CUTTING CARBON EMISSIONS AT A PROFIT (PART II): IMPACTS ON U.S. COMPETITIVENESS AND JOBS

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This article examines how an integrated least-cost implementation of the Kyoto Protocol in the United States would affect U.S. competitiveness and jobs. Drawing on previous work, the authors analyze integrated emission reduction strategies based on a $50/ton carbon tax (including border tax adjustments), a payroll tax cut, energy-productivity–oriented market reforms, and international flexibility mechanisms. This policy portfolios is compared to conventional approaches that omit market and fiscal reforms.

Input-output data are used to estimate the impact on export prices of goods and services produced in the United States. Similar data are used to translate changes in GDP and energy production into employment impacts in energy and nonenergy sectors. The costs of providing transitional assistance for workers in the coal industry are compared to the GDP benefits of a profitable Kyoto strategy.

The analysis shows that relative to purchasing international emission rights, productivity-raising domestic market, institutional, and fiscal reforms offer much broader advantages for trade-exposed U.S. industries. Though allowance purchases alone increase export prices of U.S. manufactured goods and services, an integrated no-regrets strategy reduces export prices for the large majority of U.S. industries and limits the impact of climate protection policies on the few most energy-intensive basic materials industries to very small levels. Relative to the baseline, an integrated least-cost implementation of the Kyoto target increases economy-wide employment levels by several hundred thousand jobs in 2010. (*JEL* Q43, Q48)

I. INTRODUCTION

This is the second of two articles reexamining the economics of mitigating greenhouse gas emissions in the United States based on integrated least-cost policies (Part I is Krause et al., 2002). The previous article showed that an integrated least-cost implementation of the Kyoto targets would produce a net gain in total U.S. economic output and welfare. The present article focuses on the sectoral competitiveness and employment impacts in the U.S. economy. Even if the economy-wide impacts of a well-designed

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ABBREVIATIONS

BLS: Bureau of Labor Statistics
BTA: Border Tax Adjustment
CEF: Clean Energy Future
DRI: Data Resources, Inc.
EIA: Energy Information Administration
GDP: Gross Domestic Product
ICCP: Intergovernmental Panel on Climate Change
OECD: Organisation for Economic Co-operation and Development
SIC: Standed Industry Code
WEFA: Wharton Econometrics Forecasting and Analysis

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greenhouse gas mitigation strategy are positive, the impacts on some individual sectors of the economy might be negative. These sectoral economic impacts would be determined by several factors. The first has to do with the overall effect of the climate policy on gross domestic product (GDP) and disposable income. Changes in disposable income lead to changes in the demand for products and services. This income effect on demand differs from industry to industry depending on the income elasticity of demand for different products and services. The second effect has to do with how a climate policy affects each sector's cost of production. Changes in the cost of production lead to price changes and these, in turn, lead to changes in demand. Again, these price effects differ from industry to industry according to the price elasticities of demand and supply for each product or service.

Changes in the cost of production also lead to changes in the competitiveness of U.S.-based businesses in export markets and relative to imports. The key is how the cost of production of U.S. businesses changes relative to that of foreign producers. Insofar as other Organisation for Economic Co-operation and Development (OECD) countries will be implementing carbon emission reduction policies of their own, any potential losses in competitiveness vis-à-vis these countries will be of relatively minor importance. Competitiveness issues thus mainly arise with respect to non–Annex I countries.

If climate policy consists solely of a carbon charge with no simultaneous market reforms or compensating tax cuts, overall impacts on GDP, disposable income, and jobs are negative. The carbon charge raises the cost of energy inputs, materials inputs (such as steel and plastics), and intermediate goods, leading to an increase in the cost of production. Though businesses may switch to new technologies that are more energy-efficient and also more cost-effective, they continue to face the market, organizational, and institutional barriers that have prevented them from adopting these options in the past. Although higher energy prices will make efforts to overcome these barriers more worthwhile, persistent high transaction costs and decision-making failures will prevent many of the energy-saving innovations from being fully adopted.

Increased production costs in particular U.S. industries reduce their export competitiveness or causes more of domestic demand for their output to be met by imports. Whether significant competitiveness problems do in fact arise for individual businesses depends on how exposed their markets are to international trade competition. Here the percentage relationship between carbon charge payments and the total value of shipments is important. This percentage relationship, in turn, varies with the energy intensity of each particular product or service.

Macroeconomic modeling work further suggests that alternative strategies for implementing the Kyoto treaty could shift international financial flows in a manner that would affect exchange rates. For certain industries, the resulting price effects could be more important than the price effect of the carbon charge considered in isolation. Combined effects might reduce U.S. exports by roughly 3%–10% (McKibbin et al., 1999), but the uncertainties surrounding these results are particularly large (Intergovernmental Panel on Climate Change [IPCC], 2001). Also, to date no modeling analysis of the Kyoto regime has examined scenarios that incorporate both tax shifts and market reforms in the key Annex I countries.

In the period leading up to and following the Kyoto negotiations, a number of sectorally disaggregated cost assessments were published that articulated concerns from various U.S. industries over the competitiveness impacts of a climate agreement (see, e.g., Electric Power Research Institute/CRA, 1994; American Council for Capital Formation, 1996; Szamosszegi et al., 1997; Wharton Econometrics Forecasting and Analysis [WEFA], 1998; Data Resources, Inc. [DRI], 1998). These studies analyzed the sectoral impacts of carbon charges ranging from $100/tC to close to $300/tC. They suggested that aside from slower growth economy-wide, negative impacts would be disproportionately large not only for the energy supply industry but also for a number of energy-intensive manufacturing industries, including steel, basic chemicals, and aluminum; for fuel-intensive airline services; and for U.S. automobile manufacturers whose most profitable product lines are big cars, sport utility vehicles, and trucks with low gas mileage.

These economic assessments formed the basis of opposition to the Kyoto Protocol from several influential sectors of the U.S. business community. They painted a picture of threatening competition from cheap imports from developing countries (basic chemicals, steel, airline services, automobile parts) as well as competitive advantages for Japan and Europe (automobiles), along with an overall reduction of U.S. economic growth. The theme of unfairness of the Kyoto treaty and U.S. demands for "meaningful participation by developing countries" stems in part from these anticipated trade effects. Past emphasis by U.S. negotiators on the importance of global emissions trading can be seen as an attempt to respond to these concerns and interests: such trading at once reduces the price of carbon paid by U.S. businesses and shifts most emissions reductions to other countries.

In a *least-cost strategy*, such as the one explored in the present article, the income effect on the economy is positive. GDP growth is higher than in the reference case, and disposable income rises over time relative to the baseline. This means that most businesses will experience somewhat higher demand for their products and services than without climate change mitigation. Overall employment in the economy will also rise (see also Barrett and Hoerner, 2001). Again, the impact for individual sectors will be determined by the income elasticity of demand for individual products and services.

Separately, each sector experiences price effects. In the context of an integrated no-regrets strategy, these are the sum of two countervailing impacts. On the one hand, there are additional expenditures due to payments of carbon charges, as well as additional costs for energy efficiency investments including program administration and expanded research and development efforts. These increase the cost of production. On the other hand, businesses realize economic benefits from energy savings and from tax cuts that recycle the revenues from the carbon charge. These energy savings and tax cuts reduce the cost of production. The impact of a least-cost climate policy on any individual industry depends on the net of these effects.

Because effects of the carbon charge on U.S. production costs are at least partially and possibly more than fully offset under the integrated least-cost strategy, the competitiveness issue may largely vanish or turn positive for the U.S. on balance. (Again, international flows and exchange rate effects may be important.) On the other hand, the U.S. fossil-energy industries will be affected differently. The challenge is to find policies that would let workers in the few losing industries participate in the broad economic gains accompanying the least-cost climate strategy.

II. ECONOMIC IMPACTS ON PARTICULAR SECTORS

A. Energy Intensity Structure of the U.S. Economy

In analyzing price effects, it is useful to distinguish between the fossil or predominantly fossil-based energy supply industries (coal, oil, gas, and electric utilities), whose major product is the target of climate policies, and energy-using industries. Among the energy-using industries, the groups of particular concern are the energy-intensive basic materials industries (steel, chemicals, aluminum, cement, etc.), as well as the energy-intensive transport services industries (trucking, airlines). Finally, there are all other industries. Within each of these categories, a distinction can be made between industries heavily involved in international trade and industries with little exposure to international trade. Table 1 shows the contribution of each of these sectors to the total U.S. economy in 1995.[1]

The four major fossil energy industries constitute about 4% of the economy. They represent less than 1% of all U.S. jobs. Among the four industries, only the U.S. coal industry is a significant exporter. By contrast, the domestic oil industry and, to a much lesser extent, the gas industry are competing with imports. Utilities have negligible exposure to trade.

Energy-intensive industry comprises about 3% of the total economy in terms of gross output and less than a fifth of all manufacturing output. In terms of employment, it accounts for about 1% of the U.S. economy. In this sector, energy costs typically exceed 5% of production costs, so that energy price

1. It should be kept in mind that more recent data would show a somewhat lower share for the energy industries and the energy-intensive manufacturing sectors.

TABLE 1
Distribution of Jobs and Output in the U.S. Economy in 1995

	Share of U.S. Economy in 1995		
	Employment		
	1000s	**%**	**Gross Output (%)**
Fossil-energy industries	1,253	0.9	4.6
Coal mining	106	0.08	0.19
Oil and gas extraction	318	0.24	0.98
Oil refining	104	0.08	0.60
Utilities	725	0.55	2.87
Energy-intensive manufacturing	1,423	1.1	2.7
Primary metals	411	0.31	0.68
Energy-intensive chemicals	319	0.24	0.88
Cement, glass, other nonmetallic minerals	385	0.29	0.41
Paper and allied products	215	0.16	0.47
Misc. petroleum & coal, food products	93	0.07	0.29
Transportation services	3,718	2.8	2.9
Trucking	1,867	1.41	1.26
Airlines	788	0.60	0.85
Rail and bus	874	0.66	0.57
Water and pipelines	189	0.14	0.25
Low-energy manufacturing industries	18,158	14	9
Transportation equipment	1,785	1.3	2.0
All other manufacturing	16,373	12.4	6.9
All other industries	93,323	71	73
Construction	5,158	3.9	3.7
Communication	1,333	1.0	2.7
Wholesale trade	6,412	4.8	6.5
Retail trade	21,173	16.0	9.3
Finance, insurance, real estate	6,830	5.2	18.6
Services	33,107	25.0	19.9
Government	19,310	14.6	12.3
Total employment	132,946	100	100
Total non-farm employment	117,875	89	92
Nonfarm self-employed and private households	9,868	7	6
Agriculture and forestry	5,203	4	2

Source: U.S. Department of Commerce (1996).

increases can raise the cost of production significantly.

Among basic materials industries, steel is exposed to significant trade competition, especially from developing countries, whereas chemicals face competition mainly from other OECD countries. Overall, the share of the energy-intensive basic materials industries in total U.S. exports and imports is larger than their share in total U.S. output, indicating a significant exposure to trade.

Transportation services account for another 3% of the economy, both in terms of gross output and employment. Here again, energy costs as a percentage of output prices are relatively high, so that energy price effects can have a significant impact. However, energy-intensive services have only limited trade exposure: truckers from Mexico will have to buy at least some of their fuel in the United States (and many states belong to an interstate compact that calculates trucking fuel taxes based on mileage traveled in the state rather than actual fuel purchases in the state), as will airlines based in the developing countries. U.S.-based airlines and freight firms can buy at least some of their fuel in non–Annex I countries as well.

For all other industries in the manufacturing sector, energy costs are no more than 2%–3% of total production costs. Though many of these sectors are significantly exposed to trade, energy price effects on their competitiveness will be small.

Secondary trade effects may, however, arise from shifts in demand for energy-efficient end-use equipment, such as cars and appliances. U.S. automobile manufacturers may be negatively affected by higher energy prices unless they significantly improve the energy efficiency of the larger vehicles that make up their most profitable product lines.

The rest of the economy, which makes up about three quarters of employment and gross output, is even more impervious to carbon charges in that the share of energy in production costs is generally 2% or less.

B. Sectoral Price Effects: A CEF-Based Analysis

To estimate the impacts of greenhouse gas reduction measures on individual industries in detail, various studies have used sectorally disaggregated macroeconomic models or input/output tables. The former have the advantage of formal model integration but allow a resolution of most effects only at the two-digit level of standard industry codes (SICs). Examples are the DRI model or the WEFA model for the United States. A more fine-grained analysis at the four-digit SIC level can be done with input/output tables.

Until recently, U.S. input/output analyses were limited to carbon charge effects or to combinations of carbon charge effects and tax shifts. However, a recent analysis by Hoerner and Mutl (2001) has estimated the effects of an integrated domestic no-regrets strategy including tax shifts and market reforms. It is based on the *Clean Energy Future* (CEF) scenario with a $50/tC charge (Interlaboratory Working Group, 2000) and uses a very detailed, 498-sector input/output table for the U.S. economy.

To illustrate the role of tax shifts, the carbon charge is rebated in the form of cuts in payroll taxes. The input/output tables track all scenario effects on production costs as they propagate through the economy over time. In particular, they account for changes in the prices of materials as a result of energy, investment, and tax changes in the most heavily affected trade-exposed industries in the basic materials sector.

Nonprice effects resulting from market reforms are incorporated into the input/output coefficients in the form of changes in the energy intensity of output. These are derived from the CEF scenarios. Adjustments are made on the basis of changes in the energy intensity of physical output or baskets of energy services that are most representative of total energy use in each economic sector. This procedure is necessarily only approximate where the analysis of end-uses in the CEF study does not perfectly match the aggregations of industry statistics on output, but it can serve as an indication of market reform effects in individual SIC groups.

Total production costs including carbon charges and payroll tax rebates are then calculated for 2010 and 2020. As a point of reference, the same calculation is also applied to 1997 based on that year's actual energy intensities and labor inputs.[2] The net tax burden of each sector is calculated as the carbon charge payments of the sector minus a cut in payroll taxes. The amount of payroll tax relief for each sector is based on the share of the sector in total base year employment and in total projected employment in 2010 and 2020.

In terms of carbon charges and domestic emission reductions, these calculations come reasonably close to our international CEF/Kyoto scenario with tax shifts and market reforms when combined with either a 50% supplementarity constraint and no sinks or a 30% supplementarity constraint with full sinks.[3] In these two cases, the domestic carbon charge is about $35/tC in 2010. Relative to the two Kyoto/CEF scenarios, the CEF-based calculations by Hoerner and Mutl somewhat understate the energy efficiency savings that would be realized by each industry because savings are larger for a lower carbon charge.

The payroll tax cut assumed by Hoerner and Mutl (2001) is broadly consistent with the assumption of a neutral double dividend in the CEF/Kyoto calculations of the previous article. (See Krause et al., 2002, and the references cited therein for a discussion of double dividend issues.) In previous studies, a payroll tax rebate has been found to generate either a weak double dividend or a strong double dividend (IPCC, 1996; Hoerner and Bosquet, 2001). The results of previous tax

2. The 1997 calculation is a static calculation—that is, no substitution response to higher energy prices is included.

3. See Krause et al. (2002) and the underlying calculations referred to there.

shift modeling research suggests that a payroll tax projected to produce a weak double dividend could be combined with cuts in corporate income taxes or with an increase in the investment tax credit to generate a neutral or strong double dividend.

The Hoerner and Mutl (2001) study finds that the overwhelming majority of businesses would benefit from the CEF climate policy scenario. Costs of production including shipping and retail margins (consumer prices) would drop for 84% of U.S. businesses in 2010 and for 96% in 2020 when share of business is defined as percent of the value of gross output. Measured by employment, 96% of U.S. industry would achieve lower prices in 2010, a figure that rises to 99% in 2020.

For the four fossil energy supply industries (coal, oil, gas, and electric utilities), output prices rise significantly. The price effect is completely dominated by the carbon charge and the carbon content of the input fuels. Output prices for the coal industry in 2010 and 2020 are close to 120% higher than in the CEF business-as-usual scenario. For oil the increase is about 20%, for natural gas about 15%, and for electricity about 12%. By 2020, the energy supply industry is just about the only sector of the U.S. economy with higher output prices than in the reference case. All other industries—roughly 96%—have lower output prices.

The impacts on these energy-using industries show a strong time dependence. Table 2 shows calculations based on Hoerner and Mutl (2001) for the 40 industry subgroups whose output prices at 1997 energy and labor inputs would be most strongly affected by the $50/tC charge plus labor tax rebate. These fall into the expected energy-intensive basic materials sectors: aluminum and other nonferrous metals, steel, refining and petrochemicals, food and beverages, chemicals, nonmetallic minerals, and pulp and paper. The transportation service industries also are part of this list. In total, these most affected energy-intensive manufacturing and transportation services industries represent about 6% of the economy (based on gross output) in the base year, and about 4% of total employment (see also Table 1). Had a carbon charge and a payroll tax rebate been implemented in 1997, an average rise in output prices of more than 3% would have resulted for this group.

As energy efficiency investments begin to take their effect, the weighted average rise in output prices shrinks to 0.6% in 2010, or about one fifth of the (hypothetical) base-year increase.[4] In trucking, airlines, and water transport, the growing penetration of more efficient vehicles, together with the payroll tax cuts, have the effect of reducing production costs below the levels of the reference case already by 2010. Excluding electric utilities and the fossil energy industry itself, only about 2% of the U.S. economy would see output prices rise more than 2%, and less than 0.2% of the economy would see prices rise by more than 3%.

By 2020, energy efficiency gains plus tax rebates more than compensate for the carbon charge and the levelized cost of efficiency investments for virtually all industries in Table 2. Average output prices drop by 2% relative to business as usual. All but 2 of the 40 industries in this most energy-intensive group have lower production costs than in the baseline scenario. Output prices in trucking and airlines are lower, by 5%–6%. Outside the fossil energy industry, 99% of the U.S. economy would experience a drop in output prices, and the remaining 1% would see a rise of no more than 1%.

The significant drops in production cost impacts shown in Table 2 between the hypothetical figures for 1997 and 2010 and between 2010 and 2020 mainly reflect capital stock turnover, notably in the basic materials industries. Though the transition to advanced, more energy-efficient production technologies is accelerated by market reforms, the replacement of existing processes still takes time. In the transport sector, relatively faster equipment turnover facilitates this process.

The percentage increase in the price of U.S. exports or in domestic products relative to imports depends on whether a border tax adjustment (BTA) is implemented. A BTA would impose the U.S. carbon charge on carbon-intensive imports or rebate the charge previously paid by U.S. producers of carbon-intensive exports. For the fossil fuel industries themselves, it is essential to impose BTAs, because otherwise untaxed foreign products

4. The CEF assumes that the carbon charge is phased in over the first decade after an initial announcement period of several years.

TABLE 2
Change in Output Prices in the Nonenergy Industries Most Affected by Climate Policies

	Share of Total U.S. Industry		Change in Production Cost (%) from $50/tC Charge plus Payroll Tax Rebate with Energy and Labor Use as in		
	Employment (%)	Gross Output (%)	1997 Actual	2010 CEF	2020 CEF
Nonferrous metals	0.11	0.28	6.46	4.27	0.81
Primary aluminum	0.01	0.04	14.84	11.26	3.34
Aluminum rolling	0.04	0.14	6.29	4.13	0.74
Aluminum castings	0.05	0.06	3.65	2.09	0.05
Electrometallurgical products	0.00	0.01	3.41	1.64	−0.25
Copper ore	0.01	0.03	2.68	0.88	−0.33
Steel	0.11	0.52	4.87	1.54	−0.40
Iron ore	0.00	0.02	5.46	1.89	−0.08
Blast furnaces and steel mills	0.09	0.40	4.98	1.36	−0.50
Metal cans	0.02	0.09	4.49	2.34	−0.03
Metal shipping barrels, drums, kegs	0.00	0.01	2.45	0.63	−0.49
Petroleum and coal products	0.03	0.13	4.19	1.17	−0.15
Asphalt paving mixtures	0.01	0.04	5.09	1.04	−0.25
Lubricating oils and greases	0.01	0.04	4.73	1.09	−0.20
Asphalt felts and coatings	0.01	0.03	4.23	1.92	0.00
Other products of petroleum	0.00	0.01	2.53	0.89	−0.21
Food and beverages	0.04	0.16	3.93	1.23	−0.30
Malt	0.00	0.01	4.66	1.40	−0.25
Animal and marine fats and oils	0.00	0.02	4.49	2.34	−0.03
Sugar	0.02	0.05	4.37	0.87	−0.65
Wet corn milling	0.01	0.07	3.46	1.14	−0.16
Cottonseed oil mills	0.00	0.01	3.11	1.25	−0.19
Chemicals	0.19	0.89	3.72	1.67	−0.04
Industrial chemicals	0.16	0.76	3.84	1.83	0.08
Gum and wood chemicals	0.00	0.01	2.98	1.40	−0.12
Fertilizers	0.02	0.07	2.97	0.54	−1.05
Carbon black	0.00	0.01	3.47	0.73	−0.49
Synthetic rubber	0.01	0.04	2.28	0.71	−0.36
Cellulosic man-made fibers	0.00	0.01	2.85	0.72	−0.45
Nonmetallic minerals	0.23	0.40	3.42	1.05	−0.34
Cement, hydraulic	0.01	0.04	9.94	2.95	0.32
Lime	0.00	0.01	6.92	1.78	−0.02
Brick and clay tile	0.01	0.01	3.47	0.73	−0.49
Structural clay products	0.00	0.00	2.78	0.58	−0.35
Ready-mixed concrete	0.08	0.12	2.39	0.36	−0.84
Gypsum products	0.02	0.03	2.50	0.46	−0.73
Glass containers	0.02	0.03	4.23	1.92	0.00
Glass and glass products	0.08	0.13	2.90	1.24	−0.16
Chemical and fertilizer minerals	0.01	0.03	2.56	0.61	−0.36
Transportation services	3.00	2.86	2.83	−0.40	−3.97
Natural gas transportation	0.01	0.06	6.85	0.47	−6.64
Water transportation	0.14	0.26	4.54	−0.51	−0.81
Trucking, courier services	1.34	1.46	2.66	−0.35	−5.32
Air transportation	1.03	0.87	2.45	−0.46	−1.98
Local and highway pass. transport	0.48	0.21	2.38	−0.65	−5.93
Paper and pulp	0.13	0.48	2.77	1.06	−0.62
Paper and paperboard mills	0.12	0.44	2.82	1.08	−0.62
Pulp mills	0.01	0.04	2.26	0.78	−0.66
Total/average for 40 industries	3.85	5.72	3.43	0.63	−2.07

Source: Hoerner and Mutl (2001).

would set the domestic market price and the carbon charge would have no impact on domestic consumption. In addition, the BTA would be necessary to prevent the loss of competitiveness of U.S. oil producers vis-à-vis imported oil in the domestic market. With a BTA, domestic oil producers would not be at a disadvantage relative to foreign oil producers as a result of the tax. Similarly, a BTA would allow U.S. coal producers to maintain the competitiveness of their exports even as higher domestic prices reduce coal consumption in the United States. Virtually all existing excise taxes, including U.S. federal taxes on motor fuels, have BTAs.

A U.S. cap-and-trade auctioned permit system would work in an analogous manner. Foreign oil suppliers would have to bid for permits to sell in the United States just as domestic suppliers would. At the same time, U.S. coal exporters would not need U.S. permits for shipping to other countries. Other mechanisms for eliminating competitiveness problems are caps on the percentage impact of carbon tax payments relative to production costs, or direct rebates of carbon taxes subject to certain energy efficiency investments, as implemented in some countries of the European Union. In the context of a domestic permit trading scheme, some permits could be set aside for the most affected industries.

The analysis by Hoerner and Mutl (2001) sheds light on how the CEF scenario (augmented by a payroll tax cut) would affect the competitiveness of U.S. industries. In these calculations, the change in the price of output in each subsector is weighted by the total value of exports in that industry. Competitiveness effects in the aggregate are measured by the weighted average increase in the price of total U.S. exports across all sectors. An analogous calculation is done for imports.

Excluding the fossil energy industries themselves, Hoerner and Mutl (2001) find that 7% of U.S. exports and 5% of imports are found in industries where the 1997 hypothetical carbon charge payments and payroll tax cuts would have caused a more than 3% net increase in the total price of shipments.

Assuming a BTA or its permit system equivalent just for the fossil fuel industries but not for any other industries, Hoerner and Mutl (2001) find that on a weighted average basis, U.S. export prices would *decrease* by 0.1% in 2010 and by 0.5% in 2020. Basically the same improvements in competitiveness are found for the price of U.S. domestic goods relative to imports (that is, the price of imports relative to U.S.-produced goods *rises*). Table 3 shows the distribution of changes in prices.

This favorable outcome again illustrates the importance of the market, organizational, and institutional reforms of the CEF scenarios. In the hypothetical application of the carbon charge plus payroll tax rebate to the 1997 base year (which excludes substitution effects), export prices end up 0.5% higher.

TABLE 3
Impact of CEF Scenario Plus Payroll Tax Cut on U.S. Competitiveness

	Distribution of Price Effects (%)			
	For U.S. Exports		**For U.S. Goods Rel. to Imports**	
	2010	**2020**	**2010**	**2020**
Change of prices				
+5% and more	0.00	0.00	0.01	0.00
+4% to 5%	0.02	0.00	0.02	0.00
+3% to 4%	0.00	0.00	0.00	0.01
+2% to 3%	1.25	0.00	0.55	0.00
+1% to 2%	3.53	0.00	2.89	0.00
+0% to +1%	22.75	5.72	20.58	4.42
−0% to −1%	66.37	87.09	73.68	92.67
−1% to −2%	3.95	6.99	1.92	2.42
−2% to −3%	2.13	0.11	0.35	0.37
−3% and more	0.00	0.09	0.00	0.12
Average price change	−0.12	−0.52	−0.12	−0.54

Source: Hoerner and Mutl (2001).

The transition from a rise in export prices in the 1997 reference year (tax shifts but no market reforms) to a decline in export prices in 2010 and 2020 is mainly due to energy productivity improvements brought about by the CEF reforms.

Table 3 shows that despite favorable average competitiveness impacts, a small portion of exports and imports occurs in the most energy-intensive industries where climate policy impacts lead to higher production costs. Also, near-term effects can be larger than those in 2010 or 2020. To eliminate competitiveness impacts in all industries where the 1997 (hypothetical) carbon charge effect is more than 3%, BTAs would have to be implemented for 34 different industries in addition to those for the fossil energy industries. For a threshold of 5%, the number of required BTAs beyond those for fossil fuels would decline to 13. Because U.S. imports are greater than exports, these BTAs would generate tax revenues of about \$20–\$25 billion/year in 2010 and 2020.[5]

III. ALTERNATIVE CARBON MITIGATION STRATEGIES

The authors' previous article showed that the U.S. Kyoto strategy championed by the Clinton administration—pursuing unrestricted international trading and inclusion of sinks as methods of cost reduction—did not represent an economically efficient strategy for the U.S. economy as a whole. But did it represent a sensible strategy for protecting the competitiveness of important individual U.S. industries?

The analysis suggests not. This can be seen by comparing the competitiveness impacts of a global trading scenario for implementing the Kyoto target in conjunction with a domestic strategy relying on only a carbon charge, and the CEF/Kyoto integrated least-cost scenarios based on domestic-only or international trading approaches. Table 4 summarizes this analysis.

Moving from left to right in Table 4, note as a point of reference a domestic strategy based on the average EMF-16 results (see Krause et al., 2002, for discussion of the methodology). Here, the carbon charge is \$230/tC (see Krause et al., 2002). This is followed by the global trading oriented strategy that was advanced by the United States at the post–Kyoto COP negotiations before 2001. The strategy is represented in stylized fashion by the EMF-16 case including 100 MtC in credits for sinks and no supplementarity constraint. It yields an international carbon price of \$33/tC.

Next is shown an integrated least-cost approach based on three versions of the CEF/Kyoto scenarios introduced in the previous article. In the first version, the Kyoto target is realized through a purely domestic strategy without use of sinks. Here, the carbon charge is \$136/tC.

The second case is that of Annex I trading only and no sinks. It yields a carbon price of \$61/tC. This case was not presented in the previous analysis of international strategies because that discussion focused on evaluating the U.S. negotiating positions. The present section of this analysis deals with pragmatic considerations of competitiveness and job impacts that have been key drivers in the political process surrounding the Kyoto treaty. In this context, it is fitting to acknowledge the real-world limitations of international carbon emissions trading schemes involving the developing countries. Difficulties with such schemes include accounting for national emissions, monitoring reductions, ensuring compliance, and responding appropriately to noncompliance. Although these problems may be manageable in the case of trading between Annex I nations, they are further complicated in non–Annex I nations by a lack of scientific and institutional capacity. In addition, the issue of the allocation of permits is contentious. China and India, the two largest developing countries and thus critical players in any global trading regime, have opposed trading that is not based on equal per capita allocations. There is growing support in Europe for a transition to equal emissions rights, but the potential for large North–South financial flows associated with such an allocation will make such a scheme difficult to negotiate. In short, in the time frame of our analysis, it is doubtful that the international community is capable of constructing a global greenhouse gas emissions

5. It should be noted that these results were derived for a specific carbon price and tax shift, both of which differ somewhat from the specifications of the CEF/Kyoto scenarios analyzed in the previous article. They do, however, provide a rough sketch of competitiveness issues in the context of a least-cost climate strategy.

TABLE 4
Energy Sector and All-Economy Impacts under Alternative Carbon Mitigation

	Price Signal Only		Integrated Policies		
	Domestic	Global Trading	Domestic	International Trading	
Market reforms	No	No	Yes	Yes	Yes
Tax shifts	No	No	Yes	Yes	Yes
Contribution from trading	None	Unlimited	None	Annex I only	Unlimited
Sinks	None	Full	None	None	Full
Border tax adjustments, fossil fuels	Yes	Yes	Yes	Yes	Yes
Border tax adjustments, other industries	No	No	No	No	No
Domestic carbon price, $/tC	230	33	136	61	5
International carbon price, $/tC		33		61	5
Economic efficiency of climate policy					
GDP impact rel. to BAU, $'97 billion/yr in 2010	−110	−30	48	47	59
GDP impact rel. to BAU in 2010, percent	−1.0	−0.3	0.4	0.4	0.5
Change in labor force in 2010, 1000s rel. to BAU	−549	−150	242	234	296
Impact on coal industry					
Change in 2010 coal consumption rel. to 1997	−82%	1%	−65%	−27%	1%
Change in 2010 coal consumption rel. to BAU	−84%	−10%	−69%	−35%	−10%
Change in employment in 2010, 1000s rel. to BAU	−45	−5	−37	−19	−5
Impact on oil and gas industry					
Change in 2010 oil consumption rel. to 1997	13%	20%	5%	8%	11%
Change in 2010 oil consumption rel. to BAU	−7%	−1%	−13%	−10%	−8%
Change in 2010 gas consumption rel. to 1997	52%	25%	18%	16%	14%
Change in gas consumption in 2010, % rel. to BAU	22%	0%	−6%	−7%	−9%
Change in oil and gas consumption in 2010, % rel. to BAU	4%	0%	−10%	−9%	−8%
Change in employment in 2010, 1000s rel. to BAU	33	−2	−41	−38	−37
Impact on electric utility industry					
Change in 2010 electricity consumption rel. to 1997	7%	20%	3%	9%	14%
Change in 2010 electricity consumption rel. to BAU	−13%	−2%	−16%	−11%	−7%
Change in employment in 2010, 1000s rel. to BAU	−38	−7	−49	−33	−21
Total employment impacts in 2010	−549	−150	242	234	296
Energy industries, 1000s rel. to BAU	−49	−14	−127	−90	−64
Nonenergy sectors, 1000s rel. to BAU	−500	−136	368	323	359

Note: BAU = business as usual.

trading system that is efficient, administrable, and fair, or one that ensures that the targeted emissions reductions will actually take place.[6] The current scenario case of Annex I trading acknowledges these limitations.

The third integrated CEF/Kyoto scenario is based on full sinks and no constraint on international allowance trading. This case, shown here to establish the theoretical limit for the range of effects, yields a world carbon price of $5/tC.

The energy consumption impacts for the four fossil-energy industries as shown in Table 4 are derived from the CEF model of the U.S. energy sector. To calculate the effects of any particular carbon price on the use of coal, oil, gas, and electricity, the authors interpolate using the modeling results of the CEF study.[7] Table 4 also provides a rough indication of employment impacts for each of the four major energy industries. Job changes are calculated relative to the official 10-year employment forecast of the Bureau of Labor

6. See, for example, OECD (1999), Driesen (1998), and Bernow et al. (2000). These problems are all the more compelling when emissions trading is not necessary in achieving efficient outcomes. When the countries undertaking emission reductions already have free trade in other goods, emissions trading may even be counterproductive (see Copeland and Taylor, 2000).

7. The breakdown by fuel is given in Tables 25 and 26 of Krause et al. (2001).

Statistics.[8] Calculated impacts thus take account of productivity gains under business-as-usual trends. Employment changes in each energy industry are assumed to be linearly proportional to changes in industry output in physical units.[9]

Table 4 shows the now familiar pattern: a domestic carbon charge by itself leads to low economic efficiency, GDP losses in excess of $110 billion/year, and opportunity costs approaching $170 billion/year when these losses are combined with the unrealized benefits offered by a least-cost strategy. Global trading moderates these negative impacts, but economic efficiency is highest in the CEF/Kyoto scenarios, which produce a net economic gain of about $50–60 billion/year in 2010. In percentage terms, impacts range from −1% to 0.5% of GDP.

According to the CEF model, a domestic carbon charge that by itself would be sufficient to realize the Kyoto target would lead to a roughly 80% reduction of U.S. coal consumption in 2010. Other models suggest that a domestic implementation of the Kyoto target would cut coal use by about 40–80% in 2010 and 50–90% in 2020. (See Energy Information Administration [EIA], 1998, and EMF, 1999, for a compilation of several U.S. analyses using different models.) In the case of global trading, U.S. coal consumption still shrinks below rising baseline projections but remains essentially flat relative to the base year.[10] To achieve the Kyoto emission reductions in the United States and in other Annex I countries, coal consumption is reduced in developing countries, notably in China.[11]

In the CEF/Kyoto scenario based on domestic least-cost measures only, coal consumption would again be strongly affected. With trading among Annex I countries, the decline in U.S. coal consumption is more moderate at 27% relative to the 1997 base year. This impact is greater than that of the global trading case, but it avoids two-thirds of the decline that occurs in the domestic carbon charge only scenario. The CEF/Kyoto scenario with unrestricted trading results in the same flat coal consumption as the global trading case.

These results indicate that an integrated least-cost strategy can avoid much of the deleterious effect on the U.S. coal industry without shifting most emission reductions to the developing countries. One factor leading to this outcome is that domestic energy efficiency investments cost-effectively substitute capital for energy regardless of the carbon intensity of the fuel being used. As a result, energy consumption declines not just or mainly in coal, but reductions are spread across all energy carriers.

The same dynamics are reflected in the job impacts. Given ongoing structural shifts in the coal industry and related productivity increases, employment in coal mining already is projected to decline by more than a third in the reference case, from 92,000 miners in 1998 to about 59,000 in 2008 (Thomson, 2000). Climate policy impacts come on top of these trends.

Job losses in the coal industry would likely be much lower than the percentage changes in coal consumption for several reasons. First, as discussed in the modeling work of the EIA (1998), a carbon charge would disproportionately affect the Western U.S. coal-producing regions, where coal production is much less labor-intensive than in the East. Second, there is a significant annual turnover of workers in the industry, both on account of retirement and because of workers choosing to seek other employment (this latter point applies to all the calculations of job impacts in all the energy industries). For these reasons, the estimates in Table 4 of coal mining

8. See Thomson (2000). Forecasts to 2010 are constructed from the Bureau of Labor Statistics 1988–2008 forecasts by constant growth extrapolation of production and labor productivity trends.

9. Note that this methodology slightly overprojects both the job increases and the job decreases as a portion of the change in labor demand represented here will manifest as wage increases (decreases) rather than employment increases (decreases). Also, these figures may overstate employment losses in the coal industry because they assume that coal exports would decline in proportion to reductions in U.S. coal consumption.

10. This result is in broad agreement with other models (see EIA, 1998). Relative to the rising baseline, these studies predict a decline by about 10%–20% in 2010 and about 20%–40% in 2020.

11. Several of the EMF-16 simulations find that China would be the main marginal supplier of permits in going from the Clean Development Mechanism to full global trading. For example, MacCracken et al. (1999) find that China would reduce its 2010 energy consumption by 24% in a global trading system to sell emissions allowances, and that some 85% of this reduction in energy use would come from lower consumption of coal. Very similar results are reported by McKibbin et al. (1999).

jobs lost are likely to overstate impacts on workers currently employed in the industry.

In all the climate policy scenarios shown in Table 4, both oil and gas consumption are higher in 2010 than in the 1997 base year.[12] Oil consumption is 7%–13% lower than in the business-as-usual projection. The global trading scenario would reduce baseline U.S. oil consumption by only 1% in 2010, barely affecting the business-as-usual growth trajectory. Here again, emissions reductions in developing countries—in this case those from lower oil consumption—are substituted for domestic emission reductions. This outcome would improve the position of the U.S. oil industry, but the benefit to the United States of reduced (pretax) import prices for oil largely vanishes under global trading.[13] In the CEF/Kyoto scenarios, U.S. oil consumption declines by similar percentages as in the domestic scenario based on a carbon charge alone.

Though oil consumption declines somewhat relative to business as usual in all climate change scenarios, this is not the case for gas. The domestic carbon charge leads to a significantly larger increase in 2010 gas demand than in the business-as-usual projection. This prospect has caused concern over the possibility of gas price increases due to supply bottlenecks in expanding pipeline infrastructures (EIA, 2000). However, this possibility is avoided in all the other climate policy scenarios. In the global trading case, gas consumption is the same as in the business-as-usual projection. The integrated least-cost strategies reduce gas requirements by 6%–9% below the baseline. This results in lower gas prices to the U.S. economy, not higher ones.

The Bureau of Labor Statistics (BLS) projections indicate a slow decline in employment in the oil and gas sector (defined here to include oil and gas extraction, field services, petroleum refining, and gas utilities), from 571,000 in 1998 to 474,000 in 2008. Slower growth in oil consumption and, in the case of the integrated policy scenarios, slower growth in both oil and gas consumption, would have a moderate effect on employment in the sector. In the case of a domestic carbon charge only, the disproportionate growth in gas demand would more than offset the effect of declining oil consumption, and employment would increase somewhat. With global trading, employment effects would be approximately zero in this sector. In the integrated policy scenarios, employment would decline somewhat, but the effect would remain small relative to the drop in employment implicit in the business-as-usual projections.

U.S. electricity consumption rises under all five climate policy scenarios shown in Table 4. In the purely price-based domestic strategy, electricity growth is reduced the most. In the global trading case, much of this price-driven behavioral impact on demand growth is eliminated. An integrated least-cost strategy arrives at an intermediate level of electricity use that lies between the domestic and the global trading strategy.

According to the BLS projections, total employment in the electric utility sector will decline from 364,000 in 1998 to 311,000 in 2008. In the case of the domestic policy based solely on permit prices, employment would fall by about an additional 40,000 jobs. In the global trading case, employment impacts would be negligible. In the integrated policy cases, the simplified calculations indicate additional reductions relative to business as usual of about 20,000 to 50,000.

However, in the integrated policy scenarios, slower demand growth relative to the 1997 base year is achieved in part through no-regrets energy efficiency investments, and the scenarios based on permit prices achieve lower electricity demand mainly through price-driven behavioral changes or fuel switching. This distinction is important in considering employment effects, because of the diversification of utilities into the energy efficiency business. A number of utilities have expanded into this field by acquiring energy service company subsidiaries. With restructuring, demand-side efficiency investments are being continued through system benefits

12. The CEF results for oil and gas consumption effects are broadly similar to the estimates reviewed in the EIA (1998) analysis, where consumption in 2010 and 2020 declines by about 10%–20% relative to baseline projections. The domestic implementation of the Kyoto targets in the United States and other Annex I regions would also reduce the world price of oil by 10%–20% relative to baseline projections. See EIA (1998) and McKibbin (1999). However, these savings in the United States oil bill are not sufficient to avoid the estimated GDP losses caused by this strategy.

13. See the EIA (1998) analysis, 1990 + 24% case (global trading plus 60 MtC of sinks), and McKibbin et al. (1999).

charges. A substantial number of system benefits programs are run by distribution utilities emerging from the restructuring of the electricity industry. The figures in Table 4 do not take account of these dynamics. As a result, the calculated impacts on jobs in the electricity sector are larger than what a more detailed analysis would likely indicate.

Because of their highly simplified nature, the calculations in Table 4 can provide no more than a general impression of the sectoral employment impacts of alternative U.S. climate policies. With this caveat in mind, the results for the energy industry can be summarized as follows. Overall, employment in the energy industries declines by 2%–16% relative to the baseline projection for 2010. The employment impact in the integrated least-cost policy scenarios ranges from 8% to 16%. For the scenarios based solely on permit prices, the range is 2%–6%. Within each of these two ranges, the domestic strategy represents the high end and the global trading strategy the low end. Within these modest overall impacts, the coal sector represents a special case. Here, potential job impacts are in the range of 10%–84%. For realistic scenarios based only on Annex I trading, the effect is about 35%. In absolute terms, employment in the energy industries declines by 14,000 to 127,000 jobs. Relative to the projected total U.S. employment in 2010 of about 165 million, these energy sector impacts represent a very small effect, of the order of one-tenth to one-hundredth of 1%.

Table 4 also shows the change in aggregate U.S. employment in 2010 for each scenario. The domestic price-only policy leads to a loss in employment of more than half a million jobs relative to the baseline with no climate policy.[14] Job losses in the energy sector are compounded by across-the-board losses in the economy at large as GDP grows more slowly. Global trading cuts these impacts by two-thirds but still brings net losses of 150,000 jobs. In contrast, the integrated least-cost scenarios take the employment balance into positive territory. Job reductions in the energy sector are more than compensated by several hundred thousand new jobs in the economy at large as energy productivity increases GDP growth. On a net basis, the CEF/Kyoto strategies add more than 200,000 to 300,000 jobs to the economy.

The figures developed in Table 4 illustrate the substantial economic opportunity cost of attempts to preserve energy sector jobs through nonaction in the area of climate change mitigation. For example, relative to an integrated policy that includes Annex I trading, every job preserved in the energy sector costs about $500,000 per year in forgone 2010 economic output and the loss of four new jobs that the integrated climate policy would create in other sectors.

These calculations show that an integrated least-cost strategy for mitigating U.S. greenhouse gas emissions would moderate employment impacts in the energy sector but would still have a disproportionate effect on workers and communities in the U.S. coal mining regions. The severity of potential impacts is not captured in the absolute number of jobs involved, which is only 0.01% to 0.05% of total U.S. employment. What is a cause for concern and potential policy action is the geographically concentrated nature of these impacts.

This raises an equity issue: Should U.S. coal miners be the one group of workers having to bear significantly negative economic consequences when other energy sectors suffer only minor impacts and the rest of the economy enjoys net benefits? It is important to remember that this localized burden on a small sliver of the economy would occur in the context of a significant new government revenue stream from permit auctions or carbon taxes. In principle, it should be possible to devise a strategy in which some of the revenues generated by carbon mitigation are used to support the adjustment process for those few workers and communities that will be negatively affected.

What would be the approximate cost of a socially viable transition package for affected coal miners and their communities? Table 5 shows the total adjustment fund needed if the federal government were to provide a compensation package of $120,000/year per lost job.[15] The total annual cost of such a

14. The employment impact in the EIA (1998) analysis is adjusted by the ratio of 2010 projections of total employment in the EIA (156.5 million) and BLS analysis (164.85 million). The job loss estimated under this domestic price-only scenario is lower than that of the EIA because the average GDP decline in the EMF studies is lower than the GDP loss estimated by the EIA.

15. Assuming payroll costs of roughly $60,000/year per worker and job retraining benefits, community

TABLE 5
Cost and Possible Financing of Assistance Fund for Coal Miners

	Price Signal Only		Integrated Policies		
	Domestic	Global Trading	Domestic	International Trading	
Market reforms	No	No	Yes	Yes	Yes
Tax shifts	No	No	Yes	Yes	Yes
Contribution from trading	None	Unlimited	None	Annex I only	Unlimited
Sinks	None	Full	None	None	Full
Border tax adjustments, fossil fuels	Yes	Yes	Yes	Yes	Yes
Border tax adjustments, other industries	No	No	No	No	No
Domestic carbon price, $/tC	230	33	136	61	5
International carbon price, $/tC		33		61	5
Total employment impacts in 2010	−549	−150	242	234	296
Energy industries, 1000s rel. to BAU	−49	−14	−127	−90	−64
Nonenergy sectors, 1000s rel. to BAU	−500	−136	368	323	359
Cost of social adjustment in coal regions					
Adjustment fund @ $120k/yr per job, $billion/yr in 2010	5.4	0.6	4.4	2.2	0.6
Revenue from permits or C charge, $billion/yr in 2010	288	41	170	76	6
Adjustment fund as a fraction (%) of revenue	2	2	3	3	10

program in 2010 would be in the range of $1–$5 billion per year. For realistic integrated policy scenarios, these amounts would represent only about 2% of annual revenues from permit auctions or carbon taxes.[16] This is a small enough fraction not to interfere with the overall effectiveness of tax shift reforms in the integrated CEF/Kyoto scenarios.

The level of industry-specific employment impacts and associated transition assistance costs shown here are based on the difference in aggregate employment in the industry between the base and policy cases, under the assumption that employment is linearly related to output. It should be observed that this is an upper-bound estimate. The number of individual workers in the coal mining industry that would actually lose their jobs due to climate policies is much lower. This is because all industries (including coal) see attrition from retirement, voluntary quits, and discharges for cause. Thus reductions in the coal industry workforce can be achieved at least partly (and in some cases fully) through attrition rather than layoffs. In the manufacturing sector, attrition through retirement alone is around 3% per year, and from all sources may be as high as 10% annually (Davis and Haltiwanger, 1992). Adjusting layoff estimates for attrition would substantially reduce the job loss estimates.

On the other hand, the estimates of transition costs required to make laid-off workers whole may be either high or low. If it is possible to clearly identify workers who are laid off for climate-related reasons, the estimate of transition costs will be high, for the reasons already given. On the other hand, it may not be possible to distinguish climate-related layoffs from other layoffs that are not climate-related. If benefits were to be extended to all workers laid off in the affected industries, the cost of transitional assistance could be considerably increased.[17]

IV. SUMMARY AND CONCLUSIONS

In the past, the United States has sought to minimize potential negative impacts from greenhouse gas mitigation on U.S. output, competitiveness, and jobs by seeking cost reductions through international trading of emission rights and other flexibility mechanisms. An integrated least-cost approach to

redevelopment grants, and support for workers' families that double this figure to $120,000/year, made available for 10–20 years.

16. Total revenues are based on the amount of 2010 emissions assigned to the United States under the Kyoto treaty, that is, 1,250 MtC assuming no credits for sinks.

17. See Barrett and Hoerner (2001) for a more extensive discussion.

reducing U.S. greenhouse gas emissions that includes productivity-raising domestic market, institutional, and fiscal reforms turns out to be superior not only because of positive GDP effects but also in terms of improved U.S. competitiveness and job growth.

Relative to purchasing international emission rights, domestic market, institutional, and fiscal reforms offer much broader advantages for trade-exposed U.S. industries. Although allowance purchases increase export prices of U.S. manufactured goods and services, an integrated least-cost strategy reduces export prices for the large majority of U.S. industries, and limits the impact of climate protection policies on the most energy-intensive basic materials industries to very small levels.

This analysis shows that combinations of productivity-raising domestic market, institutional, and fiscal reforms would insulate U.S. industries from competitiveness problems more effectively than a strategy relying mainly on global emissions trading. Even with a purely domestic strategy of market and fiscal reforms, the overwhelming majority of U.S. industries—about three-quarters in 2010, and about 95% in 2020—would see a decline in the prices of their exports. In these industries, energy productivity investments and tax rebates have the net effect of reducing production costs despite the application of the $50/tC charge.

An integrated approach also moderates job losses in the U.S. energy sectors. Only in the coal industry may climate-policy related job losses exceed normal rates of worker attrition. For this industry, an adjustment fund providing direct assistance to affected workers and communities could be financed with a small fraction of revenues expected from U.S. permit sales.

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