somewhat lower in 2020 in percentage terms than in 2010 because of the effect of the vintaging of capital in the EPPA model. Vintaging increases the costs in 2010 because we assume it is not possible to retrofit all physical capital in a short period of time. In later years there are opportunities to reduce emissions more cheaply as the old, less energy efficient capital stock is replaced. This influence on costs of limited capital malleability was explored by Jacoby and Sue Wing (1999) using an earlier version of the EPPA model.

Looking down the columns in Table 3, the costs to the economy of all of the sectorally differentiated policies are greater than costs with full trading. The case where all sectors face hard targets at 0.93 of their 1990 emissions (NT) increases costs to the economy a relatively small amount in 2010 (about 15%), but the cost of this policy, relative to the more efficient all-sector cap-and-trade system, increases substantially over time. By 2030 the NT case is 80% more costly than the FT case. The differential difficulty of meeting these targets is reflected in the sector-specific permit prices as given in **Table 4**.

**Table 3**. *U.S. Percentage Welfare Loss Relative to REF Case, Kyoto Protocol Target*

| | Year | | |
|---|---|---|---|
| **Case** | **2010** | **2020** | **2030** |
| **FT** | 0.96 | 0.85 | 0.89 |
| **NT** | 1.10 | 1.25 | 1.60 |
| **E/TRG** | 1.69 | 1.83 | 2.52 |
| **E/H&AG** | 1.48 | 1.65 | 2.08 |
| **E/EINT** | 1.32 | 1.24 | 1.49 |
| **E/TRAN** | 1.55 | 1.58 | 2.11 |
| **E/ELEC** | 2.79 | 3.07 | 4.00 |

In the full trading case, the common economy-wide permit price is $307 per ton of carbon in 2010.[3] Under the sectoral hard targets in the right-hand column, the sector-specific carbon permit prices range from about $160 per ton carbon in the electric utility sector to around $900 per ton carbon in the transportation sector. These results reflect the greater ability to fuel-switch in the electric sector on the time horizon to 2010.

**Table 4**. *Carbon Permit Prices in 2010* [a]

| ***Cases With Trade*** | | ***With Proportional Cap*** | |
|---|---|---|---|
| **Case** | **Price** | **Sector** | **Price** |
| **FT** | 307 | **AG** | 423 |
| **E/TRG** | 487 | **ELEC** | 157 |
| **E/H&AG** | 504 | **EINT** | 402 |
| **E/EINT** | 440 | **TRAN** | 881 |
| **E/ELEC** | 913 | **OIND** | 386 |
| **E/TRAN** | 452 | **H** | 228 |

[a] Note: prices are shown in 1995 US$ per ton Carbon

The comparison in Table 3 also illustrates one of the major benefits of a trading system. Even though initial reduction targets by sector might be established in a pattern not too far from economic efficiency, changes in an economy over time will lead these targets to become more and more inefficient. A trade system provides a mechanism that automatically adjusts to economic change (as would a uniform carbon tax). But hard sector targets or technological requirements are likely to create ever greater distortions, because it is extremely unlikely that growth in different sectors will be identical or that emissions reduction opportunities will develop equally across sectors.

The remaining cases all involve exemption of one or more sectors, and the cost penalties are correlated with the relative quantities of emissions exempted. As shown in Table 3, the cost penalty in 2010 from exemption of these sectors, relative to the case with full trading, ranges from a low of 32% when energy intensive industries are left out (E/EINT) to a high of nearly

[3] The general level of permit prices in Table 4 are somewhat higher than that realized in earlier applications of the EPPA-GTAP model to Kyoto Protocol studies (*e.g*., Reilly Babiker and Jacoby, 2000). The difference arises because key substitution elasticities have not yet been revised to account for the change in economic structure imposed within the model with the disaggregation of transportation. Research on this correction is continuing. However, the difference will not affect the conclusions of this paper, regarding the cost penalties associated with sectoral differentiation of emissions policies.

300% when electricity is omitted from the control regime (E/ELEC). And, similar to the NT case, the cost penalty associated with each of these exemptions grows over the years to 2030. The penalty rises over time because demand for products from exempted sectors grows as the prices of their goods fall relative to the prices of other goods that do bear cost of emissions reductions. Also, at the same time these exempted sectors switch to more carbon intensive fuels whose prices have fallen because of the carbon constraint elsewhere in the U.S. economy (and in other Annex B countries).

### 4.2 Sector Impacts

Another interesting question is whether these exemptions actually have their intended effect. We are not able to explore this question in detail because, as discussed earlier, we are using a model that presumes that all assets and labor are fully employed. In some policy circles there is concern about stranded assetsÑthose assets that would be retired prematurely because of an environmental policy. The best way to avoid the severe economic loss that stranded assets might involve is to introduce an economy-wide cap-and-trade system, so firms and households across the economy could buy permits rather than retire capital early. (Of course, a tight constraint introduced with little lead-time will cause some capital to be retired prematurely in any case.) To analyze this circumstance would require a model where our exogenous depreciation rate was replaced with an endogenous representation of the retirement decision. Similarly, to capture the cost imposed because of rigidities in labor adjustment a more complete model of the labor market would be needed. Still, with the existing EPPA formulation we can develop insight about these sector effects as they are reflected in the trade balance, and shifts in value added.

**Sectoral Trade Balance.** The motivation for the E/TRG case was to study the effect of efforts to maintain competitiveness of a country in its tradable goods sectors. As illustrated in **Table 5** for 2010, however, exemption from the cap does not necessarily improve the net trade position or competitiveness of all of the exempt sectors. For example, we find that the net trade position of Other Industry Products (OIND) actually improves under Kyoto with full trading (the FT case) compared with the no-policy Reference. Other Industry Products gains in this way because it is relatively less energy intensive than other sectors, so the costs of goods from this sector rise relatively less with the imposition of Kyoto restrictions. However, exemption from the cap (in the E/TRG case) actually worsens its trade position compared with a case with full trading (FT). The United States exports more agricultural products in the E/TRG case than under FT conditions, but its exports remain below those when there is no Kyoto target. Thus the exemption only partially makes up for the loss of exports in agriculture because of the emissions controls. The E/TRG case has the strongest effect on the Energy Intensive Industries (EINT), and it is in the expected direction.

**Table 5**. *Sector Net Exports (1995 US$ billions)* [a]

| | | ***With Kyoto Constraint*** | |
|---|---|---|---|
| **Sector** | **Reference** | **FT** | **E/TRG** |
| **AG** | 25.9 | 7.4 | 8.7 |
| **EINT** | 1.4 | —25.7 | 6.2 |
| **OIND** | —6.9 | —2.3 | —3.7 |

[a] Note: *plus* indicates net exports, *minus* indicates net imports

The United States moves from a net exporter of EINT goods to a net importer in moving from REF to FT, but it returns to a net export position when trade sectors are exempted.

These results may seem odd at first, particularly the negative effect on Other Industry Products (OIND), but there are several factors that occur in the economy (and that are represented in the EPPA model) that can help explain them. Perhaps the most fundamental is the restriction imposed by the overall national trade balance. A greater export of goods from one sector tends to lead to more imports (or less exports) of goods from other sectors. This effect is heightened in the current EPPA model because we exogenously specify the net capital outflow (or inflow). Starting from the 1995 level we gradually bring all economies to a zero net trade balance. In reality, a policy shock such as a carbon constraint could change the level of capital flows (and hence the goods trade balance) such that an export increase in one sector need not be balanced by an import increase in another sector. But, in general, such changes would be temporary. A more complex model of international capital flows would require that deficits be balanced by surpluses over the long term.[4] Thus, the important consideration for exports is not the absolute change in costs but the relative change in industry cost structure due to the policy.

A second factor influencing trade balance, as we move from the REF to the FT case, is the change in prices of goods from other Annex B countries as they adjust to carbon constraints, and in the prices of non-Annex B goods mainly because of the influence of Annex B actions on energy prices (see Babiker, Reilly and Jacoby, 2000). Thus, the change in competitiveness is not principally related to the absolute increase in cost due to the carbon constraint but to the increase *relative* to international competitors. This effect is complex and depends on the specific pattern of trade flows, parameterizations within the model that determine the relative substitutability of goods from different sources (*i.e.*, the Armington assumptions), and the changes in all other regions.

A third factor is that these sectors use electricity as well as transportation, the prices of which rise because of the carbon constraint. In the E/TRG case more of the burden is forced on these sectors, and the costs of these non-traded goods rise more than in FT. Thus, the relative effect on different tradable goods sectors will depend how they use, as intermediate inputs, these non-traded goods that *are* affected by the carbon constraint.

**Sector Value Added.** Another useful indicator of the impacts of these policies on individual sectors is the change in value added, which is the sum of returns to all factors (labor, capital, and natural resources). Value added gives an idea of the overall size of the sector, and because payments to labor are large fraction of value added in all sectors, shifts in this quantity also can serve as a rough proxy for labor impacts. In **Table 6** we report value added results for three of the cases above and for the Reference. The common, and not surprising, result that shows up across all the cases is that value added in the fossil fuels is severely affected. The Oil sector (OIL) is shown in Table 6, and its value added drops by roughly 37% with the imposition of Kyoto targets, with an insignificant variation across the various cases that exempt other sectors.

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[4] There are some models that include these more complex closure rules (Bernstein, Montgomery and Rutherford, 1999; McKibbon and Wilcoxen, 1999).

**Table 6**. *Percent Loss in 2010 Value Added by Sector, Kyoto Target Compared to Reference Case*

| | FT | E/TRG | E/EINT |
|---|---|---|---|
| **AG** | 11.3 | 11.4 | 16.0 |
| **EINT** | 7.2 | 5.5 | 5.0 |
| **OIND** | 5.3 | 6.6 | 6.6 |
| **ELEC** | 4.7 | 6.7 | 6.1 |
| **TRAN** | 21.8 | 21.1 | 29.0 |
| **OIL** | 37.1 | 37.1 | 37.1 |

These results combine a reduction in payments to labor and capital due to the decline in output from the sector, with a significant decline in the value of the resource asset (coal, oil and gas reserves) yielding lower payments to this factor as well. In 2010 the electric sector shows a 5% decline in value added below the Reference if Kyoto is implemented with a full trading system, and an additional drop of another 1% to 2% if other sectors are exempted. The negative effects on the electric sector are due to the shifts in labor and capital out of the sector because of declining output.

Moreover as in the case of trade effects we find that exemption from the carbon constraint can lead to a more severe effect on a sector than in the efficient, FT case. In the case with exemption of tradable goods, value added in OIND and AG is either unaffected or diminished slightly as a result of being exempt from the carbon constraint. Thus, while this policy was intended to avoid affects on these sectors, it actually worsens them. Value added in the EINT is higher than in FT but by less than 2%. The loss in value-added for EINT (FT—REF) is about 7%. Exempting it along with other tradable goods reduces the loss to about 5.5 percent. Even when EINT is the only exempt sector, the loss is only reduced to 5%. Thus these policies that are in principle designed to allow these sectors to avoid costs of the carbon policy are ineffective and for some sectors even counter-productive. At the same time, they increase the cost of the carbon constraint to the economy by 76% (TRG case) and 37% (EINT case). The relatively small gains to the EINT industry are bought at very large cost to the economy.

The economy-wide effects of these exemptions are also evident in their effects on sectors not given special treatment. Across the board the exemptions further reduce value added in all sectors that are not exempt. The small positive and even negative effect of the exemption from the carbon constraint is due to two key effects captured by a general equilibrium model like EPPA. First, the overall negative effect on the economy results in less domestic demand (both inter-industry and final demand) for goods from all sectors. Energy intensive (EINT) goods are used mainly as intermediate inputs to Other Industry Products, and to the extent exemption of EINT has adverse effects on other industries they will demand fewer EINT goods. Second, exempted sectors cannot fully escape the added higher energy costs (energy price *plus* permit price). While in principle they could benefit from lower fuel prices, prices of other goods that they purchase (especially electricity and transportation) increase more than they otherwise would because these sectors must bear the added cost of further reductions to make up for the exemptions.

Of course, exempting only one sector from the constraint is likely to benefit it, as illustrated by the exemption limited to EINT. The broader story, however, is that exempting one industry or firm can be the first step down a slippery slope that leads to broader exemptions. Once this process starts it can generate substantial costs for the overall economy, and actually prove counterproductive for some of the exempted industries.

## 5. CONCLUSIONS

Our analysis confirms that sectorally differentiated policies can increase the cost of meeting a carbon emissions target. This result is not surprising. The strong interest in a cap-and-trade system or uniform carbon tax is based on the argument that, at least in an economy without other distortions,[5] such a system will provide reductions at least cost. It is useful, therefore, for those who serve in the political bargaining process and who are subject to pressures from affected groups to have some idea of the cost penalty associated with less-than-ideal policies. A high penalty is paid for the use of exemptions to marshal political support for an emissions reduction policy, or otherwise to try to solve equity problems across sectors. Among the cases we examined the penalty in meeting the 2010 U.S. Kyoto target ranged from 38% to nearly 300%.

Moreover, each exemption increases the cost that much more for other sectors. Clearly, the magnitude of the cost penalty depends on exactly who is exempt. Again, this is not a particularly surprising result. Our model is highly aggregated, and so exemption of any one sector creates a large burden that must be shifted to others. On the other hand, we also implicitly assume that, within each of the sectors that are capped, the policy is implemented in the most efficient manner. More realistic policies might include far more specific targets, technology constraints, and exemptions that could increase costs further. Also, the cost of these sectorally-differentiated policies tend to rise substantially over time. The case we examined, where each sector was forced to meet the Kyoto target reduction without trading, turned out to have a cost penalty of only 15% initially but this grew to 80% by 2030 because of differential growth among sectors. In cases where some sectors were exempt, the exemption itself encourages more rapid expansion of the sector and greater carbon intensity.

The final question is whether these exemptions, despite their cost, may fail to achieve their intended effect. We find that exempting tradable goods sectors can actually worsen the net export position of some of the protected sectors. This result occurs because of interactions in the economy that are captured in a general equilibrium model. It is a caution against trying to assess these results in partial equilibrium analyses that do not capture these interactions.

The general result, that costs increase with differentiation, is expected, though we make no claim regarding the likelihood of the specific versions of policies considered here. Concern about such exclusions and policy limitations can, however, be motivated by observation of past attempts to implement environmental policy, and the costs are illustrative of the effects of ÒrealÓ policies. These results should serve as a counterpoint to the many studies that assess the effects of only the most efficient forms of intervention, and a warning to those who might too easily propose exemptions as a remedy for expected sectoral impacts.

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[5] Energy market distortions are included in the EPPA data, and for the U.S. they prove not to be significant enough to change the result that an economy-wide cap and trade system provides the most cost-effective control approach. We do not consider the issue of how permit revenues are recycled, however. The finding of others (see, *e.g.*, Parry, Williams and Goulder, 1999), that using the revenues to offset labor and capital taxes, can reduce the cost results from the fact that these labor and capital taxes have distortionary effects in the economy. Our data does not include these tax distortions explicitly and we, therefore, have not considered this effect.

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