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## **Minimizing Carbon Leakage under Open Trade: Strategies for the Allocation of Pollution Permits**

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Carolyn Fischer and Alan Fox\*

### **Introduction**

Building on the general equilibrium analysis conducted by the authors in “Output-Based Allocations of Emissions Permits: Efficiency and Distributional Effects in a General Equilibrium Setting with Taxes and Trade,” (2004) this paper sets out to expand on one of the central findings of the first paper. For a cap-and-trade scheme, in the absence of other market failures, lump-sum distributions of emissions permits, like auctions or grandfathering, are equally efficient. Meanwhile, output-based allocation (OBA) is an inefficient mechanism, due to the implicit output subsidy granted, which discourages conservation as a means of emissions reduction.

However, in a second-best world with tax and trade distortions, OBA does have features that make it appealing from an economic efficiency standpoint. First, it mitigates the price rises that tend to exacerbate pre-existing tax distortions to the labor market. Second, OBA potentially results in much lower rates of carbon leakage from the implementing country to the rest of world. It may also prevent leakage toward unregulated sectors within the subject economy. Finally, from a political standpoint, it may help minimize the political difficulties of achieving emissions reductions goals, given competitiveness concerns. Still, tradeoffs exist between achieving these different goals.

This paper will analyze these potential tradeoffs of choosing different allocation mechanisms in order to achieve overall emissions reductions goals while minimizing intra- and international leakage and minimizing the traditional measures of welfare loss associated with emissions reductions. To lend greater currency to the analysis, reductions will be considered in the framework outlined by the *Climate Stewardship Act of 2003*, co-sponsored by Senators John McCain and Joseph Lieberman. The goal of the paper is to propose certain rules for identifying sectors and mechanisms for minimizing the costs of

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broader emissions reduction when considering the interaction of one country's emissions policies with unregulated emissions and labor market distortions in other countries.

The analysis is carried out in a modified GTAP framework augmented with a labor-leisure choice. Such a framework allows for the consideration of how distortionary tax instruments may be offset by revenues generated from permit auctions or may be exacerbated by policies that raise prices. The current implementation employs the GTAP version 6 (Release Candidate) database.

## **Description of Model**

The model and simulations in this paper are based on version 5 of the GTAPinGAMS package developed by Thomas Rutherford and documented for version 4 of the dataset and model in Rutherford and Paltsev (2000). The GTAP-EG model serves as the platform for the model outlined here. Fischer and Fox (2004) was based on the same model. This paper extends that model, adapting the framework to employ the latest available GTAP database, Version 6.0 Release Candidate. This allows us to update the analysis to 2001, the base year of the latest GTAP database.

Two features are added to the GTAP-EG structure to allow us to model the impact of an output-based permit allocation scheme. First, the appropriate structure for simulating an output-based allocation scheme must be incorporated into the model. Next, the household is given a labor-leisure choice so that labor taxes are distorting. This distortionary tax allows us to conduct simulations recycling revenue from pollution permits to offset the distorting tax instrument. Tax instruments are also selectively incorporated into the framework of the model, so that the transport sectors may be treated differently from other heavy users of energy. This allows for a modeling approach more consistent with that proposed in the McCain-Lieberman legislation.

### **Incorporating Output-Based Allocation**

Several changes need to be made to the GTAP-EG code to incorporate output-based allocation of pollution permits. The profit function is not directly accessible in the MPSGE framework. Instead, we incorporate output-based permit allocation through the production function as a tax/subsidy, combining it with side constraints on the values of  $\mu$  and  $\bar{e}$  to duplicate the effect on the profit function above. Additionally, we create an additional composite fossil fuel nest to production. This allows us to incorporate the pollution permit as a Leontief technology, allowing us to track pollution permits through the model.

In the original GTAP-EG model, the treatment of energy goods does not allow for tracking of permits by sector. In order to track pollution permits, we need to ensure that one permit is demanded for each unit of carbon that enters into production. This is accomplished by separating out the energy goods into a separate activity, a Leontief technology combining the polluting inputs with permits, into a new composite good (labeled *ffi* in the code for fossil fuel input). The composite of permit and energy input is then included in the production block for the output good (*y*).

The next step is to incorporate a distortion in the form of an endogenous tax into the sector's production function. This tax, *z*, will allow us to mimic the impact on the firm of an output-based subsidy. This is accomplished by including constraints to establish values for  $\mu$ ,  $\bar{e}$ , and the relationship between *z*,  $\mu$ , and  $\bar{e}$ .

The sectoral unit demand for pollution permits,  $\mu$ , is defined as

$$\mu_{i,r} = \sum_{fe} \left[ \chi_{fe,i,r} \cdot \frac{\phi_{fe,i,r}}{y_{i,r}} \right]$$

where  $\chi_{fe,i,r}$  is the carbon coefficient for final energy good  $fe \in \{coal, oil, gas\}$  in sector *i* of country *r*. The variable  $\phi_{fe,i,r}$  represents the demand of the fossil fuel input. That is, the unit demand for permits is equal to the unit demand for carbon.

The allocation of pollution permits is defined simply as the baseline unit demand for carbon multiplied by the percentage cap ( $\kappa_r$ ) on emissions:

$$\bar{e}_{i,r} = \kappa_r \left[ \sum_{fe} \frac{\chi_{fe,i,r}}{\bar{y}_{i,r}} \right]$$

Note that the parameter  $\bar{y}_{i,r}$  does not appear in the MPSGE representation in Appendix A. This is because the baseline value of output in the program is calibrated to 1.

The net demand for permits and the tax instrument in the production function are then tied together through a final constraint:

$$z_{i,r} p_{i,r}^y = \gamma_r [\mu_{i,r} - \bar{e}_{i,r}]$$

That is, the unit tax/subsidy on output is equal to the value of the net unit demand for pollution permits. The MPSGE representation of these equations can be found in Appendix A.

This allocation mechanism is only active within those industries/sectors that demand carbon-containing fuel as an intermediate input. Within the GTAP-EG model, this excludes the following sectors: Coal; petroleum and coal products; crude oil; natural gas; mining; and dwellings. Final demand for energy products is also subject to emissions permitting. The permits for these activities are freely traded in the same marketplace as are those initially allocated based on output. We have a system where all pollution is subject to permitting and all permits are tradable within the country. The difference lies in how permits are distributed in the baseline and how revenues are recycled.

### **Incorporating Labor-Leisure Choice**

The GTAP-EG model has also been extended by incorporating a labor-leisure choice into the household's decision. The procedure is documented in Fox (2002). Incorporating a labor-leisure choice allows us to treat the labor tax as a distorting tax, hence giving us a distorting policy instrument to offset with auction permit revenues. Since we have no data on labor taxes within the GTAP-EG database, we assume a labor tax rate of 40 percent within Annex B countries and a 20 percent tax rate within all other countries and the Rest of World.

### **McCain-Lieberman Permitting Structure**

To lend greater currency to the simulation results, we choose to follow the general outline of the cap-and-trade scheme found in the *Climate Stewardship Act of 2003*, S.139, hereafter referred to by the names of its co-sponsors, Senators John McCain and Joseph Lieberman.<sup>1</sup> McCain Lieberman treats a much broader spectrum of airborne pollutants, but this paper will concern itself only with CO<sub>2</sub> emissions. All references to pollution in this paper are to the carbon equivalent of these CO<sub>2</sub> emissions. McCain-Lieberman foresees two classes of fossil fuel consumers who are directly affected by a cap-and-trade scheme. First, major point source emitters (those responsible for more than 10,000 metric tons of CO<sub>2</sub>, or about 2,700 metric tons of carbon) are subject to a cap-and-trades system where emitters are granted an allocation of permits proportionate to their historical emissions. We model this as a simple carbon permit requirement on the use of all final energy goods in the model—coal, refined petroleum products, or natural gas. Unfortunately, our database only provides information on the size of sectors, not on the

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<sup>1</sup> For a more complete analysis of McCain-Lieberman, see Pizer and Kopp (2003).

size of individual firms with those sectors. We therefore assume that the covered sectors are covered in their entirety. The sectors subject to the cap are petroleum and coal products (refined); natural gas; iron and steel industry; chemical industry; non-ferrous metals; non-metallic minerals; and paper, pulp, and print. This overstates somewhat the magnitude of covered pollution, depending on the distribution of firm size within each of these sectors.

The second tranche of permits relate to carbon emissions originating from transportation fuels such as gasoline, diesel, and jet fuel. Our model and database lack the sectoral and commodity detail to permit analysis by fuel type. Instead, we require that major users of transportation fuels (air transport, water transport, other transport, and household demand) pay a price for refined petroleum products that reflects the cost of obtaining the necessary pollution permits. This both understates and overstates the coverage of emitters. It overstates coverage by including all consumption of petroleum and coal products, whether or not the product is a transport fuel. However, it also understates coverage, because it excludes transport fuels used by sectors that aren't covered by the first tranche above or are transport sectors (e.g., gasoline and diesel consumed by the construction industry). However, since final demand and the transport sectors are covered, we believe that the substantial majority of such emissions are covered.

McCain-Lieberman calls for the formation of a Climate Change Credit Corporation (CCCC) to oversee the transport fuel allocation. We handle this tranche by treating it as a simple lump-sum tax rebate to the representative household.

## **Permit Allocation Mechanisms**

A total of four allocation mechanisms are employed to explore the implications of the McCain-Lieberman proposal. In addition to a simulation designed to match the legislation as closely as possible, we consider several alternative scenarios with slightly different mechanisms and implications.

**McCain-Lieberman Grandfathering:** The legislation calls for grandfathering of permits to the covered industries, while providing for the formation of a Climate Change Credit Corporation (CCCC) to receive pollution permits on behalf of final demand and the transport sectors (air, water, and other). We have interpreted this as applying a tax on purchases made by households and transport sectors of petroleum and coal products, with permit revenue being rebated back to the representative agent in the model through a lump-sum tax. The covered industrial sectors are treated differently, receiving a

grandfathered allocation of permits proportional to their historical carbon usage. The covered sectors are listed above in the discussion of the McCain-Lieberman legislation. Fiscal balance in the model is maintained by adjusting the labor tax rate (set at 40 percent in the benchmark).

**Auction Industrial Permits:** Permits for industrial users are auctioned, and the revenue is used to reduce the distorting labor tax. Permits assigned to the CCCC are treated as in the grandfathering scheme, with revenue rebated to the representative agent.

**Output-Based Allocation Based on Historical Usage:** Permits are allocated to firms based on output shares in covered sectors, sector shares are based on historical emissions, and government revenue is held constant through a labor tax. Permits assigned to the CCCC are treated as in the grandfathering scheme, with revenue rebated to the representative agent.

**Output-Based Allocation Based on Value-Added:** Permits are allocated to firms based on output shares in covered sectors, sector shares are based on historical shares of value added, and government revenue is held constant through a labor tax. Permits assigned to the CCCC are treated as in the grandfathering scheme, with revenue rebated to the representative agent.

## **Carbon Leakage through Trade Flows**

### **Tailoring Allocation Mechanisms To Minimize Leakage**

### **Balancing Leakage Minimization against Welfare Maximization**

## **Conclusion**

Note: A Complete Version of this paper will be available at the GTAP Conference or may be requested directly from the authors



**Table 1: Initial Permit Allocation for Covered Sectors  
(thousands of metric tons of carbon)**

<b>Sector</b>	<b>Historical</b>	<b>Value-Added</b>
Agriculture		
Coal		
Petroleum and coal products (refined)	126,269	5,675
Crude oil		
Natural gas	15,336	12,667
Electricity	621,064	166,386
Iron and steel industry	10,299	61,543
Chemical industry	99,509	337,254
Non-ferrous metals	5,976	33,612
Non-metallic minerals	14,877	72,613
Transport equipment		
Paper-pulp-print	13,074	216,654
Trade margins		
Other transport		
Water transport		
Air transport		
Communication		
Other machinery		
Other mining		
Food products		
Wood and wood-products		
Construction		
Textiles-wearing apparel-leather		
Other manufacturing		
Commercial and public services		
Climate Change Credit Corporation	423,237	423,237
<b>Total</b>	<b>1,329,641</b>	<b>1,329,641</b>

**Table 2: Initial Permit Allocation for Covered Sectors  
(thousands of metric tons of carbon)**

Country	Auction All + Ltax		GF Firms + Ltax		OBA Hist + Ltax		OBA VA + L Tax	
	Quantity	Percent	Quantity	Percent	Quantity	Percent	Quantity	Percent
United States	-3,290	-0.04	-7,889	-0.10	-6,771	-0.09	-1,751	-0.02
Canada	-211	-0.05	-226	-0.05	-182	-0.04	-273	-0.06
Europe	4,353	0.08	4,366	0.08	4,396	0.08	3,630	0.07
Japan	1,220	0.05	1,296	0.05	1,110	0.04	754	0.03
Other OECD	-113	-0.04	-115	-0.04	-111	-0.04	-95	-0.03
Former Soviet Union	-495	-0.20	-468	-0.19	-655	-0.27	-808	-0.33
Central European Associates	169	0.06	146	0.05	193	0.06	280	0.09
China (incl. HK & Taiwan)	231	0.03	337	0.04	121	0.01	-328	-0.04
India	273	0.08	273	0.08	277	0.08	283	0.08
Brazil	134	0.04	125	0.04	151	0.05	193	0.06
Other Asia	322	0.04	413	0.05	221	0.03	-170	-0.02
Mexico + OPEC	-2,624	-0.28	-2,633	-0.28	-2,653	-0.28	-2,849	-0.30
Rest of World	-604	-0.05	-646	-0.06	-637	-0.06	-470	-0.04

**Table 3: Carbon Emissions by Sector  
(thousands of metric tons)**

<b>Sector</b>	<b>Baseline</b>	<b>Auction All + Ltax</b>		<b>GF Firms + Ltax</b>		<b>OBA Hist + Ltax</b>		<b>OBA VA + L Tax</b>	
		<b>Quantity</b>	<b>Percent</b>	<b>Quantity</b>	<b>Percent</b>	<b>Quantity</b>	<b>Percent</b>	<b>Quantity</b>	<b>Percent</b>
Agriculture	12,635	-104	-0.8	-119	-0.9	83	0.7	-153	-1.2
Coal	100	-21	-21.3	-21	-21.3	-21	-21.4	-22	-21.5
Petroleum and coal products (refined)	126,269	-17,626	-14.0	-17,604	-13.9	-15,074	-11.9	-18,407	-14.6
Crude oil	4,982	-413	-8.3	-416	-8.3	-328	-6.6	-454	-9.1
Natural gas	15,336	-621	-4.0	-637	-4.2	-683	-4.5	-606	-4.0
Electricity	621,064	-114,323	-18.4	-114,082	-18.4	-108,252	-17.4	-112,741	-18.2
Iron and steel industry	10,299	-742	-7.2	-742	-7.2	-626	-6.1	-627	-6.1
Chemical industry	99,509	-8,992	-9.0	-8,999	-9.0	-7,688	-7.7	-5,724	-5.8
Non-ferrous metals	5,976	-501	-8.4	-502	-8.4	-393	-6.6	-378	-6.3
Non-metallic minerals	14,877	-1,901	-12.8	-1,890	-12.7	-1,979	-13.3	-1,577	-10.6
Transport equipment	4,495	-107	-2.4	-110	-2.4	25	0.6	-94	-2.1
Paper-pulp-print	13,074	-1,097	-8.4	-1,102	-8.4	-978	-7.5	-820	-6.3
Trade margins	17,764	-514	-2.9	-533	-3.0	45	0.3	-405	-2.3
Other transport	168,972	-15,412	-9.1	-15,455	-9.1	-17,074	-10.1	-16,368	-9.7
Water transport	9,881	-946	-9.6	-947	-9.6	-1,049	-10.6	-1,007	-10.2
Air transport	119,663	-15,312	-12.8	-15,331	-12.8	-17,877	-14.9	-17,181	-14.4
Communication	426	-13	-3.0	-13	-3.1	1	0.2	-11	-2.5
Other machinery	3,934	-100	-2.6	-102	-2.6	17	0.4	-96	-2.4
Other mining	45	-2	-4.2	-2	-4.2	0	0.1	-1	-2.3
Food products	12,474	-134	-1.1	-153	-1.2	193	1.5	-72	-0.6
Wood and wood-products	2,794	-78	-2.8	-78	-2.8	7	0.3	-68	-2.4
Construction	2,872	-46	-1.6	-45	-1.6	19	0.7	-36	-1.3
Textiles-wearing apparel-leather	3,185	-67	-2.1	-72	-2.3	29	0.9	-51	-1.6
Other manufacturing	3,624	-96	-2.6	-98	-2.7	14	0.4	-91	-2.5
Commercial and public services	31,851	-856	-2.7	-885	-2.8	104	0.3	-703	-2.2
Final Demand	260,543	-11,946	-4.6	-12,323	-4.7	-18,665	-7.2	-14,026	-5.4
<b>Total</b>	<b>1,566,642</b>	<b>-191,971</b>	<b>-12.3</b>	<b>-192,262</b>	<b>-12.3</b>	<b>-190,152</b>	<b>-12.1</b>	<b>-191,718</b>	<b>-12.2</b>

**Table 4: Carbon Leakage as a Percentage of U.S. Reduction**

<b>Country</b>	<b>Auction All + Ltax</b>	<b>GF Firms + Ltax</b>	<b>OBA Hist + Ltax</b>	<b>OBA VA + L Tax</b>
Canada	1.44	1.42	0.67	1.00
Europe	5.33	5.29	4.82	4.84
Japan	1.01	1.00	0.95	0.85
Other OECD	0.53	0.53	0.52	0.47
Former Soviet Union	0.98	0.98	0.86	0.81
Central European Associates	0.64	0.64	0.58	0.58
China (incl. HK & Taiwan)	2.47	2.45	2.18	1.87
India	0.73	0.73	0.68	0.62
Brazil	0.41	0.40	0.35	0.32
Other Asia	1.78	1.77	1.60	1.42
Mexico + OPEC	1.32	1.31	0.83	0.96
Rest of World	2.11	2.09	1.69	1.90
<b>Total</b>	<b>18.74</b>	<b>18.61</b>	<b>15.72</b>	<b>15.63</b>

**Table 5: Change in Production by Sector**

Sector	Auction All + Ltax			GF Firms + Ltax			OBA Hist + Ltax			OBA VA + L Tax			
	Baseline	Price	Quantity	Percent	Price	Quantity	Percent	Price	Quantity	Percent	Price	Quantity	Percent
Agriculture	221,217	-0.21	563	0.25	-0.08	302	0.14	-0.02	-310	-0.14	-0.20	-950	-0.43
Coal	32,630	-12.73	-4,481	-13.73	-12.54	-4,474	-13.71	-12.94	-4,492	-13.77	-12.96	-4,533	-13.89
Petroleum and coal products	145,767	2.14	-16,673	-11.44	2.23	-16,685	-11.45	-1.77	-12,369	-8.49	1.88	-17,268	-11.85
Crude oil	39,395	-4.54	-1,845	-4.68	-4.39	-1,857	-4.71	-3.66	-1,457	-3.70	-5.06	-2,032	-5.16
Natural gas	49,657	-0.90	-1,445	-2.91	-0.80	-1,484	-2.99	-0.52	-1,593	-3.21	-0.62	-1,412	-2.84
Electricity	258,050	8.66	-13,752	-5.33	8.66	-13,952	-5.41	-0.81	-816	-0.32	6.87	-10,263	-3.98
Iron and steel industry	142,544	0.64	-914	-0.64	0.81	-1,092	-0.77	0.03	-357	-0.25	-1.56	702	0.49
Chemical industry	716,372	0.87	-13,248	-1.85	1.01	-13,987	-1.95	0.04	-2,968	-0.41	-1.55	13,196	1.84
Non-ferrous metals	110,396	0.77	-1,642	-1.49	0.93	-1,767	-1.60	0.01	-334	-0.30	-1.09	750	0.68
Non-metallic minerals	127,295	0.60	-1,319	-1.04	0.76	-1,414	-1.11	0.06	-406	-0.32	-2.00	2,461	1.93
Transport equipment	661,162	-0.05	129	0.02	0.13	-796	-0.12	-0.02	-602	-0.09	-0.32	-2,083	-0.31
Paper-pulp-print	391,641	0.19	-1,110	-0.28	0.34	-1,729	-0.44	-0.01	-664	-0.17	-2.68	7,685	1.96
Trade margins	2,456,004	-0.27	-221	-0.01	-0.08	-4,951	-0.20	-0.10	-2,718	-0.11	-0.17	-1,402	-0.06
Other transport	459,556	1.52	-10,465	-2.28	1.67	-11,038	-2.40	2.05	-12,029	-2.62	1.78	-11,755	-2.56
Water transport	49,336	0.84	-808	-1.64	0.99	-866	-1.76	1.27	-917	-1.86	1.04	-934	-1.89
Air transport	161,518	3.44	-10,874	-6.73	3.59	-11,068	-6.85	4.30	-13,279	-8.22	3.84	-13,019	-8.06
Communication	384,623	-0.35	397	0.10	-0.21	-236	-0.06	-0.07	-529	-0.14	-0.18	-538	-0.14
Other machinery	787,603	-0.15	1,365	0.17	0.03	545	0.07	-0.06	-357	-0.05	-0.34	-3,029	-0.38
Mining	34,575	0.44	-379	-1.10	0.58	-403	-1.16	-0.08	-96	-0.28	0.31	32	0.09
Food products	744,582	-0.11	395	0.05	0.03	-925	-0.12	0.00	-954	-0.13	-0.24	-607	-0.08
Wood and wood-products	227,138	-0.07	-36	-0.02	0.09	-239	-0.11	-0.01	-222	-0.10	-0.18	-684	-0.30
Construction	1,351,225	-0.23	-1,486	-0.11	-0.04	-1,876	-0.14	-0.05	-1,022	-0.08	-0.35	-1,508	-0.11
Textiles-wearing apparel-leather	270,617	-0.03	-274	-0.10	0.15	-905	-0.33	-0.05	-180	-0.07	-0.32	-638	-0.24
Other manufacturing	705,388	-0.09	1,013	0.14	0.09	31	0.00	-0.05	-172	-0.02	-0.36	-2,830	-0.40
Commercial and public services	6,666,804	-0.35	4,354	0.07	-0.17	-6,957	-0.10	-0.09	-7,828	-0.12	-0.22	-7,805	-0.12
Dwellings	758,281	-0.42	2,244	0.30	-0.39	1,514	0.20	-0.04	-448	-0.06	-0.13	113	0.01
<b>Total</b>	<b>17,953,375</b>		<b>-70,512</b>	<b>-0.39</b>		<b>-96,311</b>	<b>-0.54</b>		<b>-67,120</b>	<b>-0.37</b>		<b>-58,351</b>	<b>-0.33</b>

**Table 6: Change in Trade  
(millions of 2001 dollars)**

Sector	Auction All + Ltax		GF Firms + Ltax		OBA Hist + Ltax		OBA VA + L Tax	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Agriculture	-128	385	-177	430	4	-55	235	-637
Coal	-336	1,872	-335	1,859	-337	1,851	-332	1,799
Petroleum and coal products (refined)	249	-1,547	207	-1,523	-1,901	332	381	-1,682
Crude oil	-9,769	19	-9,766	19	-7,171	12	-9,999	19
Natural gas	-302	25	-316	28	-177	-14	-91	-31
Electricity	520	-324	507	-320	-27	25	458	-292
Iron and steel industry	402	-332	395	-340	65	-74	-586	457
Chemical industry	2,429	-5,454	2,239	-5,379	295	-935	-2,467	5,741
Non-ferrous metals	559	-616	537	-620	87	-83	-377	408
Non-metallic minerals	386	-567	371	-568	65	-127	-925	1,338
Transport equipment	-438	291	-492	118	-200	83	866	-777
Paper-pulp-print	119	-236	85	-240	9	-48	-1,628	2,657
Trade margins	-240	318	-253	282	-106	111	228	-305
Other Transport	1,639	-2,455	1,587	-2,450	2,343	-3,215	2,674	-3,492
Water transport	55	-174	52	-175	92	-246	114	-283
Air transport	2,824	-5,005	2,769	-4,997	3,545	-6,057	3,632	-6,078
Communications	-95	187	-109	194	-34	48	60	-120
Other machinery	-1,050	1,397	-1,077	1,193	-379	392	793	-1,300
Mining	29	-53	26	-52	-3	-4	110	-108
Food products	-145	194	-224	216	-2	-81	369	-537
Wood and wood-products	-120	30	-134	24	-5	-11	437	-175
Construction	-8	51	-7	43	-2	10	3	-25
Textiles-wearing apparel-leather	-143	3	-295	-30	-95	-1	626	-269
Other manufacturing	-537	722	-645	505	-269	231	783	-1,185
Commercial and public services	-1,249	3,804	-1,300	3,525	-491	1,084	701	-2,365
Total	-5,349	-7,466	-6,355	-8,259	-4,695	-6,773	-3,935	-7,243

**Table 7: Percentage Change in U.S. Labor Demand, Leisure Demand, and Wage Rate**

Sector	Auction All + Ltax	GF Firms + Ltax	OBA Hist + Ltax	OBA VA + L Tax
Agriculture	0.35	0.06	-0.07	-0.27
Coal	-21.31	-21.28	-21.36	-21.54
Petroleum and coal products (refined)	-3.76	-4.00	0.55	-3.76
Crude oil	-8.29	-8.35	-6.58	-9.11
Natural gas	-4.05	-4.15	-4.46	-3.95
Electricity	0.00	-0.34	6.85	1.92
Iron and steel industry	0.20	0.00	0.23	1.30
Chemical industry	-0.84	-1.09	0.46	2.92
Non-ferrous metals	-0.39	-0.61	0.16	1.70
Non-metallic minerals	-0.36	-0.55	0.30	2.66
Transport equipment	0.14	-0.06	-0.07	-0.19
Paper-pulp-print	0.11	-0.17	0.06	2.38
Trade margins	0.11	-0.16	-0.08	0.07
Other Transport	-0.88	-1.12	-1.06	-1.06
Water transport	-0.48	-0.72	-0.56	-0.64
Air transport	-3.76	-3.98	-4.89	-4.95
Communications	0.19	-0.13	-0.06	0.00
Other machinery	0.27	0.08	0.00	-0.27
Mining	-0.51	-0.72	-0.25	0.61
Food products	0.22	-0.11	-0.06	0.11
Wood and wood-products	0.16	-0.04	-0.06	-0.12
Construction	-0.08	-0.17	-0.04	-0.06
Textiles-wearing apparel-leather	0.06	-0.25	-0.04	-0.08
Other manufacturing	0.26	0.04	0.01	-0.27
Commercial and public services	0.14	-0.12	-0.07	-0.02
Commercial and public services	0.41	0.04	0.09	0.23
Total	0.00	-0.24	-0.11	0.02
Demand for leisure	-0.02	1.56	0.72	-0.11
Real wage rate	0.03	-0.85	-0.38	0.07

**Labor Tax Rate**

Region	Auction All + Ltax	GF Firms + Ltax	OBA Hist + Ltax	OBA VA + L Tax
United States	39.19%	40.81%	40.27%	39.47%
Canada	40.00%	40.00%	40.00%	40.00%
Europe	40.00%	40.00%	40.00%	40.00%
Japan	40.00%	40.00%	40.00%	40.00%
Other OECD	40.00%	40.00%	40.00%	40.00%
Former Soviet Union	40.00%	40.00%	40.00%	40.00%
Central European Associates	40.00%	40.00%	40.00%	40.00%
China (incl. HK & Taiwan)	20.00%	20.00%	20.00%	20.00%
India	20.00%	20.00%	20.00%	20.00%
Brazil	20.00%	20.00%	20.00%	20.00%
Other Asia	20.00%	20.00%	20.00%	20.00%
Mexico + OPEC	20.00%	20.00%	20.00%	20.00%
Rest of World	20.00%	20.00%	20.00%	20.00%

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