Using the Inforum *LIFT* and *Mudan* Models to Investigate the Impacts of Cap and Trade Legislation on International Leakages

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Background

In the last two years, various policy initiatives have been drafted with the goal of putting a system in place for reducing U.S. carbon emissions. Most of these initiatives have incorporated some form of cap and trade system, whereby a given number of emissions allowances are marketed by the government to emitters, and a market price for the emission of carbon dioxide is established. Under certain simplifying assumptions, such a cap and trade system is equivalent to the imposition of a carbon tax, but with the advantage that the market sets the value of the allowances according to the marginal cost curves of the producers who must reduce their emissions.

An interesting and politically relevant question with regard to cap and trade is the effect of the carbon price on "international leakages". These leakages are the effect of higher export prices of U.S. goods that require energy inputs that use carbon, either directly or indirectly, which will lead to a reduction of U.S. exports. Imports to the U.S. may increase due to the increased relative cost of domestic goods compared to goods produced in other countries without an emissions reduction system, such as China.

Our study uses the Inforum *LIFT* model of the U.S. Economy, the *Mudan* model of the Chinese economy, and the Inforum Bilateral trade model to assess the leakages associated with the adoption of a carbon price in the U.S. This paper begins the analysis by comparing several scenarios for the U.S. The first scenario is the base case, based on the *Annual Energy Outlook* (AEO) 2009 "Stimulus" case, produced by the Energy Information Administration (EIA). In this scenario, the reference case is also used for *Mudan*, which assumes no price is imposed on carbon emissions. The second scenario assumes implementation of certain key features of the Waxman-Markey (WM or HR2454) legislation. In this scenario, we still assume that China does not price carbon emissions. In Scenario 3, we assume that China does price carbon, but does not try to establish the price at the same level as the U.S. price.[2] The revenue obtained by the Chinese government is recycled in the form of tax relief, to keep the China scenario roughly deficit-neutral. Finally, in Scenario 4, China also prices carbon, but the revenue is distributed as a combination of tax relief and increased health care spending. This paper discusses the implementation of these scenarios and reviews the results, including the U.S. trade impacts in the different cases. This paper focuses on effects of the

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[2] The price of carbon is determined so as to reduce emissions consistent with China's stated goals, and is actually set higher than the U.S. price.

legislation from the U.S. perspective, but we also discuss some of the policy issues and choices from the Chinese perspective.

The Inforum *LIFT* model is ideally suited for an analysis such as this since it models the U.S. economy at a detailed level of 90 industries[3]. Effects of carbon taxes on industry prices are explicitly modeled in the cost structure of each industry. A carbon tax raises the cost of energy inputs, such as electricity, petroleum and natural gas. Each industry can pass some portion of these costs on in the form of higher prices, which may lead to a reduction in competitiveness. *LIFT* also models imports and exports at this 90 industry level, and both import and export equations make use of the ratio between foreign and domestic prices for each commodity. *LIFT* models the U.S. economy annually, showing the dynamic response to policy and price changes, and is capable of making projections out to 2050[4].

The Inforum *Mudan* model of China is similar to the *LIFT* model, but has industry detail for 59 industries[5]. Energy consumption detail has recently been enhanced for a study looking at energy consumption in China under various scenarios. The *Mudan* model will be adopted for the current study to analyze the price effects of carbon taxes in China.

Mudan and *LIFT* are linked, along with other Inforum international models, in the Bilateral Trade Model[6]. This model converts import demands of each country into the exports of bilateral trading partners, using an econometrically estimated equation for each country/commodity pair that uses relative exchange rate adjusted price and relative growth in industry specific investment in each country.

We begin by summarizing the main components of the proposed Waxman-Markey legislation. We then describe the development of the base case for the U.S. *LIFT* model, which is calibrated to the *Annual Energy Outlook* (AEO) 2009 Stimulus case. The next section describes the main assumptions adopted in the modeling of the Waxman-Markey legislation, and provides an overview of results. Here we only compare the reference case ("Case 1") with the case where the U.S. prices carbon but China doesn't ("Case 2"). The next section discusses how the adoption of carbon pricing in China changes the results, and compares the differential effects of the two forms of revenue recycling. The final section concludes, and discusses how a similar framework could be adopted to analyze different cap and trade policies, as well as the calibration to newer versions of the AEO and the extension of the modeling horizon. The *LIFT* model, *Mudan* model and Bilateral Trade Model are described in more detail in appendices to this paper.

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[3] The *LIFT* model is described in McCarthy (1991) and Meade (2001), as well as in appendix A. Other studies of interest include Meade (2008), Business Roundtable (2009), Securing America's Future Energy (2009) and Wescott and Werling (2010),

[4] For calibration to the AEO, we are of course limited to the AEO forecast horizon. For the AEO 2009, this was 2030.

[5] Mudan is described in detail in Yu (1999).

[6] The Inforum Bilateral Trade Model is described in Nyhus (1991) and in Ma (1995).

Summary of the Proposed Waxman-Markey Bill

There have been many proposed bills for reducing carbon emissions in the U.S. At the time this study was initiated, the Waxman-Markey bill was being considered by Congress. The Waxman-Markey legislation (H.R. 2454) is also known as the American Clean Energy and Security Act (ACESA) of 2009. This legislation has 4 major titles:

1. **Clean Energy**: This title includes stimulus for renewable power generation, carbon capture and sequestration (CCS), clean transportation, smart grid investments and nuclear power.

2. **Energy Efficiency**: This title includes incentives for improving building efficiency (lighting and appliances) and transportation efficiency.

3. **Reducing Global Warming**: This is the title that includes the cap and trade system with allowance allocation, banking of allowances and offsets.

4. **Transition Issues**: This title consists of two major provisions: A) "Inslee/Doyle Provisions" or output-based rebates to Energy-Intensive Trade Exposed (EITE) industries, and B) "Green Jobs" or worker transition assistance.

Not all elements of the proposed legislation were modeled in *LIFT*. In the next section we discuss the development of the AEO 2009 base case in *LIFT*, and the following section describes how selected elements of the Waxman-Markey legislation were incorporated into the Waxman-Markey scenario.

Development of the AEO Base Case with the LIFT Model

The *LIFT* model was calibrated to be consistent with the AEO 2009 Stimulus case. This was done in two stages. In the first stage, industry variables, macroeconomic variables, and IO coefficients were modified to produce a macroeconomic forecast consistent with the AEO. In the second stage, imports, exports, personal consumption expenditures and IO coefficients were modified to calibrate energy and carbon projections from the AEO. For this study, the *LIFT* projections were made to 2030, which is the same forecast horizon used in AEO 2009.

The following table provides an outline of the general calibration strategy, but the final version required several iterations of these steps. The general strategy is based on the goal of getting the exogenous variables calibrated first, and then working down into further degrees of endogeneity.

Population and labor force	Population projections are made by detailed age group in *LIFT*, and participation rates by age group can be fixed by assumption. However, total population and labor force can also be set exogenously.
Government spending	Government spending in LIFT is composed of many small components, which are adjusted to control to the total government spending shown in the AEO.
Exports	In this study exports were endogenous. In other words, the export equations based on forecasts of foreign demands and foreign competing export prices. However,

	we applied add factors to exports to bring the total in line with the AEO.
Crude oil price, natural gas price and coal price	The price in *LIFT* is specified as a nominal price index. AEO presents these prices in real terms, i.e., divided by the GDP deflator. Once the path of the GDP deflator has settled down, this assumption can be fine-tuned.
Personal consumption	The real personal consumption total can be specified exogenously to *LIFT*. However, this takes away much of the model's behavioral responses. So, while it may be helpful to fix total personal consumption at first, before we are done we need to take this assumption off, and guide personal consumption total to its target, through a combination of hitting the real disposable income target, and changing the personal savings rate.
Investment	The AEO macro table only shows the total investment figure. In LIFT this is the sum of equipment investment, residential structures investment and nonresidential structures investment.
Total Imports	In LIFT, imports are the sum of imports of about 90 commodities. Individual equations relate these imports to domestic demand for that commodity, and relative domestic to foreign import prices. Imports are calibrated to the AEO base through aggregate modifiers.
Imports of Crude Oil	Imports can also be adjusted by targeting the import share of domestic demand. This is often a useful method for calibrating imports of crude oil. Given the domestic requirements for crude oil, the import share variable specifies the share of that demand that will be imported.
Labor Productivity Growth	Aggregate labor productivity growth in LIFT is essentially a weighted average of productivity growth by industry. The LIFT labor productivity equations are time trend equations with a cyclical component to model pro-cyclical labor productivity.
Employment and Unemployment	Employment is also calculated in LIFT at the industry level, based on output, productivity, and average hours worked per employee. Since employment and productivity trends are integrally related, it is useful to get the productivity targets in line first, and then make minor modifications to employment. The aggregate unemployment rate can also be calibrated by altering the multiple job adjustment, which relates industry employment to household employment.
Energy Consumption, Energy/GDP ratios	Energy consumption can be traced in the *LIFT* model at several different levels. Energy consumed in final demand includes personal consumption of gasoline, heating oil, natural gas and electricity; government purchases of fuels and electricity, and energy consumed in building residential and nonresidential structures. Energy flows in the intermediate demand part of the model include industrial consumption of energy for space heat and light, stationary power sources, transportation fuels, and electricity for many uses. These flows also include the conversion of energy from one type to another, such as the refining of crude oil into petroleum products, and the generation of electricity from coal and other fuel sources. The main objective when measuring energy use to GDP is not to double-count, but to measure only net flows of energy.
Nominal and Real Disposable Income	The AEO shows a projection for real disposable income only. Real disposable income in *LIFT* is determined by first building up personal income from its pieces (labor compensation, dividends, net interest, proprietors' income, transfer payments, etc.) and then removing personal taxes to obtain nominal disposable income. Nominal disposable income is then divided by the aggregate consumption deflator to obtain real disposable income. To calibrate real disposable income, we need to adjust components of personal income and the personal tax rate.
GDP Price Level and Inflation	The aggregate GDP price level in LIFT is determined as a combination of all commodity prices, including of course exogenous prices such as those for crude oil and coal. These prices are used to calculate final demand in current prices. The sum of all final demands equals GDP, and the price level is obtained simply by dividing nominal GDP by real GDP. We define inflation in LIFT as the first difference in logarithms of the GDP deflator, multiplied by 100. To target, or calibrate an inflation rate such as AEO, adjustments are made to the forecasts of

several categories of value added by industry.

Energy consumption by sector and by source is calibrated by mapping major sectors of the NEMS/AEO framework to industries and final demands in *LIFT*. For example, the NEMS Industrial sector includes industries 1 to 58 in LIFT. The NEMS Commercial sector includes industries 65, 68 to 88 plus government. The Residential sector corresponds to personal consumption expenditures for electricity, natural gas and heating oil. The Transportation sector maps to *LIFT* sectors 59 to 64 for commercial transportation activities, and to personal consumption of gasoline and oil for personal consumption. Sectors 66 and 67 are electric utilities and natural gas utilities, respectively.

Energy consumption by business is represented in *LIFT* in the intermediate sales block of the model. This consumption is calibrated by adjusting IO coefficients of energy products to energy-consuming industries, so that the total energy consumption by sector in real terms grows at the same rate as the energy consumption in AEO. For the personal consumption sector, which includes household energy use, and fuel for personal vehicles, a multiplicative factor is applied to the personal consumption equation in *LIFT* to match the AEO growth rate.

The electricity generation model is calibrated by first fixing the shares or levels of electricity generation by type (coal, gas, nuclear, etc.). The model can also be adjusted to model increased efficiency of generation from fuels (electricity produced from a unit of coal). The demand for fuels and other inputs from the electric power industry is then determined as a weighted sum of the inputs from the 8 types of power generation, to determine coal, gas and petroleum requirements.

The Main Assumptions for the Modeling of Waxman-Markey

The Waxman-Markey scenario was developed by starting with the AEO 2009 calibrated baseline, and then incrementally changing existing assumptions or adding new assumptions. These assumptions are described below.

Carbon allowance price. The *LIFT* model does not solve for the equilibrium carbon price. However, an exogenously derived price can be input as an assumption, and the price effects on energy sectors and energy-intensive sectors can be determined. Table 1 shows the assumed carbon price for selected years, in real and nominal terms.[7] This assumption was supplied to us by the DOE policy office, and is the price used in a parallel exercise using the Markal model.

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[7] The deflator used to calculate the implied nominal rate of tax was the GDP deflator forecasted in the AEO 2009 base case. The GDP deflator actually rises by about 1.3% in the Waxman-Markey tax simulation. However, no attempt was made to iterate to obtain consistency between the GDP deflator and the nominal carbon price.

Table 1. Carbon Price Assumption for Waxman Markey

	2008$	Nominal
2012	10.16	10.54
2015	13.21	15.01
2020	16.86	22.01
2025	21.40	31.21
2030	27.46	44.60

Changes in energy prices

In order to avoid double-counting, the carbon tax was assumed to apply to domestic and imported natural gas, coal and refined petroleum products. It was not applied to electricity, but electricity price rises due to the higher cost of fossil fuel inputs.[8] We leave the price of crude equal to that in the AEO 2009 base case.

In the Inforum model, prices satisfy the IO price identity:

$$p'_d = p'_d A_d + p'_m A_m + v'$$

where

p_d = the domestic output price vector

p_m = the import price vector

A_d = the direct requirements matrix of domestic requirements

A_m = the direct requirements matrix of import requirements

v = nominal value added per unit of real output q

The value added vector v is comprised of 13 components of value added, one of which is taxes on production and imports, or indirect taxes. Energy taxes are modeled for this exercise as a separate vector of indirect taxes. Energy taxes increase the prices of energy products directly, but also cause an increase in the prices of all other products indirectly.

The amount of carbon associated with each energy product was determined during the calibration of the *LIFT* model to the AEO 2009. Table A-18 in the *Annual Energy Outlook* shows carbon emissions by sector and source[9]. These emissions were linked to energy consumption flows in *LIFT*. *LIFT* energy flows were first calibrated to Table A-2 ("Energy Consumption by Sector and Source") and in several other tables[10], and then

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[8] However, we do assume a change in generation mix due to the carbon price, so the electricity price does not increase as much as it would without reducing fossil fuel use.

[9] Note that these are carbon dioxide emissions only.

[10] Other tables that are used to calibrate *LIFT* include: A-4 Residential sector key indicators and consumption; A-5 Commercial sector key indicators and consumption; A-6 Industrial sector key indicators and consumption; A-7 Tranportation sector key indicators and delivered energy consumption; A-8 Electricity supply, disposition, prices and emissions; A-11 Liquid fuel supply and disposition; A-14 Oil and gas supply; A-15 Coal supply, disposition and prices; and A-20 Macroeconomic indicators.

carbon emission coefficients were calculated to yield the carbon emission projections in AEO.

Note that *LIFT* maintains a full and consistent accounting for the price effects of the carbon tax, as well as the revenue generated, and the status of government receipts and expenditures.

Table 2 shows the impact of the carbon taxes on selected energy price variables. Of course, the largest difference is for coal (124% by 2030), which has a high carbon content per unit of value. The increase in the natural gas price by 2030 is also significant (18%). The gasoline price increases to a lesser extent (6.3%), with the increase in the electricity price slightly lower than this.

Table 2. Effects of the Carbon Tax on Selected Nominal Energy Prices

	Coal $/ton			Natural gas $/thous cu ft			Gasoline $/gallon			Electricity cents/Kwh		
	Base	Carbtax	% diff	Base	Carbtax	% diff	Base	Carbtax	% diff	Base	Carbtax	% diff
2012	29.80	49.83	67.2	5.49	6.09	11.0	2.82	2.93	4.0	9.50	9.88	4.0
2015	32.02	59.11	84.6	6.41	7.25	13.1	3.71	3.86	4.1	10.36	10.87	5.0
2020	35.79	71.57	100.0	8.74	9.95	13.9	4.78	4.97	3.9	11.98	12.62	5.3
2025	40.58	87.01	114.4	9.87	11.61	17.6	5.40	5.66	4.9	13.53	14.26	5.4
2030	45.55	102.44	124.9	12.86	15.20	18.2	6.21	6.60	6.3	15.63	16.47	5.4

Changes in industrial, commercial and residential energy consumption

In the industrial and commercial sectors of the *LIFT* model, there are no price-responsive energy consumption equations. Energy demand in the intermediate part of the model is determined by IO coefficients. However, these IO coefficients can be made to respond to price, either through an implied or estimated demand function, or through the behavior of another model or study. For this iteration of the current study, we drew parallel simulations using Markal to inform the degree of price response. These changes were imposed as changes in the time path of IO coefficients.

The residential sector does have price-responsive demand equations, but these were overridden for the current study, to agree with the results suggested by Markal. Table 3 below shows a summary of the aggregate demand response by sector to the carbon-induced price changes. Detail is also available by type of energy used.

Table 3. Effects of the Carbon Price on Consumption by Sector
(Quads Btus)

	Industrial			Commercial			Residential		
	Base	Carbtax	% diff	Base	Carbtax	% diff	Base	Carbtax	% diff
2012	31.56	31.10	-1.4	19.98	19.90	-0.4	21.38	21.32	-0.3
2015	31.37	30.23	-3.6	20.41	20.16	-1.2	21.29	21.07	-1.0
2020	31.59	29.86	-5.5	21.48	21.08	-1.8	22.32	21.89	-1.9
2025	32.10	29.89	-6.9	22.59	22.12	-2.0	23.03	22.31	-3.1
2030	31.35	28.41	-9.4	23.78	22.67	-4.6	24.01	22.49	-6.3

Changes in electric utility generation mix.

LIFT includes a disaggregation of the electric power sector into 8 types of generation. The total input-output column for electric power has been split into 8 columns, allocating the different types of fuel requirements according to energy supplying sector (coal, gas, oil). The nuclear, wind, solar and hydro have higher capital requirements.

The change in the mix of generation by type was made based on parallel runs done using the Markal model. The *LIFT* model then uses these shares to estimate fuel and other requirements from the electric power sector. For example, the sales of coal are much reduced. The effects of the carbon price are somewhat alleviated by the switch to less carbon-intensive modes of generation.

Table 4 shows the generation by type in each scenario, in billions of kilowatt hours. Note that total power generation is lower in the HR2454 scenario due to reductions in overall electricity demand.

Table 4. Electric Power Generation Mix
(Bil Kwh)

Base

	Coal	Gas	Petroleum	Nuclear	Hydro	Wind	Solar	Geo & Oth	Total
2012	2069.2	568.7	42.4	815.0	264.7	188.3	1.4	99.1	4048.8
2015	2058.9	546.3	41.9	831.5	277.7	189.4	2.0	121.7	4069.3
2020	2086.3	597.1	43.6	876.3	277.8	189.4	2.2	163.3	4236.0
2025	2086.7	771.0	44.0	881.6	279.0	193.4	2.5	191.2	4449.5
2030	2198.5	826.5	45.0	890.1	278.8	193.2	2.8	199.7	4634.5

Waxman-Markey

	Coal	Gas	Petroleum	Nuclear	Hydro	Wind	Solar	Geo & Oth	Total
2012	1939.7	568.4	43.6	817.8	275.0	187.3	1.4	158.7	3991.8
2015	1807.1	543.5	42.5	831.0	299.2	211.7	2.2	244.0	3981.3
2020	1670.0	582.7	41.6	876.0	299.7	278.9	3.3	352.4	4104.4
2025	1560.6	725.2	39.1	948.0	303.2	273.1	3.6	416.7	4269.5
2030	1378.6	744.3	34.1	1103.0	309.0	263.3	3.8	428.5	4264.6

Recycling of revenue

The revenue collected from the marketing of allowances represents a net drain on the economy. In the absence of any revenue recycling, this puts strong downward pressure on macroeconomic aggregates such as GDP, real income and personal consumption. The substance of the HR2454 legislation provides some guide as to how this revenue recycling may likely occur. In our modeling exercise, the recycling took the form of the following set of policy instruments:

- Personal tax rebates

- Assistance to industries: electric utility, petroleum refining, agriculture

- EITE industry assistance

- International transfers

▪   Household rebates and subsidies

The total revenue collected was modeled by assuming how many carbon allowances are allocated, multiplied by the allowance price. Table 5 shows the assumptions used in this study for the number of carbon allowances issued, the domestic offsets used, banking of allowances and the resulting international offsets purchased. The bottom section of the table shows the revenue implications of these assumptions and results.

Table 5. Waxman-Markey Allowances, Offsets and Banking

	2012	2015	2020	2025	2030
MMT					
Total carbon emissions	5598.9	5462.5	5265.7	5233.0	4919.4
Total number of credits issued	5551.0	5361.3	4906.2	4140.9	3380.5
Total domestic offsets	125.0	188.6	286.0	414.1	500.6
Annual banking of offsets	234.5	478.9	832.7	801.7	815.3
International offsets	157.4	391.5	906.2	1479.7	1853.6
Billions of Dollars					
Allowance revenue (to be distributed)	58.5	80.5	108.0	129.2	150.8
Domestic offsets payments	1.3	2.8	6.3	12.9	22.3
International offsets payments	1.7	5.9	19.9	46.2	82.7

Modeling Alternative Chinese Response to a U.S. Cap & Trade Policy

We assume that China starts implementing a carbon tax in 2010. The tax begins at 5 yuan per ton of CO_2 (approximately \$.76/ton) and gradually rises to 130 yuan in 2015 (\$23.68) 230 in 2020 (\$44.76) and 350 by 2030 (\$72.34)[11]. We have assumed that the yuan will appreciate from 6.83 per dollar today to 5.14 per dollar in 2020, and 4.84 by 2030. Since there is a direct relationship between tons of coal and CO_2 we are able to estimate the amount of the tax and the resulting increase in the price of coal to the ultimate users. The ultimate users see the high relative prices of coal (costs) and react by reducing their purchases. The reduced usage shows up as a reduction in tons used and that in turn lowers CO_2 emissions. The exact level of the tax was calibrated so that the combination of policies used (electrical generation and the tax) were able to reduce the ratio of CO_2 emissions to real GDP by 50% from the level in 2000, by 2020.

The amount of tax revenue generated can be quite large. A critical modeling question is to decide what the government will do with the carbon tax revenue. Simply letting the revenue accrue to government savings will serve as a Keynesian drag on the economy, and result in a decrease in household income (higher prices for energy goods), high prices of exports and lower real GDP. We have postulated two possible courses of action,

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[11] These prices were derived as estimates of the level of carbon price required, along with investments in nuclear and renewable energy, to enable China to meets its energy and emissions goals.

which both serve to recycle the revenue generated by the tax. The first is to reduce most indirect taxes and the other is to spend the money for social needs. Nearly 70% of government income comes from indirect taxes and rest about equally divided between social security and income taxes from persons. The second is to reduce personal income taxes and then use the remaining revenue on a massive improvement of health care across the country, particularly in the west and rural areas where about 350 million people are currently without any adequate health care. We have modeled both scenarios and they lead to somewhat different outcomes. One common feature of both scenarios is the reduction in personal income taxes.

Four sets of scenarios were run, as summarized in the following table. Each case consists of a U.S. *LIFT* model run, and China *Mudan* model run, and a run with the Bilateral Trade Model, to model the impacts on world trade flows, as well as Bilateral U.S. China flows. The next section describes results from the U.S. side. The following section discusses the Mudan results when adopting the tax. After this, we return to the U.S. perspective to see the differential impacts of China adopting or not adopting a tax framework.

Summary of Modeling Cases

Case	Summary	Description
1	Reference	Neither country pursues a carbon tax or cap and trade system in this reference case.
2	US yes, China no	US pursues a cap & trade policy but China doesn't enact any policy.
3	US yes, China yes, with tax cuts	China fulfills plans to move its electrical generation capacity away from coal and towards nuclear and renewable sources, and also introduces a carbon tax. It reduces other indirect taxes (except those on tobacco and alcohol) and reduces personal income taxes such that the effect on the government budget is approximately neutral.
4	US yes, China yes, tax cuts & health care	China fulfills its electrical generation plans and introduces a carbon tax (same as case 3) and provides for personal income tax reductions. However instead of lowering other indirect taxes it uses the money on a massive improvement of health care across the country particularly in the west and rural areas where about 350 million people are currently without any adequate health care.

U.S. Modeling Results

A full set of modeling results are available for China, from the *Mudan* model. However, this part of the paper focuses on the impact of the carbon pricing and any resulting trade leakages from the U.S. perspective. From the U.S. side, we will begin by examining the differences between the reference case (Case 1) and the case where only the U.S. imposes a tax (Case 2).

Carbon dioxide emissions

The *LIFT* model calculates carbon dioxide emissions by sector and source, based on the energy consumption by type of energy product in each industry, and assumed carbon emissions ratios to energy consumption by type.[12]

Table 6 shows the emissions by sector and source in 2010, and then the estimated emissions in the base case and the Waxman-Markey case in 2030.

Table 6. Carbon Dioxide emissions by Sector and Source
(Million metric tons)

	2010	Base (Case 1) 2030	Waxman-Markey (Case 2) 2030
Residential	398	374	336
Commercial	223	233	229
Industrial	927	1004	886
Transportation	1903	2021	1928
Electric Power			
Petroleum	46	41	31
Natural Gas	317	361	302
Coal	1931	2199	1196
Other	11	11	11
Total electric power	2305	2612	1540
Total Economy	**5755**	**6244**	**4919**
Carbon Dioxide Emissions			
(tons per person)	18.5	16.6	13.1
(tons per million$ GDP)	500.1	324.3	256.2

Note that even in the base case, although the total emissions are rising from 2010 to 2030, emissions per person have fallen, from 18.5 tons to 16.6 tons, a decline of 10.3%. Emissions to real GDP also decline, from 500 tons per millions $ GDP to 324.3 tons, a decline of 35.2%. These declines in the base case are due mainly to the following three factors:

1. Increasing energy efficiency of the industrial, commercial and transportation sectors, and a reduction in residential energy use.

2. A shift away from coal in electric power generation.

3. Sectoral shifts from energy/carbon intensive sectors to sectors that are less energy/carbon intensive.[13]

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[12] For this study, the carbon emissions ratios used were for aggregate sectors. However, a more detailed set of emissions data and ratios is currently being developed, in conjunction with the Department of Commerce.

In the Waxman Markey (Case 2), there is a further decline in emissions, to 13.1 tons per person (29.2% decline) and to 256.2 tons per million$ GDP (48.8% decline). These changes from the base case are also due to an intensification of the same 3 factors listed above which were already changing over time in the base. Efficiencies in response to higher energy costs have accelerated, the electric power sector has shifted even further away from fossil fuels (especially coal) than in the base case, and there have been further sectoral shifts, partially from international trade.

Macroeconomic effects: GDP, real income, GDP deflator, net exports.

Table 7 summarizes the broad picture of the macroeconomic effects of the HR2454 ("Case 2") scenario. GDP falls significantly (-1.1%) relative to the base as the carbon price is first introduced. However, due partly to increased energy efficiencies, and partly to the positive effects of revenue recycling, the decline in GDP from the base is only -0.6% by 2020, and is -0.3% by 2030. Real exports and real imports both decline in the aggregate, but exports decline more than imports. Some of the import decline is a decline in oil imports. The impact on real disposable income is relatively larger than the impact on GDP in the early, declining by 1.2% in 2015, but about the same level as the GDP decline in the subsequent years. The effect of HR2454 on the aggregate GDP price deflator is positive, reflecting the higher energy prices due to the carbon price. The last line of the table summarizes economy wide energy efficiency, as summarized by the ratio of Btus to real GDP. Energy efficiency increases by 5.9% by 2030.

Table 7. Macroeconomic indicators

Line 1: Case 1 (Reference)
Line 2: Case 2 (US Waxman-Markey, No China response)

Alternatives are shown in percentage deviations from base.

	2012	2015	2020	2025	2030
Real Gross Domestic Product (bil 2000$)	12642.7	13500.8	15123.2	17119.0	19252.9
	-1.1	-0.9	-0.6	-0.4	-0.3
Real Exports	1623.2	2052.4	2557.1	3230.9	3938.8
	-0.9	-2.2	-2.2	-2.0	-1.8
Real Imports	2105.6	2345.3	2760.7	3213.5	3750.9
	-1.5	-1.2	-1.2	-1.1	-1.2
Real Disposable Personal Income	9648.3	10195.2	11324.2	12839.3	14430.5
	-1.3	-1.2	-0.6	-0.4	-0.2
GDP Deflator	1.3	1.4	1.6	1.8	2.0
	2.0	2.7	2.6	2.0	1.3
Energy Intensity	8.0	7.5	6.9	6.3	5.7
	0.0	-1.1	-2.6	-3.4	-5.9

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[13] As we discuss below, emissions intensive sectors such as Agricultural fertilizers and chemicals, Ferrous metals, and Stone, clay and glass experience declines in exports.

Price effects on other industries.

In addition to the increased price of energy products, sectors that use energy intensively also experience price increases. Table 8 shows the top 10 sectors, ranked by the percent of price increase in 2030. We have removed from the ranking the energy extraction, petroleum refining and utilities sectors.

All industries in the list except for are either transportation or energy-intensive industrial sectors. Agricultural fertilizers (7.4%), Stone, clay and glass (6.3%), Other chemicals (5.4%), Primary ferrous metals (4.0%), Plastics and synthetics (2.6%) and Paper (2.3%) are the industrial sectors with the largest price increases, that we would expect to suffer from international trade leakages.

Table 8. Top 10 Industries, Ranked by Percent of Price Increase in 2030
(Price indexes, 2000=100)

	Base (Case 1) 2020	WM (Case 2) 2020	Base (Case 1) 2030	WM (Case 2) 2030	Percent Difference 2030
1 62 Air transport	140.0	151.5	161.3	174.3	7.73
2 20 Agricultural fertilizers and chemicals	181.7	194.2	225.5	242.7	7.39
3 60 Trucking, highway passenger transit	148.8	159.4	172.0	184.5	7.00
4 31 Stone, clay & glass	150.9	160.6	175.4	186.9	6.34
5 59 Railroads	116.3	124.9	130.3	138.2	5.90
6 23 Other chemicals	175.1	185.6	214.9	226.7	5.35
7 32 Primary ferrous metals	168.6	175.7	196.5	204.6	4.03
8 61 Water transport	152.0	156.8	171.8	176.4	2.65
9 21 Plastics & synthetics	150.6	155.5	177.2	181.8	2.59
10 18 Paper	140.7	144.8	162.3	166.1	2.30

Changes in sectoral exports and imports

Imports for a given commodity are determined by domestic demand of that commodity and relative domestic and import prices. With domestic prices rising in response to the carbon price, we expect imports of several sectors to rise. Table 9 shows imports between the base case and the Waxman-Markey case 2 for 2020 and 2030, ranked by the percentage difference in 2030. This table does not bear out the result that the import changes are in those sectors with the highest domestic price increase. The largest 5 sectors are investment goods, and the next several sectors are consumer goods. The increase in imports is likely related to the revenue recycling mechanism. Note that overall imports are down, which is a reflection of a slower economy, and the fact that oil imports have been reduced.

Table 10 shows the results for exports, again ranked by the percentage change. This time, we have ranked the sectors with the largest decline first. In the case of exports, the biggest losers are also sectors with large increases in domestic price, such as Agricultural fertilizers, Ferrous metals, Stone clay and glass, and Chemicals. Remember, total exports are down by 1.8% by 2030, and exports of most sectors have declined, though not nearly as much as in these sectors that have carbon intensive production techniques.

Table 9. Top 10 Industries, Ranked by Percentage Increase in Imports in 2030

	Base (Case 1) 2020	WM (Case 2) 2020	Base (Case 1) 2030	WM (Case 2) 2030	Percent Difference 2030
1 40 Computers	151839	152625	231619	233931	1.0
2 41 Office equipment	10405	10437	15036	15178	0.9
3 58 Miscellaneous manufacturing	100840	100513	131173	132341	0.9
4 38 Special industry machinery	15419	15495	23372	23579	0.9
5 37 Metalworking machinery	22575	22673	38773	39108	0.9
6 13 Alcoholic beverages	13139	13260	12132	12236	0.9
7 44 Household appliances	23077	23245	29314	29552	0.8
8 46 TV's, VCR's, radios & phonographs	81508	80988	91747	92468	0.8
9 55 Medical instruments & supplies	40253	40519	62666	63107	0.7
10 87 Education, social services, NPO	3498	3505	4192	4219	0.7

Table 10. Top 10 Industries, Ranked by Percentage Decrease in Exports in 2030

	Base (Case 1) 2020	WM (Case 2) 2020	Base (Case 1) 2030	WM (Case 2) 2030	Percent Difference 2030
1 20 Agricultural fertilizers and chemicals	3812	3286	2940	2570	-12.6
2 32 Primary ferrous metals	14208	13183	18641	17265	-7.4
3 31 Stone, clay & glass	12881	12203	23299	22237	-4.6
4 23 Other chemicals	73146	70482	109483	106311	-2.9
5 26 Rubber products	15864	15377	19931	19370	-2.8
6 33 Primary nonferrous metals	20255	19871	15739	15394	-2.2
7 1 Agriculture, forestry, and fisheries	74774	72680	121405	118944	-2.0
8 27 Plastic products	14853	14514	21495	21085	-1.9
9 79 Advertising	2446	2387	4065	3999	-1.6
10 41 Office equipment	3016	2898	3258	3206	-1.6

China Modeling Results

Before turning back to the U.S. to see the effects of China adopting the tax, we will look at a few features of the China modeling results, to better understand the full model scenarios. The *Mudan* model maintains a domestic price vector, but also a vector of prices for exported goods. It is the domestic price that is directly affected by the carbon charge, and the export price is related to that price.

Table 11 compares the export prices with and without the carbon tax (Case 2 compared with Case 3), for the 10 sectors with the largest export price increase. We have removed the energy industries from this ranking (coal, gas, petroleum and electricity). In China, logging and transport of timber and bamboo has the highest export price increase

(19.7%). Four of the other top 10 industries are transportation industries. The only overlap with the high price increase sectors in the U.S. is ferrous ore mining (2.2%) and non-ferrous metals (1.5%).

Table 11. Top 10 China Industries, Ranked by Percent of Export Price Increase in 2030

	Case 2 2020	Case 3 2020	Case 2 2030	Case 3 2030	Percent Difference 2030
10 Logging and transport of timber and bamboo	212.5	240.3	313.2	371.9	18.7
48 Water transportation	146.9	164.8	158.4	174.8	10.3
9 Non-metal minerals mining and mining, n.e.c.	214.9	230.7	238.6	256.4	7.5
46 Railway transportation	158.4	169.4	167.0	178.2	6.7
47 Highway transportation	165.4	179.1	172.7	184.2	6.6
45 Construction	182.5	192.4	210.8	222.4	5.5
7 Ferrous ore mining	192.3	195.9	211.2	215.8	2.2
50 Pipeline transportation	187.8	193.5	232.1	235.8	1.6
30 Primary non-ferrous metals manufacturing	269.8	274.7	336.6	341.6	1.5
52 Commerce	130.7	134.6	135.6	137.2	1.2

Table 12 shows the differences in Chinese exports after imposing the carbon tax. The top 10 industries are shown, ranked by the largest decline in exports relative to Case 2. Only 3 of these sectors are also in table 11: Logging and transport of timber and bamboo (-6.9%), Primary non-ferrous metals manufacturing (-4.8%) and Non-ferrous ore mining (-3.9%). Forestry, with a large export decline (-6.9%), had only a small export price increase (0.1%). Aerospace, with a 4.6% decline, had only a 0.2% export price increase[14].

The Bilateral Trade Model, which determines the exports for each country, relies not just on relative prices, but also on relative investment growth. It is possible that for some reason these sectors saw relative investment declines compared to case 2. This is because case 3 also had large investments in nuclear and renewable energy, which crowded out investments in other sectors.

Table 12. China Exports
Top 10 Industries, Ranked by Percentage Difference

	Case 2 2020	Case 3 2020	Case 2 2030	Case 3 2030	Percent Difference 2030
2 Forestry	10	9	11	10	-6.9
10 Logging and transport of timber and bamboo	0	0	0	0	-6.9
30 Primary non-ferrous metals manufacturing	1932	1842	4248	4044	-4.8
36 Aerospace	185	182	397	379	-4.6
8 Non-ferrous ore mining	33	33	47	45	-3.9
13 Tobacco manufacture	43	41	239	230	-3.8
9 Non-metal minerals mining and mining, n.e.c.	427	411	704	679	-3.6
26 Rubber products	3587	3525	7045	6920	-1.8
16 Leather, fur and their products	3869	3812	6751	6647	-1.5
33 Railway Equipment	302	296	932	919	-1.4

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[14] The response of exports to a change in price is a weighted combination of import price elasticities of the trading partners, and price response in the Bilateral Trade model.

Table 13 shows selected variables in the macroeconomic summary for China, comparing cases 3 and 4 with case 2. Unlike in the U.S. scenarios, GDP in China after imposing the tax regime is higher than without the tax (except for 2012 in case 3). In case 3 GDP rises to be 1.1% higher than case 2 by 2030. In case 4 it is 0.7% higher. However, the mix of GDP changes is quite different between the two simulations. Case 4 of course is characterized by a large increase in "public consumption" of health care, which increases total public consumption by 12.2% by 2030, relative to case 2. Conversely, total private consumption falls in this case compared with case 2, by 2.1% by 2030, whereas private construction rises slightly (0.5% by 2030) in case 3. Total fixed investment is down in both cases. This is due to the fact that to achieve the necessary reduction in carbon emissions, there was a large investment in nuclear power. Investment funds were assumed to be diverted from other industries to achieve the targeted nuclear capacity level. In case 4, total fixed investment is down even further than in case 3 (3.8% vs. 3.4%), as the increase in health investment is crowding out some private investment.

Imports are down significantly in both cases, falling by 5.5% by 2030. This is due partly to a reduction in energy imports, particularly crude oil and natural gas. However, it is also due to a reduction in capital goods imports, driven by the reduction in fixed investment described above.

Exports are down for most years in case 3, but reach rough parity with case 2 by 2030. In case 4, exports are reduced in all years. Real disposable income is higher in most years in case 3, rising to 1% above case 2 by 2030. However, in case 4 it is reduced. Finally, in either scenario China is able to make a big cut in carbon emissions, which see a decline of about 40% by 2030.

Prices are higher with the carbon tax, as we would expect, and this shows up as a higher aggregate GDP deflator. However, in case 3, where part of the carbon tax revenue was recycled in the form of reduced other indirect taxes, the price increases are ameliorated. However, in the case where a large portion of the recycling is through health care spending, the price increases show up more strongly. In this case (case 4), the aggregate deflator is 4.7% higher than case 2 by 2030, whereas it is only 0.9% higher in case 3.

What is the logic driving these results? Contrary to many other studies that have investigated the impact of a CO2 tax, this set of results from Mudan shows an increase in GDP, whether revenue is recycled as other taxes, or whether it is recycled as a combination of taxes and health care investment. Is it true that such revenue recycling can fully compensate for the negative impacts of a carbon tax? The differences from case 2 do not appear to be caused by the behavior of exports, which are predominantly lower than case 2 in both cases 3 and 4. Both cases see a sizeable reduction in imports, whereas we might have expected to see an *increase* in imports in response to a tax driving up domestic prices. However, as mentioned above, the import reductions are concentrated in energy imports and capital goods imports.

Table 13. China Macroeconomic Summary

Line 1: Case 2 (US Waxman-Markey, No China response)
Line 2: Case 3 (US Waxman-Markey, China carbon tax, recycle through tax)
Line 3: Case 4 (US Waxman-Markey, China carbon tax, recycle through tax and health investments)

Alternatives are shown in percentage deviations from base.

	2012	2015	2020	2025	2030
Gross Domestic Product	292984	349074	471186	631178	836652
	-0.2	0.6	0.8	1.1	1.1
	0.2	1.1	1.2	1.1	0.7
Private Consumption	105209	129617	172509	227411	302267
	-0.1	0.8	0.5	0.8	0.5
	-0.7	-0.7	-1.6	-1.6	-2.1
Public Consumption (*)	41015	49876	67461	89752	118516
	0.0	0.0	0.0	0.0	0.0
	8.5	10.5	12.4	12.1	12.2
Total Fixed Investment	131570	165705	233911	320481	429733
	0.5	0.1	-1.8	-2.3	-3.1
	0.0	-0.2	-2.2	-2.9	-3.8
Exports (*)	126006	154079	206863	278794	379886
	-1.2	-1.3	-0.8	-0.3	0.1
	-2.0	-1.9	-1.4	-1.3	-1.4
Imports	-110013.6	-151541.3	-210707.4	-285531.3	-387387.8
	-1.3	-3.0	-4.9	-5.0	-5.5
	-1.5	-2.8	-4.6	-4.9	-5.5
GDP deflator	137.3	149.6	162.8	177.5	189.4
	2.3	2.7	2.4	1.3	0.9
	3.2	4.1	4.4	4.2	4.7
Real disposable income	148450	175308	238778	327034	458571
	-0.4	0.3	0.4	1.0	1.0
	-1.0	-0.9	-1.5	-1.6	-2.2
CO_2 Emissions	7790	9072	10973	13467	16320
	-19.7	-31.8	-38.2	-40.0	-40.2
	-20.0	-31.9	-38.0	-39.7	-40.0

Comparison of U.S. Macro and Trade Impacts with China Tax

In this section, we bring in the comparison of case 3 and case 4 for the U.S. Case 2 will be used as the reference for comparison, as we are trying to establish clearly the differences due to China adopting the carbon tax.

Table 14 is the U.S. macroeconomic summary, comparing cases 3 and 4 with case 2. In case 3, where China recycles the tax through a reduction in other taxes, U.S. GDP is higher by 2030, by 0.3%. In case 4, where China uses a combination of taxes and health care investment, U.S. GDP is 0.1% lower. Total U.S. real exports are reduced from case 2 in both cases, down 0.4% in case 3, and 0.2% in case 4. This is contrary to our expectations, which is that we would see less leakage in the form of export loss, once China also adopted a carbon pricing regime. Total U.S. real imports are higher in case 3 than in case 2, but there is no significant change in case 4.

Table 14. U.S. Macroeconomic Indicators with Comparison of China Response

Line 1: Case 2 (US Waxman-Markey, No China response)
Line 2: Case 3 (US Waxman-Markey, China carbon tax, recycle through tax)
Line 3: Case 4 (US Waxman-Markey, China carbon tax, recycle through tax and health investments)

Alternatives are shown in percentage deviations from base.

	2012	2015	2020	2025	2030
Real Gross Domestic Product (bil 2000$)	12504.1	13378.5	15036.0	17047.7	19199.2
	0.0	0.0	0.1	0.3	0.3
	0.0	0.0	0.0	-0.1	-0.1
Real Exports	1607.9	2008.2	2501.4	3166.9	3867.4
	0.1	0.0	-0.1	-0.2	-0.4
	0.1	0.0	-0.1	-0.2	-0.2
Real Imports	2075.0	2316.2	2727.9	3176.9	3704.1
	0.0	0.0	0.1	0.3	0.5
	-0.1	0.0	0.0	-0.1	-0.1
Real Disposable Personal Income	9521.0	10077.8	11256.6	12789.8	14408.8
	-0.1	0.0	0.2	0.4	0.6
	-0.1	0.0	-0.1	-0.1	-0.1
GDP Deflator	1.3	1.4	1.6	1.8	2.0
	0.0	0.0	-0.3	-0.9	-1.5
	0.0	0.0	0.0	0.0	0.0
Energy Intensity	7.97	7.46	6.68	6.08	5.37
	0.0	0.0	0.1	0.3	0.5
	0.0	0.0	0.0	0.0	0.0

What of the effects of China's carbon taxes on the export sectors that had been hit the hardest by the U.S. carbon price? Table 15 is the summary of exports changes, comparing the percent difference from base in cases 2 through 4. These comparisons are for the 10 industries which lost the most in exports with the adoption of the U.S. carbon pricing scheme. We would have expected to see some mitigation of the exports leakage as China adopts an energy tax. There is a minor reduction in the loss in some sectors (Agricultural fertilizers, Rubber products, Plastic products), a stronger reduction in a few sectors (Primary nonferrous metals, Office equipment), but some sectors see a larger

export loss in cases 3 and 4 (Metal mining, Agriculture, forestry and fisheries, Advertising).

On the whole, these results are inconclusive. It is possible that the mechanism for recycling the tax revenue is responsible. In the case of recycling revenue by reducing other indirect taxes, we have muddied the price response. In other words, in sectors where the increase in price from the carbon tax outweighs the reduction in other indirect taxes, the price will go up. In sectors where the reduction in indirect taxes outweighs the carbon tax, prices go down. This can have the effect of reducing any mitigation of U.S. export reductions that would have otherwise taken place without this form of revenue recycling.

Another factor at play is the assumption that increasing nuclear capacity is done at the expense of total fixed investment. This results in a reduction of imports of capital goods, which are supplied partly from the U.S.

Table 15. Effects of China Carbon Policies on U.S. Exports

	Base	WM	Case 3	Case 4	Case 2	Case 3	Case 4
					Percent Difference from		
	2030	2030	2030	2030	Base in 2030		
20 Agricultural fertilizers and chemicals	2940	2570	2592	2593	-12.6	-11.8	-11.8
2 Metal mining	2932	2624	2550	2563	-10.5	-13.0	-12.6
32 Primary ferrous metals	18641	17265	16819	16860	-7.4	-9.8	-9.6
31 Stone, clay & glass	23299	22237	22214	22229	-4.6	-4.7	-4.6
23 Other chemicals	109483	106311	106327	106433	-2.9	-2.9	-2.8
26 Rubber products	19931	19370	19441	19430	-2.8	-2.5	-2.5
33 Primary nonferrous metals	15739	15394	15846	15806	-2.2	0.7	0.4
1 Agriculture, forestry, and fisheries	121405	118944	118438	118739	-2.0	-2.4	-2.2
27 Plastic products	21495	21085	21099	21117	-1.9	-1.8	-1.8
79 Advertising	4065	3999	3981	3992	-1.6	-2.1	-1.8
41 Office equipment	3258	3206	3224	3230	-1.6	-1.0	-0.9

Conclusions

This paper has illustrated the use of the Inforum LIFT model of the U.S., the Mudan model of China, and the Inforum Bilateral Trade Model (BTM) to examine the question of the differential impact on U.S. trade leakages. A reference case was first developed that embodied "business as usual" assumptions for both the U.S. and China. In the U.S. case, the base was calibrated to the Department of Energy Annual Energy Outlook (with stimulus) for 2009. In the case of China, the Inforum base case was used. A second case was developed where the U.S. adopted the major features of the Waxman-Markey legislation, but China did not adopt any similar policy. In the third and fourth cases, China did adopt a carbon tax, though not exactly the same as that of the U.S. Furthermore, the revenue recycling mechanism chosen for China was different from that assumed for the U.S.

In conclusion, it does not appear that the parallel adoption of carbon tax policy in China necessarily will significantly reduce the trade leakage in the U.S. As we have alluded above, this could be partly due to the nature of the carbon tax revenue recycling

mechanisms we have assumed for China. But from a broader perspective, it is also due to the fact that China is not the only trading partner of the U.S., although it is a significant one, especially with regard to U.S. imports. However, the behavior of other countries has a much larger affect on the path of U.S. exports.   According to the current Census trade data, China is the third largest purchaser of U.S. exports, after Canada and Mexico. However, exports to China represent only about 7% of total U.S. exports. On the import side, China is the single largest source of U.S. imports, with Canada and Mexico not far behind. Of total U.S. imports, those from China comprise 17.7%. However, U.S. imports actually increased from case 2 to case 3, where China adopted a carbon tax but recycled other taxes. There was no significant change in imports from case 2 to case 4. Our conclusion should lead to caution in the assumption that a matched response in carbon policy will completely ameliorate the leakages expected from higher export prices in certain U.S. industries.

Appendix A. The Structure of the Inforum LIFT Model

The Inforum *LIFT* (Long-term Interindustry Forecasting Tool) model is unique among large-scale models of the U.S. economy in that it is based on an input-output (IO) core, and builds up macroeconomic forecasts from the bottom up. In fact, this characteristic of *LIFT* is one of the principles that has guided the development of Inforum models from the beginning. This is in part because the understanding of industry behavior is important in its own right, but also because this parallels how the economy actually works. Investments are made in individual firms in response to market conditions in the industries in which those firms produce and compete. Aggregate investment is simply the sum of these industry investment purchases. Decisions to hire and fire workers are made jointly with investment decisions with a view to the outlook for product demand in each industry. The net result of these hiring and firing decisions across all industries determines total employment, and hence the unemployment rate. In the real world economy pricing decisions are made at the detailed product level. Modeling price changes at the commodity level certainly captures the price structure of the economy better than an aggregate price equation. In *LIFT*, prices and incomes are forced into consistency through the fundamental input-output identity, and the aggregate price level is determined as current price GDP divided by constant price GDP.

Despite its industry basis, *LIFT* is a full macroeconomic model, with more than 1200 macroeconomic variables determined either by econometric equation, exogenously or by identity. The econometric equations tend to be those where behavior is more naturally modeled in the aggregate. Many aggregates are formed as the sum of industry detail, such as total corporate profits. An equation for the effective corporate tax rate is used to determine total profits taxes, which is a source of revenue in the Federal government account. Equations for contribution rates for social insurance programs and equations for transfer payments out of these programs can be used to study the future solvency of the trust funds. Certain macrovariables provide important levers for studying effects of government policy. Examples are the monetary base and the personal tax rate. Other macrovariables, such as potential GDP and the associated GDP gap provide a framework for perceiving tightness or slack in the economy.

Since its inception, *LIFT* has continued to develop and change. We have learned much about the properties of the model through analytical studies and simulation tests. We have learned about the behavior of the general Inforum type of model, from work with Inforum partners in other countries, including China, Japan, Germany and Italy.

In the last several years, the *LIFT* model has been extended through the incorporation of several modules that can be used to study energy demand and supply, and the implications of energy use on carbon emissions.

An Overview of the Model

We first focus on the "real side" of the model, where the expenditure components of GDP are calculated in constant prices. First personal savings are determined, which affect how much of real disposable income will result in total expenditures on consumption. Personal consumption is modeled in the PADS (consumer demand system) function to

get consumption by category. PADS allows the classification of consumption goods into related expenditure groups, for example food, transportation or medical care. In PADS, motor vehicles prices affect the demand for public transportation, since motor vehicles and public transport are substitutes.

Exports by commodity may be determined outside the model, from the Inforum bilateral trade model (BTM) or by equations use information from BTM in the form of weighted foreign demands and foreign prices. The equipment investment equations are based on a Diewert cost function, that models the substitution (or complementarity) of equipment capital with labor and energy. The equations use a cost of capital measure that includes real interest rates, present value of depreciation, investment tax credit and corporate profits tax. The construction equations are for the roughly 20 categories of private construction. Though each has a different form, common variables are interest rates, disposable income and sectoral output.

Federal and state and local consumption and investment expenditures are specified exogenously in real terms, but *LIFT* allows for detailed control of these expenditures. For example, defense purchases of aircraft can be specified independently of missiles, ships or tanks.

The input-output solution solves jointly for output, imports and inventory change. Note that the IO matrix coefficients are specified to change over time, according to trends for each row. However, individual coefficients can also be fixed, to model changes in price or technology.

Labor productivity equations are used to determine the ratio of output to hours worked by industry. Average hours equations determine the average hours per employed person per year. Together, the productivity, average hours and output forecast generate employment by industry in the private sector. Adding in exogenous projections of government and domestic employment, total civilian employment is obtained. Subtracting total employment from projected labor force yields unemployment, and the unemployment rate, which is a pivotal variable in the model.

Prices in LIFT are determined as a markup over unit intermediate and labor costs. However, all components of value added are calculated first. Some are then scaled so that value added by commodity and prices are consistent. The largest component of value added is labor compensation by industry, which we call simply the "wage rate", although it also includes supplements. The "wage" equations relate the growth of the wage rate to growth in the ratio of M2 to GDP, expected inflation, and the growth in labor productivity. Multiplying the wage rate by the total hours worked per industry gives total labor compensation per industry.

It is also important to determine the components of capital income. Such items as corporate profits, proprietors' income and capital consumption allowances are calculated in LIFT by industry. The value added relationships not only play a role in the determination of prices, but are also needed to be able to calculate corporate profits taxes, and retained earnings and capital consumption allowances are the large components of business savings, which is an important part of the savings-investment identity. Furthermore, dividends, proprietors' income, interest income and rental income all contribute to personal income.

Finally, there is a block of the model called "the Accountant", which is a large set of equations and identities that aggregate industry and commodity level variables up to the aggregate level, and calculate many of the main variables in the National Income and Product Accounts (NIPA). Part of the job of the accountant is to estimate all of the components of national income, personal income and disposable income. It also calculates federal and state and local government receipts and expenditures, as well as transfer payments and social insurance contributions. All of the fundamental national accounts identities are also calculated by the Accountant.

The standard solution interval for *LIFT* has recently been to 2030. For the calibration to the *2010 Annual Energy Outlook*, the solution interval will be extended to 2035. Note that we have also developed special versions of *LIFT* that forecast to 2050 (for carbon emissions modeling) or to 2085 (for long-term health care projects).

The Use of LIFT for Energy Modeling

As described above, *LIFT* is an interindustry macroeconomic (IM) model. Price and quantity calculations are grounded in the IO relationships. To a large extent, the macroeconomic forecasts are aggregates of detailed industry equations. The *LIFT* model embodies industry and interindustry detail for about 90 commodities, as well as a full set of NIPA (national accounts) variables. While not an energy model *per se*, LIFT maintains detail for the following energy industries.

3. Coal
4. Natural gas extraction
5. Crude petroleum
24. Petroleum refining
25. Fuel oil
66. Electric utilities
67. Natural gas distribution

LIFT shows constant and current price sales of these industries to all other industries and to final demand, as well as showing the purchases of these industries from other industries in the economy.

The calculation of prices in *LIFT* is also based on IO relationships. Prices are based on the prices of domestic and imported inputs, and the value added generated in production, including labor compensation, gross operating surplus and indirect taxes. Energy taxes, such as those analyzed in this study, are implemented as an indirect tax, which affects the price of the target industry directly, and the prices of all other industries indirectly.

Residential energy demand and household transportation are modeled as part of a system of personal consumption expenditure equations. These consumption equations respond to disposable income, relative prices and other variables. Industrial, commercial and non-household transportation energy demand is modeled via IO relationships. The IO relationships are not static, but may be modeled to incorporate efficiency improvements, price-induced substitution, or changes in structure due to technological change. The structure of the electric power generating industry is represented as a disaggregation into the following list of 8 separate components, based on the technology or fuel type.

Types of Electricity Generation

1. Coal
2. Natural gas
3. Petroleum
4. Nuclear
5. Hydro
6. Wind
7. Solar
8. Geothermal, biomass and other

Additional modules have been built into *LIFT*, which perform side calculations. These modules take output, price and other variables from the model, solve, and then provide variables to feed back to the main model. Examples of modules now functioning with *LIFT* include:

- Biofuels
- Light-duty vehicles
- Building efficiency
- CCS
- Renewable power (wind and solar)
- Nuclear power
- Carbon and carbon tax calculator
- Electricity generation by type

A module such as the building efficiency or light duty vehicles calculates variables such as residential and commercial energy demand for which *LIFT* would normally use the personal consumption equations or the IO coefficients. With the addition of the module, these default calculations are either replaced or modified. Personal consumption expenditures on gasoline may then be calculated as the sum of fuels of vehicles of different types, based on MPG and vehicle miles traveled instead of the default equations which rely on income and price. Changes in commercial energy demand coming through building or vehicle efficiency are implemented as changes in IO coefficients.

Producing Sectors of the Lift Model of the U.S. Economy

1 Agriculture, forestry, & fisheries

Mining
2 Metal mining
3 Coal mining
4 Natural gas extraction
5 Crude petroleum
6 Non-metallic mining

Construction
7 New construction
8 M & R construction

Non-Durables
9 Meat products
10 Dairy products
11 Canned & frozen foods
12 Bakery & grain mill product
13 Alcoholic beverages
14 Other food products
15 Tobacco products
16 Textiles and knitting
17 Apparel
18 Paper
19 Printing & publishing
20 Agric fertilizers & chemicals
21 Plastics & synthetics
22 Drugs
23 Other chemicals
24 Petroleum refining
25 Fuel oil
26 Rubber products
27 Plastic products
28 Shoes & leather

Durable Material & Products
29 Lumber
30 Furniture
31 Stone, clay & glass
32 Primary ferrous metals
33 Primary nonferrous metals
34 Metal products

Non-Electrical Machinery
35 Engines and turbines
36 Agr., constr., min & oil equip
37 Metalworking machinery
38 Special industry machinery
39 General & misc. industrial
40 Computers
41 Office equipment
42 Service industry machinery

Electrical Machinery
43 Elect. industry equipment
44 Household appliances
45 Elect. lighting & wiring eq
46 TV's, VCR's, radios
47 Communication equipment
48 Electronic components

Transportation Equipment
49 Motor vehicles
50 Motor vehicle parts
51 Aerospace
52 Ships & boats
53 Other transportation equip

Instruments & Miscellaneous Manufacturing
54 Search & navigation equip
55 Medical instr & supplies
56 Opthalmic goods
57 Other instruments
58 Miscellaneous manufacturing

Transportation
59 Railroads
60 Truck, highway pass transit
61 Water transport
62 Air transport
63 Pipeline
64 Transportation services

Utilities
65 Communications services
66 Electric utilities
67 Gas utilities
68 Water and sanitary services

Trade
69 Wholesale trade
70 Retail trade
71 Restaurants and bars

Finance & Real Estate
72 Finance & insurance
73 Real estate and royalties
74 Owner-occupied housing

Services
75 Hotels
76 Personal & repair services
77 Professional services
78 Computer & data processing
79 Advertising
80 Other business services
81 Automobile services
82 Movies & amusements
83 Private hospitals
84 Physicians
85 Other medical serv & dentists
86 Nursing homes
87 Education, social serv, NPO

Miscellaneous
88 Government enterprises
89 Non-competitive imports
90 Miscellaneous tiny flows
91 Scrap & used goods
92 Rest of the world industry
93 Government industry
94 Domestic servants
95 Inforum statistic discrepancy
96 NIPA statistical discrepancy
97 Chain weighting residual

Appendix B. The Inforum *Mudan* Model of China

The Inforum model of the Chinese economy is called *Mudan* (MUltisector Dynamic ANalysis). It is a 59 sector IM (Interindustry Macromodel) which has a complete set of industry accounts, household accounts and government accounts. These various industry accounts are aggregated to produce the macroeconomic accounts. The industry accounts show for each industry: output, exports, imports, personal consumption purchases, investment purchases, government purchases and changes in inventories (in nominal and real terms) and for value added wages, depreciation, indirect business taxes less subsidies and surplus (nominal values). The ratios of current to real values are the various price indices for output, exports, imports, etc. Household consumption is modeled for 24 categories of urban household spending and 10 categories of rural household spending. Investment is modeled by investing industry for some 52 industries (an aggregation of the 59). Employment is modeled for the same 52 industries. The household accounts show household income from wages, capital type income (dividends) and government transfers (social insurance) while household expenditures for goods and services, social insurance taxes, income taxes, etc. are also modeled. The resulting excess of income is household savings (currently about 30% of income). The same is done for the government accounts where the model shows government incomes from indirect taxes (a value added category), income taxes, from profits, interest, etc. The result is government savings. From the household accounts the model produces disposable income which goes back into the household consumption equations.

Through its various accounts the model is able to trace the flows of income from one sector (household, industry, government) to another. This ensures consistency. The input-output identities ensure the consistency of the industry accounts. Thus for example if China is able obtain an export market at the expense of the US because of the carbon tax in the US we can trace that flow from exports to output to increased demands for inputs to incomes (wages and profits) and back to households and the government.

The data base of *Mudan* is a set of input-output tables in current and constant prices (2002) from 1992-2007. These tables are consistent with the published national accounts in nominal terms and with published price indexes. They are not fully consistent with published constant price values for GDP. No detailed data for constant price GDP on the product side (household consumption, exports, investment, etc) exists for China. The Chinese do publish constant price estimates of value added by very broad categories (primary, secondary and tertiary). These estimates use a vast array of information found in the Chinese Statistical Yearbooks and the Chinese Statistical Labour Yearbooks.

China Energy Use

Historical Energy Data in China

The *China Statistical Yearbook* provides chapters on energy for at least the past 15 years. Several tables in the yearbook are relevant for this study. There are balances for petroleum, coal, and electricity for the years 1992-2007. These balances are in physical units and show production, exports, imports, stock changes, and consumption. In addition, there are data on the consumption of energy by detailed sector and energy type,

all in physical units. This data are available from 1995-2007. Table 1 below shows a sample break down of the data as it appears. Most of the manufacturing rows and all of the service rows have been omitted. In addition the columns for Gasoline and Kerosene have also been omitted. The data are in physical units (tons, cubic meters, kilowatt hours) and by purchasing industry and by households.

Historical data and the Input-Output Accounts

One of the useful characteristics of input-output accounting is that the physical flows in tons (or other physical unit) given in Table 1 can be matched to input-output transactions (sales from one industry to another industry). That is, we can move the flow (in constant price monetary units) by the corresponding movement in physical units to obtain a flow in constant prices. For example from Table 1 we have Paper and Paper Products consuming 3379 units (unit = 10,000 tons) of coal. The flow from the input-output table for coal into paper is 26.93 in monetary units. Using this historical data on physical flows of tons of coal consumed by paper we have a measure of the flow in constant price units which can be measured against the constant price measure of the output of paper. The resulting coefficient then represents, in effect, the number of tons needed of coal to produce a given amount of paper. If we then convert these flows to direct coefficients we can examine how, over time, the particular coefficient has moved. It is then possible to study how these coefficients might change in the future. This enables us to make a forecast of Chinese energy consumption in physical units, which is useful for determining carbon emissions.

Table 1: Consumption of Energy by Sector (2007)

Source: CSY Table 7-9

Sector	Coal Consumption (10 000 tons)	Coke Consumption 10 000 tons	Crude Oil Consumption 10 000 tons	Diesel Oil Consumption 10 000 tons	Fuel Oil Consumption 10 000 tons	Natural Gas Consumption (100 million cu.m)	Electricity Consumption (100 million kwh)
Total Consumption	**258641**	**30337**	**34032**	**12493**	**4077**	**695**	**32712**
Primary Industry	**2338**	**82**		**1875**	**1**		**979**
Mining	**17660**	**217**	**1204**	**326**	**42**	**96**	**1614**
Mining and Washing of Coal	16518	75		57	6	5	609
Manufacturing	**94188**	**29826**	**32655**	**1118**	**1983**	**333**	**18106**
….other manufacturing industries							
Manufacture of Paper and Paper Products	3379	5	1	22	32	1	442
Electric Power, Gas and Water Production and Supply	**133424**	**39**	**9**	**279**	**609**	**80**	**4911**
Production and Supply of Electric Power and Heat Power	131923	7	8	267	604	71	4642
Production and Supply of Gas	1471	32	0	9	6	9	46
Production and Supply of Water	31	0	0	2	0	0	224
Construction	**565**	**17**		**434**	**16**	**2**	**309**
…other services							
Household Consumption	**8101**	**76**		**205**		**133**	**3623**

Chinese historical data on the usage of each energy type relative to GDP establishes the following:

1. Coal consumption relative to GDP fell rapidly from 1997 to 2002 as more modern electricity generating plants were put online in the late 1990's and as households switched from using coal to other forms of energy for heating and cooking. The surge in industrial production after China's entry into the WTO (in 2001) required vast amounts of new electricity generating capacity.

2. Substantial improvements in industrial energy efficiency in the use of refined petroleum products have occurred over the past decade. (This does not include transportation.)

3. The Chinese economy has become much more electricity intensive. This is a result of three factors.

    a. Many industries have switched to technologies that are electricity intensive as the use of electronic equipment has increased.

    b. A change in the mix of production stemming from faster growth of the electronic and electrical machinery industries compared to that of apparel and textiles.

    c. As Chinese household income has increased, more air conditioning, refrigerators, televisions and other household appliances are being used.

4. The increase in the intensity of use of natural gas has been dramatic – rising one and a half times as fast as real GDP. This increase is especially strong in the household sector.

5. The pattern of coal used to generate electricity has followed an erratic pattern. For the period 1997-2002 there was substantial scrapping of old generating equipment and new investment to expand capacity. The new equipment was substantially more efficient and this tended to reduce coal intensity. After 2002, the pace of new investment slackened substantially and coal consumption rose again. These changes are driven both by technology and relative prices.

6. Transportation use of petroleum relative to real GDP has steadily increased over the period of our database. The dominant factor is the increasing use of trucking for inter-provincial trade. As late as 1997 a portion of trucking consisted of human powered vehicles (types of bicycles) to move food and produce from the farms into the cities.

Equations for Energy Consumption by Sector

Modeling energy use by sector in a developing economy is a particularly complex matter. New technologies may greatly enhance production capacity while at the same time being energy intensive. At the same time older inefficient technologies are being replaced. The interactions of technology coupled with a widely varying international oil price makes estimation difficult.

The equation we estimate is:

$$\ln c_{i,k,t} = b_0 + b_1 t + b_2 \ln\left(\sum_{j=0}^{j=4} (price_{i,t-j} / pgdp_{t-j})\right)/5.$$

where:

$c_{i,k,t}$ is the coefficient of fuel type i (row of the input-output table) used by sector k in year t;

The time trend t is a specially created time variable to reflect the rapid changes taking place in the first part of the estimation period as old factories were closed (values were 1995=1972; 2000= 1994; 2002= 1998.32; 2004=2002.64; 2007= 2006.7);

$price_{i,t-j}$ is the price of domestically used energy type i in year t-j;

and

$pgdp_{t-j}$ is the gross domestic product deflator for year t-j.

These coefficient equations have been estimated individual coefficients for Refined petroleum, Coal, Natural gas and Electricity.

Measurement of CO2 Emissions

Data on emissions by China is available from the IEA website. The emissions are by fuel type. The amount of emissions per physical unit of energy (tons, mcf, etc) is very stable. The variance for natural gas is essentially zero. The variance in the ratio for coal and oil reflect some small changes in mix of fuel. For this study we have chosen to keep the 2007 ratios of emissions to physical unit of fuel constant. This focuses on energy use by industrial sector and by households.

Electricity Generation

A crucial focus of China's energy policy is on reducing coal as a primary fuel and replacing it with hydro, nuclear and renewables. For each method of production (hydro, thermal, etc) input coefficient are calculated and projected forward by assumption. These direct coefficients are then used in *Mudan* when making a forecast. These input-output coefficients can be thought of in terms of physical units such as tons (coal and oil) or mcf (gas) per kwh.

Mudan Output Sectors

1 Farming
2 Forestry
3 Livestock
4 Fishing
5 Coal mining
6 Crude petroleum and natural gas production
7 Ferrous ore mining
8 Non-ferrous ore mining
9 Non-metal minerals, and mining n.e.c.
10 Logging and transport of timber and bamboo
11 Food processing & manufacturing
12 Beverages
13 Tobacco manufacturing
14 Textiles
15 Wearing apparel
16 Leather, fur and products
17 Sawmills and bamboo etc. products
18 Furniture
19 Paper and paper products
20 Printing industries
21 Cultural, education, sports articles
22 Petroleum refineries and coking products
23 Chemical industries
24 Medicines
25 Chemical fibres
26 Rubber products
27 Plastic products
28 Building materials and other non-metallic mineral
29 Primary iron and steel manufacturing
30 Primary non-ferrous metals manufacturing

31 Metal products
32 Machinery
33 Manufacturing and repair of railroad equipment
34 Manufacturing and repair of motor vehicles
35 Shipbuilding and repair of ships
36 Manufacturing and repair of aircraft
37 Manufacturing and repair of transportation equipment
38 Electric machinery and instrument
39 Electronic and communication equipment
40 Instrument, meters and other measuring equipment
41 Industries n.e.c
42 Electricity, steam and hot water production
43 Gas production and supply
44 Production and supply of water
45 Construction
46 Railway transportation
47 Highway transportation
48 Water transportation
49 Air transportation
50 Pipeline transportation
51 Communications
52 Commerce
53 Restaurants
54 Finance and insurance
55 Real estate and social services
56 Health care, sports and social welfare
57 Education, culture, arts, radio, film and television
58 Scientific research and polytechnical services
59 Public administration

Appendix C. Inforum International Models and the Bilateral Trade Model

The Inforum system of macroeconometric, dynamic, input-output models has been producing annual forecasts and analyses of public policy since 1979. The current system contains models for the United States, Canada, Mexico, Japan, Korea, China, Germany, France, United Kingdom, Italy, Spain, Austria, and Belgium. Models of Denmark, Holland, Poland, Hungary, Russia, South Africa, India, and Thailand are underway, but not yet a part of the linked system.

Each of the models builds from industry detail to macroeconomic totals and has its own macroeconomic properties. The models produce all of the principal results of any aggregate model, such as GDP, the price level, the unemployment rate, and so on. In addition, they produce sectoral (product) forecasts for gross output, exports, imports, consumption, price indexes, and value added. These sectoral series are internally consistent with each other and consistent with the macro results. Indeed, the macro results are, with the exception of household and government consumption, the sum of sectoral results. Thus, real GDP is the sum of final demands expressed in constant prices, nominal GDP is the sum of value added by industry, and the GDP deflator is the ratio of the two.

Each of the models has sectoral equations for private consumption expenditures, capital investment, government purchases, imports, exports (see below for the link with the bilateral trade mode), labor compensation, return to capital, profits, etc. In each of the models, these sectoral equations are an integral part of the macroeconomic results. Hence, in the case of imports, the sum of the forecasts of the sectoral imports is the figure for total imports. The macroeconomic behavior of imports is thus derived as the sum of the behaviors of individual sectoral equations. To cite another example, a change in the rate of productivity growth in the construction sector will affect the overall growth rate of productivity and hence real GDP.

Each of the models has as a basic building block an input-output table linking the various sectors of the entire economy in a consistent manner. The table is used for the calculation of product outputs and product prices for each year of the forecast. The input-output coefficients have dynamic paths of change over time, which, in some instances, are responsive to changes in relative prices. Product outputs are determined using the familiar input-output calculation where the output of any one sector is the sum of sales to each of the other sectors and of sales to final demand. Likewise, prices are derived as the sum of the costs of intermediate goods and service inputs (including the cost of imported goods and services), and the costs of primary factors (labor, capital, etc.) per unit of real output. The individual country sectoral dimensions are shown below.

Each of the models is dynamic. That is, past levels of output, together with their pattern of change over time, will influence the level of investment and employment by industry.

Each of the country models is linked to the others bilaterally, by commodity, through trade flows and prices. The links are at both the macroeconomic and sectoral level. The macroeconomic side provides the exchange rate assumptions. All other links are at the sectoral level. Thus, steel imports in the USA influence steel exports of Japan; German auto prices affect the price of auto imports to the USA; and, USA grain prices affect

Canadian exports of Grain. The model that links all of the country models is the Bilateral Trade Model, or BTM.

Exchange rates are exogenous. The system emphasizes the flows of goods and services at the industry level between countries together with the price impacts of such flows.

The models are linked together with the Bilateral Trade Model (BTM). BTM, as its name implies, shows bilateral trade flows between the countries in the system for some 120 commodities. Historical data are based on Statistics Canada's World Trade Database. BTM uses country and sector specific data on prices and investment to estimate the import shares and then the importing country's imports to obtain the level of imports from each exporting country. Summing across the importers then yields the exports by country and commodity. These estimates are then used in the country models as indicators of exports. In addition, BTM gives the importing country information on its import prices by commodity.

Every six months, both macroeconomic and microeconomic model solutions are updated. In accordance, reviews of details and analysis are also performed in six-month intervals and are available upon request. Historical and forecast databases exist as part of the standard model data banks.

The following table briefly summarizes the overall capabilities of the individual models. Documentation varies substantially between models. Two were constructed as a part of a Ph.D. thesis; some have substantial papers written concerning their properties; others have only limited documentation. All documentation can be made available upon request.

Summary of Individual Model Dimensions (Output Sectors, Categories, etc.)

Country	Output	Consumption	Investment	Employment
USA	97	92	55	97
Canada	94	94	40	38
Mexico	74	12	1	74
Japan	102	85	101	102
Korea	71	29	25	17
China	59	34	52	52
German	58	22	58	58
France	88	88	38	36
Italy	45	40	21	41
UK	55	39	54	55
Spain	43	43	11	43
Australia	53	59	3	19
Belgium	53	61	24	44

The forecast horizon is 2030. The system can be used to study the industrial and aggregate impacts of macroeconomic developments such as changes in exchange rates, trade policy, and government policy. Some specific examples of applications of the International System include:

Examination of Customs Unions, Free Trade Areas, and International Trade Issues

- The Canadian, Mexican, and USA models were used by the Canadian government (Department of External Affairs) in a study of the impacts of alternative free trade agreements between the U.S. and Canada on the Canadian economy. Later, a similar study was completed looking at the NAFTA accord.

- Using detailed microeconomic studies for several industries a comprehensive and consistent study was made of the economic effects of European economic integration.

- A study of the economic effects of China's entry into the World Trade Organization (WTO) was conducted using detailed data on tariffs and non-tariff barriers.

- A study of the possible macroeconomic and sectoral impacts of the establishment of a free trade area for China, Japan and South Korea.

- The impact on American international trade competitiveness of increased capital investment in the US was investigated.

- An extremely detailed study showing the jobs required to produce exports was done for Canada, Japan, Germany, France, Italy, the United Kingdom, and the European Union.

- Our analyses of the impact of the U.S. and Japan imposing tariffs on each other's products showed that both countries could be very negatively affected. The drop in personal income in the U.S. could be so large that even U.S. autos would experience a drop in output, despite a substantial drop in imports of autos from Japan.

Specialized Studies

- The Department of Commerce has used the USA, Canadian, and Japanese models to show the embodiment of R&D expenditures in exports, imports and domestic consumption.

- The impact of achieving hypersonic (5-10 times the speed of sound) commercial travel ten years earlier than expected was studied in an international environment. Cases in which the U.S. alone had the capability were studied in contrast to cases in which Japan and Europe had it as well. Detailed impacts on technology in several industries were used

- A study of the industrial and trade impacts of alternative growth paths for the Chinese and Japanese economies was conducted. The impacts on Korea and the United States also

- A study of the effects of changing world oil prices on the US, Japanese, and European economies was done for a US manufacturer of plastic resins.

- An analysis of the effect on the Japanese economy of allowing free trade in rice at international prices was conducted.

- The system is used to provide the U.S. model, LIFT, with forecasts of foreign prices and demands for U.S. exports by sector.

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