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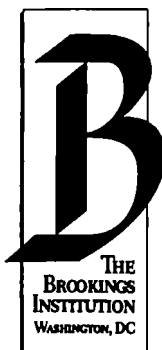
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Background Paper

THE NEXT STEP FOR CLIMATE CHANGE POLICY

Warwick McKibbin and Peter J. Wilcoxon

Do you know these
guys?

Warwick J. McKibbin is a Nonresident Senior Fellow in Economic Studies at the Brookings Institution, and Professor of International Economics at The Australian National University. He is also head of their Department of Economics.

Peter J. Wilcoxon is a Nonresident Senior Fellow in Economics at the Brookings Institution, and an Assistant Professor in the Department of Economics at the University of Texas.

1. INTRODUCTION

The Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), which was negotiated in Kyoto in December 1997, is yet to be ratified. There are still many unresolved problems with implementing this convention—not least is the problem that the Kyoto Protocol is fundamentally unsustainable.¹ Little progress in implementation of the Kyoto Protocol was achieved at previous meetings in Buenos Aires and Bonn. The next major negotiations will be held in The Hague in November 2000, although there will be intense activity leading up to this meeting, which will be the last serious chance for countries to implement the Kyoto Protocol. Rhetoric will not achieve the tight targets of the Kyoto Protocol and at some stage either actual policies must be implemented or the Kyoto Protocol must be jettisoned. The irony of the current state of climate change policy is that the Kyoto Protocol is actually raising greenhouse emissions because some corporations are postponing taking low-cost actions until it is clear what actions will be given credit in future abatement systems.

Before taking the next step, it is worth reflecting on what a sustainable and realistic climate change policy should look like. First, the policy should slow down carbon dioxide emissions where it is cost-effective to do so, but only as an insurance policy until further information on climate change is accumulated. Second, the policy should involve some mechanism for compensating those countries who will be hurt economically without requiring massive transfers of wealth that could undermine economic stability. Third, since climate change is potentially a global problem, any solution will require a high degree of consensus both domestically and internationally. Few countries want to relinquish sovereignty, especially when the policies in question can have large economic effects. A system that does not ultimately include developing countries will do little to achieve the goals of the UNFCCC because these countries are large future emitters of carbon and because the cheapest reductions will be found where carbon-intensive capital investments have not yet been made. Fourth, the regime must allow new countries to enter with minimum disruption and also allow a core group of countries to continue to participate even if other countries exit the system at certain times. A system involving many countries that doesn't survive changing composition over time is destined to fail since the reality is that a country's commitment to the regime is a function of the commitment of political incumbents at any point of time.

Given these criteria, the next step in climate change policy should not be in the direction taken by the negotiators at Kyoto. We propose here a different approach: one that sets the price of emission permits in the short run, but over the longer run, allows the market to determine the price of emission allowances.

2. WHAT IS WRONG WITH THE KYOTO PROTOCOL?

The objective of the Kyoto Protocol is to impose binding greenhouse gas (GHG) emission targets for the world's industrial economies and former communist economies of Europe ("Annex I" countries) to be achieved by the period 2008-2012. By directly binding emissions, policymakers presumably believed that they could achieve the goals of the UNFCCC through political commitment. Given that fixed targets for emissions by Annex I countries have been agreed, although not yet ratified in key countries,² the main issues currently being debated are how to minimize the costs of the Kyoto Protocol and how to bring developing countries into the agreement.

¹ See McKibbin and Wilcoxon (1997a, 1997b, 1999).

² As of October 5, 1999, 84 countries have signed but only 15 have ratified.

The issues of cost minimization and developing country participation are clearly recognized in the Kyoto Protocol. Costs are addressed through provision for international trading of emission allowances among the countries that accept binding targets. In addition, the Protocol provides for a Clean Development Mechanism, under which agents from industrial countries can earn emission credits for certified reductions from investments in "clean development" projects in developing countries that have not taken on binding targets.

The first problem with the Kyoto Protocol is the focus on achieving rigid "targets and timetables" for emissions reductions at any cost, rather than substantial reductions in emissions at reasonable cost. The problem with fixed targets was understood by some negotiators at Kyoto and flexibility mechanisms, such as permit trading, were thus included in the Protocol. A crucial but mostly ignored issue is that any fixed targets for the world or for a group of countries, even differentiated targets, are likely to be inefficient because we really don't know what these will cost over the long period of time being discussed.³ If the actual costs of abatement turn out to be much larger than estimated, it is unlikely that countries will continue to voluntarily adhere to the Kyoto Protocol. Some form of extreme enforcement mechanism needs to be designed to hold the Protocol together. Imposing arbitrary but binding targets on developing countries is even more problematic because there is even greater uncertainty about what the appropriate targets should be. An overly tight target will cause countries to depart from the agreement and an overly loose target will mean that low cost opportunities will have been lost.

Permit trading within the Kyoto Protocol is essential to minimize these problems. However even a permit trading system could be problematic. In a series of papers (McKibbin and Wilcoxon (1997a, 1997b)) we have pointed out that under some plausible scenarios for the future evolution of the global economy, the economic pressures caused by the large transfers of wealth internationally that underlie the claims over permits could cause severe fluctuations in real exchange rates and international capital and trade flows. Whether this actually emerges as a future problem is highly uncertain but will depend on a number of factors including the ultimate price of permits and the initial allocation of permits. In particular, international wealth transfers may be a problem if permit allocations are used excessively as a way of persuading countries to participate in an agreement. Although there is uncertainty about whether this effect is large or small, the main point is that we can't be sure that the economic problems we highlight will not emerge in the future.

Another problem with permit trading under the Kyoto Protocol is that the price of permits for all countries depends on the demand and supply of permits by large countries. If one large country cheats, then the value of permits for all countries will be affected and the system will likely collapse. There is currently no international rule of law that can prevent this from happening, nor is it easy to see what credible penalties could be imposed to prevent this from happening under all possible scenarios. It is also hard to imagine why developing countries would want to participate in a

...both politically and economically, there may be potential problems with the Kyoto Protocol involving the possibly large wealth transfers between economies.

³ See McKibbin and Wilcoxon (1997a) and Kopp, et al., (1997) for arguments about the difference between price and quantity caps under uncertainty.

centralized system like the Kyoto Protocol, especially once the enforcement mechanisms are made explicit and without knowing the possible costs of accepting a binding emissions target.

Overall it seems that both politically and economically, there may be potential problems with the Kyoto Protocol involving possibly large wealth transfers between economies. More fundamentally, the incentives of key players are not clearly consistent with the protocol under extreme developments without some as yet to be identified enforcement (and monitoring) mechanism.

3. AN ALTERNATIVE APPROACH

Our proposal is an attempt to design a decentralized but coordinated system that gives participating countries the incentive to participate as well as giving appropriate incentives to households and firms to change the amount of carbon emissions where it is cost effective to do so. We also build in the notion that developing countries should not incur the same costs in the short run as industrialized economies. But investment decisions in the developing countries need to be conditioned on expected future costs of abatement in these countries.

The basis of our system is the creation of two new assets (in each economy) as a part of establishing a clear system of property rights with respect to carbon emissions. The two assets are *emission permits* and *emission endowments*. An emission permit is an asset that is required every year to be held by a carbon producer in order to produce a single unit of carbon. The price of the permits will be equal to the marginal cost of reducing an additional unit of carbon for every carbon emitter in an economy.

An emission endowment gives the owner an annual emission permit that can be used in a given country every year forever. The endowment reflects a country's longer term commitment to emissions reductions but is not a binding constraint in the short run. There would be markets created domestically for both permits and endowments. The holder of an emission endowment can either decide to claim an emission permit and use it for current activities, or to sell that permit on the current market or to sell the endowment depending on the price they currently see versus the price they expect in future years. The price of the emission permit will be the marginal cost of abatement in a given year whereas the price of the emission endowment will be the expected future marginal cost of abatement.

As under the earlier forms of our proposal, in Annex I countries, rather than setting targets for emissions, we propose setting targets for the *marginal abatement costs*—we make the cost of cutting emission certain (i.e., the fixed permit price) and the environmental outcome uncertain. Specifically, the domestic price of permits would be guaranteed within each Annex I country for a period of 10 years at a maximum of \$US10 per ton of carbon.⁴ This fixed price is achieved by each government in each Annex I market selling as many emission permits as required to keep the price from rising above \$US10 per ton. There is no cap on permits and therefore no cap on emissions but the marginal cost of abatement is known for a fixed period. Many studies estimate that the permit price in 2010 associated with the Kyoto targets, range from \$US65 to many hundreds of dollars. Thus in Annex I countries there is likely to be an initial excess demand for permits and the permit price of \$US10 per ton will be binding. The price of emission endowments on the other hand would be flexible (given a fixed quantity of endowments) and would reflect expected future prices of emission permits.

⁴ Both the period between negotiations and the price would be the subject of negotiation.

The dilemma facing developing countries is that they are yet to emit the substantial amounts of carbon that have been essential to the development strategies of Annex I countries. Yet to go down the high carbon path of Annex I countries implies possibly very large future costs for developing countries if climate change becomes as fundamentally important as some scenarios would imply. Most of the costs of climate change abatement occur because existing economic structures have to be changed to be less carbon intensive. Most of this cost is a capital loss given that physical capital, which is largely fixed, is expensive to change quickly. Changing economic structures is far less expensive to do before the capital stock is in place rather than after it is in place. Just as there are different

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costs of carbon abatement across countries, there are also different costs across time. It is clear that a low-cost option for abatement over future years will be found in changing the future energy intensity of developing economies. This issue is recognized in our proposal by the use of endowments versus permits in developing countries in a different way to that in Annex I countries. A developing country would be included in our regime by negotiating an initial endowment allocation that allows for the fact that rapid growth is likely during development.

For example an endowment of $(100+X)\%$ for each participating non-Annex I country would allow a large expansion in fossil fuel use before the constraint becomes binding. If the government in the non-Annex I country were to distribute all of this endowment, the price of permits would be zero in the first year because there would be an excess supply of permits.

Thus a developing country would face no short run cost of emitting carbon. However, the price of endowments would be non-zero because the future expected price of permits would be expected to rise as the constraint becomes binding. We have introduced a price signal to current firms and households within non-Annex I countries that future carbon emissions will be priced. Thus they have the incentive to begin investing in low carbon emitting technology so that they can sell their future permits or their endowments and make a future profit from planning low-cost abatement over time. There are no direct costs introduced into the economy in the short term because the annual price of permits will initially be zero. However, there is a price signal through the price of endowments. Thus decisions about future energy use can incorporate the cost of carbon emissions without imposing short run costs. Of course, the price of the emission endowments in any economy will reflect the credibility of that government's commitment as well as the expected future growth prospects of the economy.

Another important aspect of this approach, is that developing economies that grow slowly will hit a binding emissions constraint much later than rapidly growing economies. Thus, countries begin to contribute to the global reduction of carbon emissions when a country's capacity to pay is higher.

In the long run, all countries are paying the same price for carbon whereas we have allowed a transition path with differential abatement between Annex I and non-Annex I economies. This is

an important difference to the Kyoto Protocol because there is currently no firm commitment by developing economies. Once a developing country joins the Kyoto permit trading system, its price of carbon and hence marginal cost of abatement would be the same as in industrial economies, which some argue is not equitable. No amount of initial permit allocation within a multi-country permit trading system would change the fact that they incur short run costs for carbon emissions—the same as industrial economies. This is precisely why developing countries have not committed to the Kyoto Protocol.

We believe it should be up to individual countries how they allocate the emission endowments. Once the endowments are created the system then evolves over time with the annual price of permits being set every ten years by international agreement. There is no need for international trade in emission permits because the price of permits is the same in all markets by construction. There is no reason for a Japanese firm to buy an emission permit from Russia when they can get a permit from the Japanese government for the same price. There is no trade allowed in emission endowments even though the values of these may differ across countries—this is the tradeoff of short run efficiency for equity.

The net effect of this policy would be to raise the current and expected future price of emitting carbon in Annex I countries. This would discourage increases in emissions, and encourage reductions in emissions where they are cost-effective, but without levying a sudden multi-billion dollar burden on fuel users. This also creates a mechanism for banking and renting emission rights that is internally consistent and credible. To temporarily raise emissions above an initial endowment holding, a firm can buy a short term emission permit from the permit market. To bank emission reductions for future use a firm can sell permits in the permit market (just like renting the emission endowments annually) but hold the emission endowment for future emission increases. No special institutional constructions are required outside the creation of the two assets and a domestic mechanism that ensures the value of these assets through monitoring and enforcement mechanisms and a rule of law that exists *within* each economy. It is true that techniques of monitoring and enforcement will likely will differ across countries, but this difference does not directly harm the effectiveness of a given outcome in another country.

A key feature of the policy is that it is flexible. The permit price could be adjusted by international negotiation at a regular interval (we propose every decade) or as needed when better information becomes available on the seriousness or otherwise of climate change and the cost of reducing emissions. Equally important, it would be easy to add countries to the system over time: those interested in joining would only have to adopt the policy domestically and no international negotiations would be required. This flexibility is crucial because it is clear from current negotiations that only a small subset of countries would agree to be initial participants in a climate change treaty. Also, countries can defect from the scheme without debasing the value of the permits for the remaining countries. Although the defection of a country would be undesirable, the system is sustainable.

In the long run, all countries are paying the same price for carbon whereas we have allowed a transition path with differential abatement between Annex I and non-Annex I economies.

Since the policy does not focus on achieving a specified target at any cost (indeed the cost of our proposal is known with certainty), such a system would be far more likely to be ratified, and by more countries. The political attractiveness of our proposal is that it is a decentralized, coordinated system implemented by individual countries within national rather than supranational institutional structures.

The system we advocate is flexible enough to adapt to changing political, economic and climate circumstances. Most importantly, we believe that the system we have designed, although simple in concept, solves many of the insurmountable problems of the Kyoto Protocol and delivers an outcome in which global emissions will be lower than otherwise would be the case.

Key elements of the McKibbin Wilcoxon Proposal

All countries create two assets:

- an *emission permit* which is required by fossil fuel industries to supply a unit of carbon annually;
- an *emission endowment* which gives the owner an emission permit every year forever.

All countries create two domestic markets:

- a domestic *emission permit* trading system with a fixed price of \$US10 per ton of carbon in Annex I countries and a cap price of \$US10 in non-Annex I countries;
- a domestic *emission endowment* trading system with a flexible price.

In 2000, all countries are allowed to make a one time only allocation of emission endowments domestically based on Kyoto targets for Annex I countries and current emissions plus x% for non-Annex I countries. Trading in both markets begins in January 2001.

Permits must be reconciled against production or imports of carbon at an annual basis at the top of the carbon production chain—coal mines, oil refineries, gas refiners. Production that is exported is exempted.

Every decade there is a meeting of the Conference of the Parties to the UNFCCC to evaluate the extent of abatement and the climate science and to negotiate a new price for permits.

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U.S. COMPETITIVENESS IS NOT AT RISK IN THE CLIMATE NEGOTIATIONS

BY ROBERT REPETTO AND CRESCENCIA MAURER, WITH GARREN C. BIRD

If the climate negotiations in Kyoto set different commitments for developed and developing countries to reduce emissions of greenhouse gases, U.S. industries can still maintain strong international competitiveness. A comparison of trends in trade, investment, energy costs and energy pricing between the United States and key developing countries point to few adverse trade impacts and significant opportunities for U.S. business.

Business groups have warned that U.S. actions to limit greenhouse gas emissions, without parallel steps by developing nations, will undermine the international competitiveness of American industry.¹ These arguments—that limits on U.S. emissions will drive energy-intensive industries off-shore, generate significant unemployment, and limit the ability of U.S. business to compete²—ignore important facts. For example:

* National differences in energy prices do not drive international investment flows. Furthermore, U.S. foreign direct investments

(FDI) in energy-intensive sectors have not been flowing to countries with low energy prices.

* Energy costs are an insignificant share of the value of most tradeable goods and services. More than 80 percent of output and 90 percent of employment in trade-

Differentiated commitments do not mean that the Framework Convention on Climate Change (FCCC) signed in 1992 lets developing countries off the hook.

ables are in industries in which energy costs represent no more than 3 percent the value of sales.

* Energy prices are climbing in most of the developing world. Since 1990, real energy prices in key developing countries and economies in transition have risen and energy subsidies fallen relative to those in the United States. Motivated by economic self-interest, these market reforms are likely to continue even without formal climate commitments.

* Energy reforms in developing countries are generating significant trade and investment opportunities for U.S. firms that can help provide cleaner and more efficient energy sources.

These facts indicate that differentiated commitments for developed and developing countries can work without compromising U.S. economic competitiveness. Differentiated commitments do not mean that the Framework Convention on Climate Change (FCCC) signed in 1992

lets developing countries off the hook. The FCCC explicitly recognizes that all countries must cooperate in stabilizing the world's climate because no country can solve the problem alone. But the Convention does call for developed countries—including the United States—to do more at the outset because of their historic responsibility for the build-up of greenhouse gases in the atmosphere, and because developing countries must meet basic development needs even as they take action to limit emissions.³



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November 15, 1999

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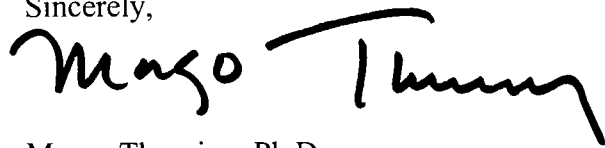
Dear Mr. Ballentine:

Your remarks on global climate change at the November 12 meeting hosted by Chemical Manufacturer's Association were extremely interesting and insightful. As you know I spoke following your remarks. I am sorry you were unable to stay to hear my presentation; it provided an overview of the analysis of numerous credible climate policy scholars on the Kyoto Protocol's severe economic impacts and minimal environmental benefits. My remarks included discussion of the U.S. EIA's important work in this area as well.

I would very much appreciate the chance to meet with you to exchange views. Enclosed please find some of our recent climate policy reports, including my testimony before the Senate Committee on Energy and Natural Resources, *The Impact of the Kyoto Protocol on U.S. Economic Growth and Projected Budget Surpluses*; a special report by Mary Novak, senior vice president, WEFA, Inc., *The Kyoto Protocol: Can Annex B Countries Meet Their Commitments?*; a monograph by the ACCF Center for Policy Research, *Climate Change Policy: Practical Strategies to Promote Economic Growth and Environmental Quality*; and background on the ACCF. You can find additional research we have sponsored on climate policy at our website: ACCF.org.

I will call your office in the near future to schedule this dialogue.

Sincerely,



Margo Thorning, Ph.D.
Senior Vice President and Director of Research

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SPECIAL REPORT

October 1999

The Kyoto Protocol: Can Annex B Countries Meet Their Commitments?

by Mary H. Novak*

The Kyoto Protocol sets the ambitious target of reducing greenhouse gas emissions to 5 percent below 1990 levels by 2008–2012 for 38 industrialized countries including the United States. A review of five recent government studies and one independent report by WEFA Energy analysts in Europe shows that the industrialized countries of North America, the Pacific region, and Western Europe cannot meet their emission targets without exorbitant carbon taxes. In addition, the use of “Kyoto mechanisms” would only reduce the cost if the emissions credits were plentiful relative to the total requirement of countries vying for them. At issue is whether Eastern Europe’s plans for economic growth will leave them with any surplus credits to sell. While Western Europe’s leaders have adopted the “spirit” of Kyoto, their primary goals are job growth and economic expansion.

INTRODUCTION

The Kyoto Protocol to the Framework Convention on Climate Change, a proposed amendment to the international treaty on mitigating the risk of global warming, sets the ambitious greenhouse gas emission target of 5 percent below 1990 levels by 2008–2012 for 38 industrialized countries including the United States. Many studies have shown that it would be extremely costly for the United States to achieve its target. Even under the assumption that the United States could take advantage of the flexibility mechanisms proposed in the Protocol to reduce the cost of compliance, the impact on U.S. consumers and businesses would still be substantial.

The United States is but one of the 38 countries in Annex B to the Kyoto Protocol that face the challenge of meeting the targets established for reducing greenhouse gas emissions by the end of the next decade if the Protocol is ratified.¹ Proponents of the Protocol have claimed that these countries can achieve their targets at a low cost.

ARE ANNEX B EMISSIONS TARGETS ACHIEVABLE?

Many previous analyses have shown that the industrialized countries of North America and the Pacific region who are signatories of the Framework Convention on Climate Change cannot achieve their Kyoto targets without extensive use of the “Kyoto mechanisms” (i.e., international emissions trading). A review of five recent government studies and an independent report by WEFA Energy analysts in Europe supports the conclusion that the emissions targets cannot be achieved without exorbitant carbon taxes or extensive use of Kyoto mechanisms.² The range of estimates of the required reductions in emissions from baseline levels for North America is –21.3 percent to –29.8 percent (see Table 1 and Figure 1a). The estimates for the Pacific region (Japan, Australia, and New Zealand) are equally draconian: –18.5 percent to –28.5 percent (see Table 1 and Figure 1b).

The assessments of Western Europe’s potential for reducing carbon emissions from its energy sector as

*Mary H. Novak is senior vice president, WEFA Energy Services. This Special Report is based on a paper prepared for an October 13, 1999, policy conference, and will be published in the ACCF Center for Policy Research’s upcoming book, *The Kyoto Commitments: Can Nations Meet Them With the Help of Technology?* The ACCF Center for Policy Research is the education and research affiliate of the American Council for Capital Formation. Its mandate is to enhance the public’s understanding of the need to promote economic growth through sound tax, trade, and environmental policies. For further information, contact the ACCF Center for Policy Research, 1750 K Street, N.W., Suite 400, Washington, D.C. 20006-2302; telephone: 202/293-5811; fax: 202/785-8165; e-mail: info@accf.org; Web site: www.accf.org.

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CONGRESSIONAL TESTIMONY

March 25, 1999

The Impact of the Kyoto Protocol on U.S. Economic Growth and Projected Budget Surpluses

ACCF Senior Vice President and Chief Economist Dr. Margo Thorning testified as a committee-invited expert witness on March 25, 1999, before the Senate Committee on Energy and Natural Resources. The executive summary and full text of the ACCF's testimony are presented here.

EXECUTIVE SUMMARY

Macroeconomic Effects of CO₂ Emissions Limits Are Significant. A wide range of economic models predict that reducing U.S. carbon dioxide (CO₂) emissions to either 1990 levels or to the Kyoto target (7 percent below 1990 emission levels) would reduce U.S. GDP and slow wage growth significantly, worsen the distribution of income, and reduce growth in living standards. If the United States is not able to take advantage of "where" flexibility (reducing emissions wherever it is cheapest globally) through international emissions trading to meet the Kyoto target, the cost in terms of lost output will range from about 1 percent to over 4 percent of GDP.

In addition, near-term emissions reductions would reduce U.S. competitiveness in energy-intensive manufacturing industries as well as in agriculture. Meeting the Kyoto emission targets would make it much more difficult to sustain tax cuts or "save" social security, and could require sharp changes in fiscal policy to avoid deficit spending.

The Administration's Analysis Is Questionable. The Administration's estimates of economic damage from CO₂ emission reductions are far below those of other models due to unrealistic assumptions that global trading of emissions will be available in the near term and that developing countries will participate, and the use of an economic model (SGM)

which appears to assume costless capital adjustments to energy price changes.

International Emissions Trading Issues Are Major. Emissions trading could substantially reduce the cost of complying with the Kyoto targets, especially if developing countries participate. Major obstacles to trading include securing developing country participation, allocating CO₂ emissions rights, and distributing the resulting revenue.

Conclusion: The Kyoto Approach Isn't the Answer. U.S. goals in international climate policy meetings should include finding ways to involve developing countries in emissions reduction, clarifying flexible mechanisms, and avoiding trading caps. Voluntary measures to reduce U.S. CO₂ emissions should include modifications to U.S. tax policy that reduce the cost of capital for energy-efficient investment. Moreover, the introduction of carbon capture and sequestration techniques from central power facilities, soil sequestration, and reforestation could radically change both the cost and character of carbon mitigation. Adopting a thoughtfully timed climate change policy—based on science, improved climate models, and global participation—is essential, both to U.S. and global economic growth and to the eventual stabilization of carbon concentrations in the atmosphere.



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Joseph E. Aldy
08/26/99 05:36:38 PM

Record Type: Record

To: David B Sandalow/CEQ/EOP@EOP
cc: roger s. ballentine/who/eop@eop
Subject: Re: WWF/Tellus

Several weeks ago when this analysis was first announced, Eliot D. and Jeff S. asked me to take a look at the WWF study. This study combines some dubious analytic assumptions with some very aggressive policies to achieve the outcome. For example, the study appears to assume off-line that significant increases in CAFE (1.5 mpg per year for 12 years), new appliance standards, and new building standards would have no costs to the economy. Further, the study makes off-line assumptions about renewables: 1) 10% RPS by 2010 -- it is assumed to have a much lower cost than DOE projects for the Administration's 7.5% RPS proposal; 2) 10% cofiring of biomass in coal plants -- with no detail on how the costs were estimated, and how the costs vary with the demand for biomass associated with the ethanol assumption; and 3) 10% of transportation fuels comprised of cellulosic ethanol -- it is difficult to see how the fuel system could handle this, since the very optimistic 5 Labs Study claims that cellulosic ethanol could comprise no more than 3.5% of the transportation fuels because of economic and technical problems associated with blending. In the industry sector, they assume that unspecified policies could reduce the discount rate used by firms for investment decisions by more than half. While I have seen such an assumption before (the 5 Labs Study), I have yet to see an economic justification for such an assumption or a detailed description of the policies that could influence firms' rates of time preference.

By making off-line assumptions about many of the big-ticket policies pushed in this analysis, the study has effectively assumed away the costs of reducing emissions. Thus, it can assume that reducing emissions is better for the economy. The bottom line is that I seriously doubt any mainstream economist would defend such an analysis.

Joe

ECONOMY

Flat CO2 Emissions Give Experts Hope

Compliance With Pollution Curbs Seen More Likely

By JOHN J. FIALKA

Staff Reporter of THE WALL STREET JOURNAL

WASHINGTON—Despite a booming economy, emissions of man-made carbon dioxide remained almost flat in the U.S. last year, and global emissions appear to have dropped.

That has led some experts to believe the economic shock of complying with international pollution curbs aimed at stemming global warming may not be so jolting.

Until now, some government and private industry projections have assumed economic growth is linked to energy consumption, particularly the burning of oil, gas and other fossil fuels that release carbon dioxide. CO2 is the main "greenhouse gas" many scientists believe is overheating the planet by trapping more of the sun's rays in the atmosphere.

But in 1998, a year when the U.S. economy grew almost 4% and the price of gasoline dropped to records, CO2 emissions in the U.S. barely moved, rising only 0.04%, according to a Department of Energy report. "I think there's a decent chance that we're seeing a significant change," said Christopher Flavin, vice president of Worldwatch Institute, a Washington environmental think tank.

Mr. Flavin's group sees the same phenomenon happening globally. It believes the trend, if it continues, could make the political decisions required by the Kyoto Treaty to curb global warming less diffi-

Thinning Carbon Dioxide

Even while the U.S. economy soared, 1998 carbon-dioxide emissions were flat, basting compliance with international treaties.

	EMISSION (millions of tons)	INTENSITY (tons/\$millions of GDP)	CHANGE FROM 1997
U.S.	4,606	199.1	+0.4%
China	883	213.4	-3.7
E.U.	603	116.6	-0.9
Russia	440	717.2	-1.3
Japan	327	111.1	-2.5
India	304	178.2	+1.8
World	6,950	168.3	-0.5

*Relates how much carbon dioxide a country emits to the size of its economy, as measured by gross domestic product, or economic output.

Source: Worldwatch Institute

cult. The treaty, which the U.S. Congress has yet to ratify, requires the U.S. to cut CO2 emissions, measured against 1990 levels, by 7% starting in 2008.

"Kyoto is still going to be a stretch for some countries," Mr. Flavin said, "but the amount of emissions trading needed and the degree of domestic effort may turn out to be significantly less than everyone expected."

Because many experts assumed economic growth and CO2 emissions move in lockstep, they had predicted the U.S. might

have to impose an economy-wrenching emissions cut of 30% to 40% by 2008, when the treaty's schedule of emissions curbs begins. One safety valve planned by the Clinton administration is emissions trading, which would let U.S. companies buy permits—from other companies or countries that have exceeded the treaty's targets—to emit additional CO2. This has provoked a fight with European nations that want emissions trading to be limited.

But flat or slumping emissions could

Please Turn to Page A6, Column 1

WALL STREET JOURNAL

Monday Aug 2, 1999

The F-22 funding cut, which caught Lockheed and the Pentagon by surprise, led to one session in which Mr. Coffman

Flat CO2 Emissions Give Experts Hope On Pollution Curbs

Continued From Page A2

defuse some of this tension. "Most of this is due to market forces," said Howard Geller, executive director at American Council for an Energy-Efficient Economy, a nonprofit Washington research firm that represents business and academic groups. He and Mr. Flavin see the rise of the information sector, which features industries with light CO2 emission levels, and the increasing use of more energy-efficient machines and appliances as two major factors that appear to have caused emissions to remain nearly level in 1998.

Roger S. Ballentine, a White House lawyer who handles the climate change issue, says the full statistical picture of what happened in the energy sector in 1998 is incomplete. "What we've got so far is a snapshot, but it certainly is consistent with what we've been saying, which is you can grow the economy and reduce emissions at the same time."

Mr. Ballentine is about to depart for China, a key player in the Kyoto deliberations. China also has produced some recent statistical surprises. According to Mr. Flavin, China's economy grew 7% last year, while its use of coal fell 5%. Mr. Ballentine attributes the drop in coal use to efforts by Chinese officials to remove subsidies that have favored lavish use of coal, which has fouled the air of many Chinese cities.

The Clinton administration will need China and other developing nations to become involved in the Kyoto Treaty to get Congress to ratify it. Lawmakers here are reluctant to put the U.S. at an economic disadvantage with the emission cuts if other nations don't follow suit. But data of energy use from China and Eastern Europe also indicate emissions levels there are dropping because industries are leaping into the information economy, too.

So far, the slump in emissions has been documented by two studies. A preview of a report by the DOE's Energy Information Administration on use of fossil fuels in 1998 shows that despite the rapid growth of the economy, emissions from the U.S. industrial sector fell 1.2% last year. Separately, a Worldwatch analysis of 1998 energy data gathered by BP Amoco PLC shows global emissions declined 0.5% last year, while the world economy expanded 2.5%.

Senate Committee Delays On Economic Nominations

WASHINGTON — The Senate Banking Committee delayed action on several key economic nominations because of objections raised in the Senate floor.

The committee was forced to adjourn a confirmation hearing Friday on several

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Talking Points on EIA Economic Analysis

The Energy Information Administration's (EIA) recent analysis of the Kyoto Protocol is significantly flawed. In modeling implementation of the Protocol, EIA fails to take into account the Protocol's flexibility mechanisms, incorrectly assumes that most businesses will fail to take action to address climate change until 2005 or later, and uses a model that underestimates the dynamism of the U.S. economy. In contrast, the Administration's economic analysis of the Protocol, released in July, demonstrates that with effective market mechanisms, meaningful developing country participation, and a realistic ramp up period, the costs of meeting the Kyoto target should be modest.

The EIA Analysis Fails to Model the Kyoto Protocol's Flexibility

- ***The EIA analysis fails to model international trading.*** EIA's model is not capable of modeling international emissions trading, even though this is a critical feature in reducing the cost of compliance for the United States and other countries. By contrast, the Administration explicitly modeled international trading, as has every modeling team participating in the exercise assessing Kyoto conducted under Stanford's Energy Modeling Forum -- which includes virtually all of the leading energy economic modelers in the world. These models have demonstrated that international trading among industrialized countries could lower costs of emissions reductions by as much as half.

EIA does attempt to include scenarios which assume an amount of domestic reductions intended to mirror the level of domestic reductions implied in the model used by the Administration. However, these EIA scenarios still overstate the cost of permits because they fail to take into account the way that an international market, bidding to a single international permit price, lowers cost.

- ***The EIA analysis fails to account for all six types of greenhouse gases.*** The EIA study assumes that the United States would achieve its target only through carbon dioxide reductions. In fact, the Kyoto Protocol covers all six major greenhouse gases, and permits countries to achieve their targets through reductions made in any of these gases. This flexibility allows countries and companies to make reductions in the most cost-effective manner possible, reducing the cost of compliance.

EIA Assumes Firms Take Little or No Action to Address Climate Change before 2005

- In EIA's study, most businesses do not take action to address climate change until 2005, and therefore only have a short time until the 2008-2012 budget window to reduce emissions. Studies have demonstrated that the amount of lead time a company takes has dramatic economic implications. For example with EIA's model, a 5-year "ramp-up" (starting in 2005) would result in economic costs 65% greater in 2010 than that associated with a 10-year "ramp-up" (starting in 2000). Thus, EIA's assumption that many businesses would fail to plan for the future results in higher projected costs.

- Already businesses are taking action to address climate change. For example, on September 18, British Petroleum announced its plan to reduce emissions of greenhouse gases worldwide by 10% below 1990 levels by the year 2010. In July, United Technologies announced their plan to reduce its worldwide energy consumption by 25% by the year 2007.

The EIA Analysis Does Not Include Policy Elements That Will Lower Costs

- In the Administration's analysis, additional elements of policy were recognized as having the potential to significantly decrease the costs of compliance and increase the amount of reductions that might be accomplished at home. These policies were not factored into the illustrative model the Administration cited, but were qualitatively taken into account in reaching the conclusion that the United States could meet its Kyoto target for a relatively modest cost. The EIA analysis, however, ignores elements such as forestry activities (covered under the Kyoto Protocol) and the Administration's electricity restructuring proposal, which could significantly lower compliance costs.
- Studies put out by the Department of Energy's National Laboratories (the so-called Five Lab and Eleven Lab studies) demonstrate that there are many viable technology pathways to reduce greenhouse gas emissions at low cost.

The EIA Study Ignores the Dynamism of the U.S. Economy

- The EIA study uses a macroeconomic model -- a short-term forecasting tool that is inappropriate to use for making forecasts going out a decade or more -- as opposed to a general equilibrium-type model that would incorporate the dynamism and flexibility that is the hallmark of the American economy. (For example, the American economy has adopted the Internet in the past decade, leading to industries and services that could not have been imagined a decade ago.) A study by the World Resources Institute indicates that this one factor is often enough to double the estimated costs of meeting a given emissions reduction goal.
- The EIA study assumes that in their use of energy, consumers and businesses are much less responsive to price changes than is commonly assumed in the economics literature. A more moderate choice of price responsiveness would reduce the estimated permit prices and reduce the economic costs estimated by EIA.

The EIA Study is Pessimistic About the Role of Technology

- The EIA study is pessimistic about the potential of technology and market innovation. It assumes no direct effect of substantially higher fuel prices on the availability of more advanced technology or more innovative uses of technology, both of which could contribute significantly to reducing emissions.

Economic Impact of the Kyoto Protocol

June 9, 1998

- 1. The WEFA study was funded by the Global Climate Coalition, a corporate group of fossil fuel and other interests that is leading the opposition to taking responsible action on global climate change.***
 - 2. The model used to derive the WEFA numbers is flawed. It omits all the flexibility mechanisms included in the Kyoto Protocol and the Administration's policies.***
- **The WEFA analysis omits international emissions trading.** This study assumes that no countries undertake emissions trading, even though the right to trade is explicitly stated in the Kyoto agreement. International trading among industrialized countries could reduce costs of emissions by half.
 - **The WEFA study does not include developing country participation in emissions reduction.** This study assumes developing countries do nothing to reduce greenhouse gas emissions. However, the Kyoto Protocol establishes the Clean Development Mechanism, and even if developing nations only participate in this mechanism the costs to the United States could be 20 to 25% lower. If key developing countries participate more fully, for example by taking on emissions targets and undertake emissions trading, the costs to the United States could be reduced even more.
 - **The WEFA study does not account for six categories of greenhouse gases.** This study assumes that emissions reductions would occur only through carbon dioxide reductions, even though all six major greenhouse gases are covered by the Protocol. Since the Kyoto agreement requires countries to reduce emissions to specific targets, on average across all kinds of greenhouse gases, the flexibility is available to reduce emissions of some gases more than others if it is cost-effective. Allowing for trading across gases could lower costs by about 10%.
 - **The WEFA analysis omits carbon sinks.** This study assumes that no carbon sink opportunities for absorbing greenhouse gas emissions are available, even though the Kyoto agreement explicitly includes forestry activities. Low-cost carbon sink options provide another opportunity to achieve emissions targets at a modest cost.

By ignoring these flexibility mechanisms, this analysis fails to assess accurately the Kyoto Protocol as well as the Administration's efforts to reduce greenhouse gas emissions. The Administration has always said that reducing emissions can be done smart or dumb. By failing to account for these flexibility mechanisms, the WEFA analysis illustrates the costs of doing it dumb. The Administration believes that by including market mechanisms it can be done smart.

The costs of meeting the challenge of climate change will be modest. The Administration is working to ensure that greenhouse gas emissions that contribute to global warming are reduced in common sense, cost-effective ways. The Administration believes that with effective market mechanisms -- international emissions permit trading, the Clean Development Mechanism joint implementation, timing flexibility during the commitment period, opportunities to trade across greenhouse gases, and carbon sinks -- as well as with meaningful developing country participation and flexible timetables, the economic cost to the United States of meeting the Kyoto targets will be modest.

3. ***The potential costs of waiting too long to address the threat of climate change exceed the costs of acting now.*** The threats climate change presents are widespread and range from potential increases in asthma and infectious diseases to increasingly frequent and severe storms. Despite the challenge of putting a price tag on the risks of inaction, economists have nonetheless developed troubling cost estimates of the risks of global climate change -- ranging in the tens of billions of dollars per year for the United States.
- ***Human health.*** Warmer temperatures are projected to increase fatalities attributable to heat waves in the U.S. of the kind that killed 400 in Chicago in 1995. The incidence of asthma and other respiratory illnesses, particularly among children and the elderly, is expected to increase from the additional smog caused by warmer temperatures. In a warmer, wetter world, the geographic ranges for infectious diseases could significantly expand. The incidence of malaria, for example, could increase by 50 million or more cases a year by 2100.
 - ***Extreme weather.*** Warmer, wetter weather is projected to increase the frequency and intensity of extreme events such as floods and drought. The 1993 Mississippi River flood alone caused damages of \$10-20 billion, while the Pacific Northwest floods in 1996-97, and the 1997 Ohio River and Red River floods resulted in substantial costs to business and homeowners. Global warming may also mean increased drought in the U.S., particularly in the Great Plains and other arid areas.
 - ***Sea level rise.*** Scientists project that sea level will rise by an additional 6-38 inches by 2100. A 20 inch-rise could inundate 7,000 square miles of the U.S. coastline, with Florida and the Gulf Coast at greatest risk. Changes in rain and snowfall could affect water supplies and water quality, posing threats to irrigation, fisheries, and drinking supplies
 - ***Agricultural impacts.*** Changes in growing seasons, water availability, soil moisture and precipitation could cause significant regional shifts in food productivity, with decreases in food production.
4. ***The President's plan protects the environment and grows the economy.*** In October 1997, President Clinton put forward a responsible, balanced approach to begin meeting the challenge of global warming, while protecting our economy and maintaining our international competitiveness. This plan emphasizes win-win initiatives designed to cut emissions by increasing energy efficiency; developing new, cleaner energy technologies; working with industry and others to promote sensible solutions; and relying on market-based mechanisms to ensure cost-effective reductions.
- The plan includes a \$6.3 billion package of tax incentives and R&D aimed at cutting greenhouse gas emissions and building partnerships with industry to remove barriers to the development and widespread use of energy efficient technologies and practices.
5. ***Enabling environmental protection and economic growth to go hand-in-hand.*** For the past 25 years, efforts to protect the environment, whether by cleaning our air and water, eliminating acid rain or closing the ozone hole, have been repeatedly assailed as a threat to our economy. Yet today we have the cleanest environment in a generation and the strongest economy in a generation. President Clinton's balanced approach to the challenge of climate change will allow us to grow the economy and protect the environment at the same time.

**ADMINISTRATION ECONOMIC ANALYSIS:
MEETING THE CHALLENGE OF CLIMATE CHANGE AT A REASONABLE COST
July 31, 1998**

The Administration's economic analysis of the Kyoto Protocol concludes that the costs of meeting our Kyoto target for reducing greenhouse gases should be modest; that taking action to address global warming amounts to an insurance policy against a serious threat; that there are significant opportunities for lost cost reductions both at home and abroad; and that the benefits of averting climate change could be very large.

There is a powerful scientific rationale for taking action on global warming; taking action amounts to an insurance policy against a serious risk. Greenhouse gases are rapidly building up in the atmosphere and at current rates will reach levels not seen in 50 million years by 2100. The nine hottest years on record have occurred since 1987, 1997 was the hottest year ever, and 1998 has been hotter still. Our leading scientists warn of serious consequences, like severe droughts and floods and health problems, if global warming is ignored. In 1992, the National Academy of Sciences said: "...even given the considerable uncertainties in our knowledge of the relevant phenomena, greenhouse warming poses a potential threat sufficient to merit prompt responses....Investment in mitigation measures acts as insurance protection against the great uncertainties and the possibility of dramatic surprises."

The costs of meeting our Kyoto target should be modest. Even without counting the impact of domestic policies or the benefits of acting to mitigate climate change, estimates derived using the Second Generation Model (SGM) suggest an emissions price in the range of \$14 to \$23 per ton of greenhouse gases. In 2010, that would translate into an increase of \$70-\$110 per year for an average family's energy bill, although such increase would be substantially offset by the decline in electricity prices resulting from restructuring the electricity industry, as the Administration and others have proposed.

Domestic actions -- which are not factored into the SGM model -- can further reduce costs and substantially increase the amount of reductions made at home. These include federal electricity restructuring; efforts to increase the rate of technology improvement, such as the President's \$6.3 billion budget package; activities, like forestry activities, which can sequester carbon; industry consultations; and initiatives to reform federal energy use and procurement.

Doing it smart: The Kyoto Protocol is based upon flexibility measures that reduce costs. At U.S. insistence, the Kyoto Protocol allows emissions to be reduced where and when such reductions are cheapest. Key provisions include international trading of emissions permits as well as measures that allow our companies to share credit for emissions reducing projects abroad.

The benefits of acting to address climate change could be very large. Noted economists have estimated the environmental, health, and economic costs of global warming projected to occur during the next century to be 1% of GDP or more -- over \$80 billion a year in today's terms. In the short term, ancillary benefits of reducing greenhouse gas emissions -- such as reduced air pollution -- could produce savings equal to one quarter of the costs of meeting our Kyoto target.

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The Detroit News

July 07, 1998, Tuesday

SECTION: LetterstotheEditor; Pg. Pg. A8

LENGTH: 495 words

HEADLINE: Rebuttal: WEFA report spins worst-case scenario

BODY:

The June 17 editorial "Kyoto's Impossible Targets" failed to recognize that the WEFA economic report on the Kyoto Protocol on Climate Change provides a worst-case -- indeed, an impossible case -- analysis of the costs of U.S. compliance. As the WEFA analysts acknowledge, their model omits all of the flexibility mechanisms included in the Kyoto Protocol and in the Clinton administration's stated policy positions.

First, the WEFA study assumes that no countries undertake emissions trading, even though the right to trade is stated in the Kyoto agreement. Stanford University's highly regarded Energy Modeling Forum studies indicate international trading among industrialized countries could reduce U.S. costs of emission reductions by 50 percent.

Second, the WEFA study assumes that developing countries do nothing to reduce greenhouse gas emissions. But the Kyoto Protocol establishes the Clean Development Mechanism, which could lower U.S. costs by an additional 20 percent. More important, if key developing countries participate more fully, for example by taking on emissions targets and participating in international trading, the U.S. costs could be reduced even more.

Third, the WEFA study assumes that emissions reductions would occur only through carbon dioxide reductions. But all six major greenhouse gases are covered by the protocol. Moreover, the Kyoto agreement gives nations the flexibility to choose which greenhouse gases to reduce. Allowing for "trading" across gases could lower costs by another 10 percent.

Finally, the WEFA study assumes that no carbon sink opportunities for absorbing greenhouse gas emissions are available. But the Kyoto agreement explicitly includes forestry activities and counts them in a way that is particularly attractive for the United States. Including low-cost carbon sink options reduces U.S. compliance costs even more.

By ignoring these flexibility mechanisms, the WEFA analysis fails to assess accurately the costs of complying with the Kyoto Protocol. As the administration has stated over and over again, reducing greenhouse emissions can be done smart or it can be done dumb. The WEFA analysis calculates the costs of doing it dumb.

Greenhouse gas emissions that contribute to global warming can be reduced cost-effectively by employing market mechanisms -- all with meaningful developing country participation and flexible timetables. The result is that the economic cost to the United States of complying with the Kyoto Protocol targets can be 90 percent less than the WEFA study claims.

The Detroit News, July 07, 1998

The president and vice-president have made it clear that the Kyoto Protocol will not be submitted to the Senate until there is meaningful participation by developing countries. Thus, the WEFA study, which the editorial so enthusiastically embraces, is not only a worst-case analysis, it is essentially an impossible-case analysis.

Robert N. Stavins

Harvard University

Cambridge, Mass.

LOAD-DATE: July 07, 1998

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April 12, 1999

Economic Analysis of the Impacts of the Kyoto Protocol on U.S. Agriculture

This analysis was prepared by the Roy Darwin, Robert House, Jan Lewandrowski, Howard McDowell, and Marc Peters of the Economic Research Service (USDA) under the direction of the USDA's Global Change Program Office.

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Executive Summary

USDA's analysis of the economic impacts of the Kyoto Protocol on agriculture concludes that the impacts are relatively small. Our core analysis is consistent with the Kyoto Protocol and the Administration's estimation of the impacts on energy prices when all the key provisions including emission trading, a multi-year commitment period, allowance for forestry carbon sinks, joint implementation, and the Clean Development Mechanism are taken into consideration. Other analyses may arrive at larger impacts but these analyses fail to model energy price increases that are consistent with the Kyoto Protocol's cost-reducing provisions or the resulting adjustments to these increases made by farmers and consumers

The Kyoto Protocol will primarily effect U.S. agriculture through its effect on energy prices. Rising energy prices will cause the cost of agricultural production to rise slightly as input costs (fuel, fertilizer, chemicals and other energy intensive inputs) increase. This will in turn cause production and net farm income to fall. As production falls commodity prices will increase partially offsetting the increase in the cost of production. At the same time the increase in prices reduces the quantity demanded. The extent of these changes and their impact on farm income will depend on the magnitude of the increase in energy prices, farmers ability to reduce energy use, and the demand for agricultural commodities. Some regions, particularly those more dependent on energy-intensive irrigation, could be more negatively affected than others

For carbon prices consistent with the Kyoto Protocol, agricultural production declines from 0.1 percent for soybeans to 0.9 percent for rice. Prices increases range from about two cents per bushel for feedgrains, one cent per bushel for wheat, and 11 cents per hundredweight for rice. Rice prices increase more than other crops owing to its greater energy and carbon intensity in production. Soybean, silage and hay prices rise less than 1 percent owing to lesser carbon intensity in production. Livestock would be affected negligibly, with prices increasing about a half percent or less and production declining a twentieth of a percent or less.

Farmers' expenditures on energy related inputs increase by 2.3 percent. Expenditures of fuel increases 4.6 percent and expenditures for fertilizers increase by 2.1 percent. About 75 percent of the changes in fertilizer expenditures are attributed to nitrogen, which is higher in carbon content than potash and phosphates. Chemical expenditures increase by 1.2 percent while expenditures on electricity increase by 2.6 percent. The significant increases in energy related costs cause farmer's total variable costs to increase by 0.6 percent.

The increase in commodity prices partially offset the increase in production costs and as a result, net cash returns to farmers fall by only 0.5 percent or \$371 million and consumer welfare declines 0.05 percent. Declines in regional net cash returns to farmers range from 0.3 percent in the Corn Belt to 2.3 percent in the Southern Plains. Most regions experience declines in net farm income near the national average. The exceptions are the Southern and Northern Plains which experience declines in net farm income greater than one percent.

The USDA analysis uses the U.S. Regional Agricultural Sector Model (USMP), which predicts how changes in energy prices will affect the supply of crops and livestock, commodity prices, consumer demand, use of production inputs, farm income, government expenditures, participation

in farm programs, and environmental indicators. USMP is linked with regularly-updated USDA production practices surveys, the USDA multi-year baseline, and geographic information system databases such as the National Resources Inventory. USMP covers 10 crops, livestock, as well as several dozen processed and retail products. Impacts are estimated by commodity for 10 farm production region, and 45 land resource regions

Some have expressed concerns that increasing the costs of fossil fuels only in Annex-I countries will increase the likelihood that agricultural production will shift to non-Annex-I regions. But this is inconsistent with the Administration's position. The Protocol will not even be delivered to the Senate unless it includes meaningful participation from developing countries. With developing country participation—and one major competitor, Argentina is already committed to taking on a emission reduction target—energy prices will increase similarly across regions.

We also look at how the agricultural sector is affected for every \$50 increase in carbon prices. But even under higher carbon prices—which are not consistent with the Administration's position on climate change—we do not find significant negative impacts of American farmers. Why? Because farmers respond to slightly higher input prices by changing the mix of inputs, reducing output, and shifting to other commodities. Other analyses that show much larger impacts allow no such adjustment to take place.

The effects of the Kyoto Protocol on U.S. agriculture depend on other factors still under negotiation, such as whether certain types of agricultural and forestry activities are ultimately included in the Protocol. Equally important is the economic potential of carbon sequestration: while there may be significant physical potential to sequester carbon on agricultural lands, the cost of actually sequestering must be taken into consideration. U.S. agriculture could benefit if terrestrial carbon sinks are eventually included in the Protocol.

Introduction

The international community is addressing climate change through the United Nations Framework Convention on Climate Change, which the United States ratified in 1992 and has over 170 member countries. The Convention seeks to stabilize atmospheric concentrations of greenhouse gases at safe levels. The Kyoto Protocol, which requires the advice and consent of the Senate, formalizes this commitment and calls for the industrialized nations to reduce their average national emissions over the period 2008-2012 to about five percent below 1990 levels.

Key elements of the Protocol include: 1) a multi-year commitment period; 2) the inclusion of all six greenhouse gases (enabling reductions of one gas to be used to substitute for increases in emissions of another); 3) allowing international emissions trading and joint implementation among countries that take on binding targets; 4) a clean development mechanism that allows industrial countries or firms to earn credits for projects in the developing world; and 5) the inclusion of limited set of activities that sequester carbon (with provisions to expand the list of carbon sequestering activities to include forestry and agricultural management practices). These elements, particularly emissions trading, can significantly reduce the costs of meeting emissions reductions targets.

Land-use change and forestry is an important element of the Kyoto Protocol. Net changes in greenhouse gases and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, are to be used to meet emissions target commitments. The Protocol also provides that additional human-induced activities related to change in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories can be added by the Parties to the Protocol.

The potential effects of the Kyoto Protocol on U.S. agriculture depend, in part, on the

degree of energy price increases, the energy intensity of agricultural production, the ability of the sector to adjust to changes in energy prices, and the degree to which international competitiveness is affected by changes in energy costs.

In this analysis of the economic impact of the Kyoto Protocol on agriculture, we first discuss how agriculture will be affected by climate change. We conclude that while climate-induced changes are unlikely to impair the ability of the United States to produce enough food to feed itself through the next century there are several limitations in the current understanding of the impacts of climate change on agriculture. First, water resources are poorly linked with agronomic and economic processes so that our understanding of climate-related impacts on flooding, water-logging of soils, and the availability of irrigation water is limited. Changes in climate variability and extreme weather events are also poorly understood. And many of the climate-sensitive relationships between crops and livestock with pests and diseases are excluded from current models. Consequently, there is still much we do not know about the impacts of climate change on agriculture and our estimates will likely change as more research is undertaken.

We also examine how agricultural activities contribute to greenhouse gas emissions. In the United States, contributions result from emissions of methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) due to biomass burning, ruminant animals, decomposition of soil organic carbon from tillage practices, rice cultivation, fertilizer application, use of manure, and degradation of wetlands. Indirect effects, which account for most of agricultural GHG emissions, are attributed to emissions of nitrous oxides and other gases from concentrated livestock operations and from microbial activities in soil and water following applications of fertilizers and manures.

We then turn to a discussion of economic analyses of the Kyoto Protocol. We review recent analysis on the impacts of the Kyoto Protocol on agriculture noting that these studies reach

unreasonable conclusions either due to assumptions regarding carbon prices that are inconsistent with the Kyoto Protocol or because agricultural markets are not modeled appropriately.

We analyze the effects of the Kyoto Protocol on agriculture in several steps. For our core scenario, we use the Administration's Economic Analysis (1998) carbon price of \$23 per metric ton (we also estimate the effects for every \$50 increase in carbon prices). To accurately capture the effects of carbon prices on agricultural inputs, we estimate the carbon embodied in agricultural inputs for crop and livestock production by region. We then introduce the changes in input prices into a detailed model of the U.S. agricultural sector, which estimates the corresponding impacts on agricultural commodity price, supply, demand, income, erosion, nitrogen loss, and other important agriculture sector indicators. We do not examine how the sector might be affected by domestic policy actions to encourage reductions of emissions from agricultural sources. While agricultural sources are an important source of some greenhouse gases, it is premature to anticipate what policy options may be implemented to address these sources.

We use the U.S. Regional Agricultural Sector Model (USMP) which is designed for general purpose economic, environmental, and policy analysis. USMP is linked with USDA production practices surveys; the USDA multi-year baseline, and geographic information system databases such as USDA's National Resources Inventory. USMP predicts how changes in farm, resource, environmental, or trade policy, commodity demand or technology will affect regional supply of crops and livestock, commodity prices and demand, use of production inputs, farm income, government expenditures, participation in farm programs, and environmental indicators. USMP incorporates agricultural commodity supply, use, and policy measures, and a wide range of production practices: natural resource and environmental impacts are derived through biophysical models.

USMP is a medium term model. We hold the energy efficiency of available production

technology constant which means that farmers are not assumed to respond to increased energy costs by adopting new, currently unavailable, technology. Farmer can switch among a wide range of tillage practices, crop rotations, etc. We consider this an appropriate, although conservative, assumption given the medium term nature of the USMP model. Because producers are routinely observed to economize on scarce or more expensive inputs, over the longer term we would expect to see increases in the adoption of more energy efficient production practices. We assume that the prices of fuels, electricity, agricultural chemicals, and other inputs will increase by the value of the carbon embedded in each input unit. This in effect assumes a perfectly elastic supply function for each of the inputs. While conservative, our model is not yet capable of modeling the input sector more precisely.

We take as a starting point that energy prices increase the equivalent of \$23 per metric ton of carbon. These rising energy prices increase the costs of production, which increases commodity prices. Higher prices in a market with inelastic demand result in increased revenues with a smaller quantity demand. While the net effect of net farm income depends on the relative supply and demand elasticities in the input and commodity markets, higher farm production costs are likely to at least be partially offset by higher revenues given the inelastic demand for food.

We find the \$23 per ton carbon price leads to production declines ranging from 0.1 percent for soybeans to 0.9 percent for rice. Prices increases range from about two cents per bushel for feedgrains, one cent per bushel for wheat, and 11 cents per hundredweight for rice. Rice prices increase more than other crops owing to its greater energy and carbon intensity in production. Soybean, silage and hay prices rise less than 1 percent owing to lesser carbon intensity in production. We find that the Kyoto Protocol would affect livestock products negligibly, with prices increasing about a half percent or less and production declining a twentieth of a percent or less.

Fertilizers, particularly nitrogen, and chemicals are energy intensive inputs. Under the Kyoto Protocol, farmers' expenditures for fertilizers increase by 2.1 percent. About 75 percent of the changes are attributed to nitrogen, which is higher in carbon content than potash and phosphates. Chemical expenditures increase by 1.2 percent while expenditures on electricity increase by 2.6 percent.

We also look at how the agricultural sector is affected for every \$50 increase in carbon prices. But even under higher carbon prices—which are not consistent with the Administration's position on climate change—we do not find significant negative impacts of American farmers. This is because farmers respond to slightly higher input prices by changing the mix of inputs, reducing output, and shifting to other commodities.

Our analysis briefly looks at the potential for including agricultural carbon sequestration activities in the Kyoto Protocol, the role of biomass and other greenhouse gas mitigation options.

CHAPTER I. CLIMATE CHANGE AND AGRICULTURE

The Effects of Climate Change on U.S. Agriculture

Global changes in climate and the level of atmospheric carbon dioxide (CO₂) could affect the location and level of agricultural production in the United States (Adams *et al.*, 1988, 1990, 1995, and 1999; Darwin, 1999; Darwin *et al.*, 1994 and 1995; Easterling *et al.*, 1992; Kaiser *et al.*, 1993; Kane, Reilly, and Tobey, 1991; Mendelsohn, Nordhaus, and Shaw, 1994) or the world (Darwin, 1999 and 1998a; Darwin *et al.*, 1995; Rosenzweig and Parry, 1994). These studies and others conclude:¹ Climate-induced shifts in agricultural possibilities and other effects of rising concentrations of atmospheric CO₂ are unlikely to impair the ability of the United States to produce enough food to feed itself through the next century. Climate-induced shifts are likely, however, to reduce the ability of some communities to obtain their livelihoods from agriculture.

Climate Change and Agriculture. Climate is a major factor in agricultural productivity and farming is located in those areas where potential agricultural productivity is consistently high. The two most important climate-related indicators of agricultural productivity are length of growing season and temperature regime (Food and Agriculture Organization of the United Nations, 1996). Length of growing season is the length of time during the year that soil temperature and soil moisture conditions are continuously suitable to crop growth. Temperature regime is the average temperature during the growing season. Crops vary in their requirements for these two variables, which depend on local temperature, precipitation, and solar radiation. In areas where the timing and intensity of precipitation limits soil moisture, irrigation may be used to extend the length of the natural growing season. The source of the water used in such localities

¹Other recent summaries include Adams, Hurd, and Reilly (1999), Intergovernmental Panel on Climate Change (IPPC, 1996), Lewandrowski and Schimmelpfennig (1999), and Schimmelpfennig, *et al.* (1996).

may depend on local precipitation, precipitation in some distant location, or precipitation from the distant past. Climate also affects livestock production. Temperatures that are too high or too low can generate stress that lowers livestock productivity. Livestock also require a daily source of drinking water, which like irrigation water depends on precipitation. Livestock production also depends on the availability of crop feeds, such as hay or grain.

Climate is also related to extreme weather events such as floods, wind storms, and droughts; to seasonal variability of frost-free periods, cold temperatures, and rainfall patterns; and to the incidence and distribution of pests and pathogens. Changes in these variables also affect agricultural productivity. Extreme weather events involving heavy precipitation are especially important. They are responsible for most water-related soil erosion and for offsite deposition of agricultural pollutants such as livestock wastes and chemicals leached from agricultural lands. Global changes in climate, therefore, could affect the location and level of agricultural production in many areas.

Direct CO₂ Effects. The level of CO₂ in the atmosphere also affects agricultural productivity directly. Plants combine solar energy with water (generally from the soil) and CO₂ from the air to photosynthesize glucose, a simple sugar. Stomata, primarily on the leaves, control the passage of water vapor and other gases to and from the plant to the atmosphere and vice versa. The size of the stomatal openings are negatively correlated with the atmospheric concentration of CO₂, that is, the higher the level of CO₂, the smaller the stomatal openings and the slower the rate of transpiration (the loss of water vapor from the plant). Hence, elevated CO₂ increases plant water use efficiency and would tend to reduce water requirements and yield loss due to water stress. Leaf temperatures also rise. Crops are generally divided into two groups—C3 or C4—depending on the number of carbon atoms in the first compound into which CO₂ is incorporated during photosynthesis. Experimental yield responses for C3 crops (e.g. wheat, rice, barley, oats,

potatoes, and most other crops) to a doubling (700 ppmv) of atmospheric CO₂ averages +30%, with a range of -10% to +80% (IPCC, 1996). Factors known to affect the magnitude of the response include the crop species, availability of water and plant nutrients, environmental factors such as temperature, and differences in experimental technique. The yield response of C4 crops (corn, millet, sorghum, and sugar cane) to a doubling of atmospheric CO₂ is lower (IPCC, 1996). A commonly used estimate for corn's yield response to a doubling (555 ppmv) of atmospheric CO₂ is 7 percent (Rosenzweig *et al.*, 1993).

There remains considerable debate about whether such CO₂-induced increases will be observed under commercial conditions. First, estimates of CO₂ enhancement are from controlled experiments and might be lower in a farmer's field. Second, incorporating yield changes into economic models inappropriately also leads to overestimates of CO₂'s benefits (Darwin, 1997 and 1998b). Also, although higher levels of atmospheric CO₂ may have a beneficial effect on plant growth, other gases released by burning fossil fuels (particularly ozone, sulfur dioxide, and nitrogen dioxide) have detrimental effects on plant growth. In addition, differential effects on C3 versus C4 crops could alter the competitive advantage between crops and weeds—C3 weeds could become more competitive with C4 crops. Finally, reduced transpiration and higher leaf temperatures could affect climate, i.e., temperatures could be higher and precipitation lower than those projected by general circulation models (Sellers *et al.*, 1996).

Analyses of climate change cover a wide range of temperature and precipitation changes. Some studies (Adams *et al.*, 1995; Darwin *et al.*, 1995; Rosenzweig and Parry, 1994) rely on results from equilibrium climate change scenarios in which atmospheric CO₂ is doubled (2xCO₂ scenarios). Global mean changes in temperature (2.8 °C to 5.2 °C) and precipitation (7.8 percent to 15.0 percent) are relatively large when compared with more recent IPCC conclusions on how climate is likely to change through 2100. Darwin (1998a) relies on results from transient climate

change scenarios that are consistent with emissions of greenhouse gases and tropospheric aerosols projected by the IPCC business-as-usual scenario, IS92a, assuming a 2.5°C increase in global mean surface temperature in response to a doubling of atmospheric CO₂ (Greco *et al.*, 1994; Schlesinger *et al.*, 1997). In these scenarios, increases in global mean temperature range from 1.0°C to 1.8°C in 2050 relative to 1990, while increases in global mean precipitation range from 1.3 percent to 2.8 percent. Adams, *et al.* (1999) study the effects of scenarios that combine four temperature changes (e.g., 0.0, 1.5, 2.5, and 5.0°C) with four precipitation changes (e.g., -10, 0, 7, and 15 percent) and four levels of atmospheric CO₂ (e.g., 355, 440, 530, and 600 ppmv) on 1990 and 2060 agricultural economies.

Agricultural Impacts. Global analyses of climate change indicate that agricultural productivity is likely to increase at higher latitudes and in alpine areas where climate temperatures are relatively cool, but is likely to decrease in tropical areas where temperatures are relatively warm or in dry areas where precipitation is relatively low (Rosenzweig and Parry, 1994; Darwin *et al.*, 1995; Darwin, 1998a). This means that reduced production potential in some areas is likely to be offset somewhat by increased potential in other areas. Losses in productivity are also offset by the direct effects of rising concentrations of atmospheric CO₂ (Rosenzweig and Parry, 1994; Darwin, 1998a). The net effects on world agricultural production, accordingly, have been shown to be relatively small and often positive, i.e., plus or minus 3 percent for world cereal production in 2xCO₂ scenarios with limited adaptation and CO₂ fertilization (Rosenzweig and Parry, 1994), plus or minus one percent for crop production and livestock production in 2xCO₂ scenarios with extensive adaptation and no CO₂ fertilization (Darwin, 1995), and less than plus four percent for crop and livestock production in transient scenarios with moderate adaptation and CO₂ fertilization (Darwin, 1998a). As expected, world prices generally move in the opposite direction of production, increasing when production decreases and decreasing when production increases

(Rosenzweig and Parry, 1994; Darwin *et al.*, 1995; Darwin, 1998a). Prices are lower when CO₂ fertilization is included in the scenarios (Rosenzweig and Parry, 1994; Darwin, 1998a)

The effects of climate change on U.S. agricultural productivity are similar to those on world productivity—agricultural productivity is likely to increase at higher latitudes and in alpine areas, but may decrease in relatively warm or dry areas (Adams *et al.*, 1995; Darwin *et al.*, 1995; Adams *et al.*, 1999; Darwin, 1998a). The net effects on U.S. production, however, are larger than those on global production, i.e., from 0 to -11 percent for agricultural commodities in 2xCO₂ scenarios with limited adaptation and CO₂ fertilization (Adams *et al.*, 1995), from -0.8 to -3.4 percent and from -0.5 to -1.3 percent for crop and livestock production, respectively, in 2xCO₂ scenarios with extensive adaptation and no CO₂ fertilization (Darwin *et al.*, 1995), from -0.7 to 27.1 percent and from -4.7 to 32.3 percent for crop and livestock production, respectively, in 2.5°C and 5.0°C temperature increase scenarios with moderate adaptation and CO₂ fertilization (Adams *et al.*, 1999), and from -1.3 to 4.2 percent and from -1.1 to -10.0 percent for crop and livestock production, respectively in scenarios with moderate adaptation and CO₂ fertilization (Darwin, 1998a).

U.S. prices, too, are more variable than world prices under global climate change. They also tend to move in the opposite direction of production, increasing when production decreases and decreasing when production increases (Adams *et al.*, 1995 and 1999; Darwin *et al.*, 1995). In Darwin (1998a), however, U.S. prices, like world prices, generally decline. U.S. prices, like world prices, are lower when CO₂ fertilization is included in the scenarios (Adams *et al.*, 1995 and 1999, 1998; Darwin, 1998a). These lower prices may be associated with lower returns to land, labor, and capital employed in the agricultural sector as well (Darwin, 1998a).

Climate-induced impacts at the regional level are linked to shifts in agricultural productivity. Under transient climate change scenarios, for example, reductions in soil moisture could shorten

growing seasons in one or more of the U.S.'s highly productive agricultural regions such as the Corn Belt, Lake States, Northern Plains, and Southern Plains by 2050 (Darwin, 1998a). In other regions, however, growing seasons are likely to increase. Given these changes in growing season, U.S. production of grains declines, while U.S. production of non-grains increases. These results are consistent with the crop yield changes (in general declining for grain crops and increasing for non-grain crops) used to simulate climate change by Adams, *et al.* (1999). Adams, *et al.* (1999), also report decreases in crop production in the Northeast, Appalachia, Delta States, and Southern Plains as well as in the Lake States, Corn Belt, and Southeast regions depending on the scenario².

Implications. These results suggest that, barring any unforeseen catastrophic events, climate-induced shifts in agricultural possibilities and other effects of rising concentrations of atmospheric CO₂ are unlikely to impair the ability of the United States to feed itself through the next century. Much depends, however, on how well farmers will be able to adapt to new climatic conditions by selecting the most profitable mix of inputs and outputs on existing cropland as well as by changing the amount of land under cultivation. The ability of U.S. farmers to adapt, however, will be determined by how well they can foresee the climatic future, the costs of adapting, and government programs. In the studies evaluated here, farmers and other economic agents are assumed to know what the future climate will be at all locations and movement toward that climate is assumed to proceed in a slow and smooth manner. In fact, we do not know what

² These regional and sectoral changes are also likely to interact with changes in the international competitiveness of U.S. agricultural products. In the absence of any effort to mitigate climate change, Canada and northern Europe, for example, may become relatively more competitive in grain and livestock production, while agricultural production in tropical regions, which tend to specialize in non-grains products, is likely to decline. U.S. competitiveness in the production of grains and livestock may decline, while U.S. competitiveness in the production of non-grains is likely to increase (Darwin, 1998a). Adams *et al.* (1999) conclude that the demand for U.S. farm commodities in foreign markets will increase under global climate change.

the future climate will be in a given location, changes could occur relatively rapidly, and the transition may be erratic, (i.e., locations that might be wetter in, say, 2050 might become drier at some point before then). We know even less about future changes in seasonal variability and extreme weather events. Given that U.S. farmers continuously adjust to interannual weather variability and extreme events, however, these uncertainties are unlikely to significantly hamper adaptation.

The studies evaluated here also generally ignore adjustment costs. It takes resources, for example, to convert forest land into agricultural land, to add or expand irrigation and flood control systems, or to establish new cropping systems. The costs associated with these adaptations will be negligible only if changes in climate occur slowly enough so that the rate of capital turnover assumed under some base case scenario is sufficient to make climate-induced adaptations without incurring additional costs. If not, then adaptation might be hampered. Adjustment costs are likely to be greater, however, in regions where the only viable adaptation would be to abandon farming.

Government policies and programs ranging from crop insurance and disaster assistance to acreage reduction programs, tariffs and quotas, and the level of agricultural research and extension will influence the farm sector's response to climate change by providing the economic incentives (or disincentives) for farmers and other economic agents to adapt and by expanding the number of technological options with which they can adapt. Given the greater uncertainty about weather variability under global climate change, farmers need as much flexibility in choices of farming practices and crops as possible.

Limitations. There are several limitations in the current understanding of the impacts of climate change on agriculture.. First, water resources are poorly linked with agronomic and economic processes. The major unknowns pertain to erosion, flooding, water-logging of soils, and the availability of irrigation water. A related unknown pertains to sea level rise. Second and

somewhat related to the first, changes in climate variability and extreme weather events are not explicitly included in existing models. This limits our knowledge of how climate change might effect the probability of crop failure in a given area. Third, many of the climate-sensitive relationships between crops and livestock with pests and diseases are excluded from current models. It is important to recognize that current understanding of climate change and agriculture will probably be modified as research on these topics becomes available.

Agriculture's contribution to GHG emissions

Agricultural activities contribute to GHG emissions directly and indirectly. Direct contributions result from emissions of CH₄, N₂O, and CO₂ are due to deforestation, biomass burning, ruminant animals, decomposition of soil organic carbon (SOC) from tillage practices, rice cultivation, fertilizer application, use of manure, and degradation of wetlands. Plowing or soil turnover is the major cause of CO₂ emissions from cropland. Indirect effects, which account for most of agricultural GHG emissions, are attributed to emissions of nitrous oxides and other gases from concentrated livestock operations and from microbial activities in soil and water following applications of fertilizers and manures.

In 1996, U.S. agricultural activities were responsible for 125.6 million metric tons of carbon equivalent (MMTCE) or about 7 percent of total U.S. greenhouse gas emissions. (Table I.1)

Agricultural activities contribute carbon dioxide (CO₂), emissions through combustion of fossil fuels, soil organic carbon (SOC) decomposition, and biomass burning. Although the farm sector is energy-intensive, total energy use is small compared to other major industries. In the U.S. carbon dioxide emissions from deforestation are small. Emissions of methane (CH₄) from agricultural activities are primarily from enteric fermentation in ruminant animals, rice cultivation, and biomass burning. The principal sources of nitrous oxide emissions (N₂O) are soils, fertilizers and manures, and biomass burning.

Not included in the annual inventories are net emissions of carbon dioxide from agricultural soils (croplands, rangelands, and pasture lands). Methane emissions from wetlands, grassland and forest lands are also not included in the current inventory due to an inadequate scientific abases for estimating net emissions from these sources. Further research and methodological research is needed to accurately include these source in the national inventory of greenhouse gas emissions..

CHAPTER II. CLIMATE CHANGE POLICIES and U.S. AGRICULTURE: ECONOMIC IMPACTS

This section reviews several studies that focus on the economic impacts of the Kyoto Protocol on U.S. agriculture. In evaluating the potential impacts of the Kyoto Protocol on U.S. agriculture, the common approach is to exogenously specify a carbon price (either arbitrarily or selected from a macroeconomic or energy model), and estimate the effects on energy intensive farm inputs, agricultural production costs, supply, prices and farm income. Three recent studies examine how energy price increases affect the agricultural sector: Franc1 (1997), McCarl, Gowen, and Yeats (1997), and Sparks Companies, Incorporated (1999). The key features, assumptions, and results of these studies are summarized in Table II.1. Input prices estimated by these studies appear in Table II.2.

The studies reviewed here (as well as the subsequent USDA analysis) do not actually estimate the carbon charges that would be necessary to reduce U.S. GHG emissions to those specified in the Kyoto Protocol. Sparks Commodities, Inc., (1999) use a carbon charge estimated by the DRI/McGraw Hill (1997) macroeconomic model while McCarl, Gowen, and Yeats (1997) and Franc1 (1999) simply assume a range of different carbon prices and estimate the impacts for various values within that range. The USDA analysis (Chapter III) uses the carbon permit price reported consistent with the Kyoto Protocol as analyzed in the Administration's Economic Analysis (AEA) (1998).³

Because the analyses focus on agricultural energy use, it is important to review how energy is used in the sector (see Appendix 2 for a more detailed discussion of energy use in the sector). Agricultural energy use is comprised of on-farm direct uses of fuels and electricity to operate vehicles, machinery, irrigation, and drying systems; indirect uses of energy in manufactured

³ The Administration's Economic Analysis (1998) is discussed in more detail in Chapter III.

fertilizers and pesticides; and uses of energy in hired or purchased services. Energy is included in smaller proportion in other expenses such as commodity transportation, hired custom and machine work, and purchased feed.

Increased input prices that result from a permit price on carbon or energy use would increase these variable costs of production. The effect on agricultural supply, market prices and farm income depend critically on: 1) the extent to which input prices increase, which in turn depends on the ability of input suppliers to pass on higher energy prices to their agricultural customers; 2) the degree to which farmers adjust to higher energy prices by reducing output and/or adopting less energy intensive cropping systems; 3) the degree to which consumers respond to higher output prices; and 4) the degree to which revenues transferred out of the agricultural sector by the carbon charge are recycled back agricultural producers. Consequently, the incidence of the carbon permit price depends on the supply and demand elasticities for primary, intermediate, and final goods, which can vary over the short, medium and longer term. Assumptions made regarding carbon prices, elasticities of supply and demand, technological change, and market adjustments are crucial to an accurate assessment of the Kyoto Protocol on the agricultural sector.

Sparks Companies, Inc. (1999) and Francel (1997) are reviewed together because of their similarity in the use of partial budgeting technique in analyzing the agricultural sector. Partial budgeting focuses on an enterprise's revenue components, cost components, and calculates the difference between these to compute net returns. It is partial in the sense that if cost component changes—such as an increase in fuel costs—net returns are simply recomputed without taking into consideration any farm level or market adjustments. Partial budgeting assumes that the full cost of an input price increase is passed on to farmers from input suppliers, and that farmers are unable to pass on any increase in costs and do not respond to changes in production costs. Partial budgeting is a reasonable approach when looking at a single production period (producers have

limited flexibility to make changes once crops are planted, for example) but will overstate the impacts because adjustments are not taken into account. Partial budgeting also assumes that changes in the firm or enterprise are so small as to not affect the market.

However, it is generally accepted that faced with rising production costs, producers reduce quantities supplied which leads to increased market prices. In the case of many agricultural commodities, demand is “inelastic” with the result that increases in production costs can actually lead to increases in net returns. Because farmers would likely respond to higher energy prices by and reducing output and/or shifting resources to other uses, commodity markets would clear at higher prices for the reduced quantities. Consequently, partial budgeting approaches are likely to overstate the actual effects of input price increases on the agricultural sector.

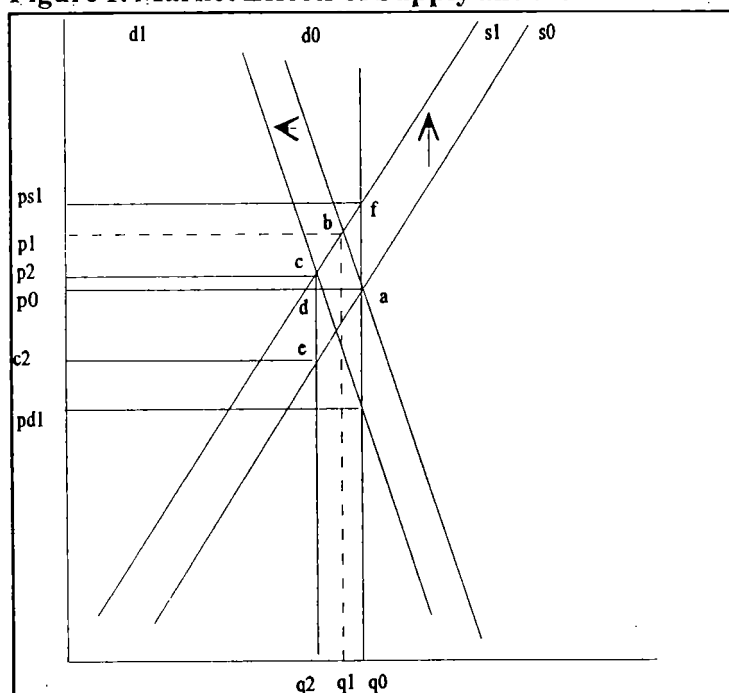
Francel (1997) estimates Kyoto Protocol impacts on farm income by calculating and summing the increased costs of production and comparing them with average farm revenues. Sparks (1999) estimates Kyoto Protocol impacts on farm income by calculating and summing up the increase in 1998 costs of production and the declines in 1998 revenues due to shifts in demand. Both Sparks (1999) and Francel (1977) substantially overestimate the impacts because they leave out important farmer and market responses. By employing partial budgeting techniques to the sector, Sparks (1999) and Francel (1977) invalidate their results.

The Sparks (1999) analysis is shown graphically in Figure 1. Agricultural markets are initially in equilibrium at point *a* where the aggregate supply function, s_0 , intersects the aggregate demand function d_0 . The price level is p_0 and the quantity is q_0 . Increased input prices increase the variable costs of production and the agricultural supply function shifts from s_0 to s_1 . Farmers adjust to the higher cost structure by producing less and the market reaches a new equilibrium at point *b* with a higher price (p_1) and lower quantity (q_1).

Demand could shift (as assumed in the Sparks's analysis) in response to both income declines and reductions in export demand. As demand shifts from $d0$ to $d1$, a new equilibrium is reached at point c , or at $p2$ and $q2$ where the new supply and demand functions intersect. The relative shifts in supply and demand in this case result in a new price above the original.

The change in farm income is the sum of revenue and cost changes. Because the domestic demand for agricultural commodities is generally inelastic, revenues increase when quantity declines, and partially offset cost increases, and the change in income is the area $c2p0ae$.⁴ The increased costs are distributed between producers and consumers according to their relative price elasticities.

Figure 1. Market Effects of Supply and Demand Shifts



The Sparks (1999) analysis does not include any adjustment to quantity supplied by farmers and the market to reach an equilibrium solution such as c . Sparks (1999)' quantity remains at $q0$ while supply and demand shift, thus Sparks (1999) includes the area $p0ps1fa$ in the cost component, approximately doubling the income loss estimation. The Sparks (1999) cost increase of

$ps1c2eaf$ does not correspond to a market result or an income loss that would result from the Kyoto Protocol.

⁴ The increase in revenues for up to quantity $q2$ is $p0p2cd$, the increase in cost is $c2p2ce$, and the net loss is $c2p0de$. For the remaining quantity up to $q0$, the revenue loss $adq2q0$, the cost reduction is $aeq2q0$, for a net loss of ade . Adding the net income losses yields $c2p0ae$.

Francel (1997) assumes that costs increase would be represented by the upward shift in the supply function from s_0 to s_1 in Figure 1. But by assuming that revenues are a past average, producers are assumed to not respond to higher input prices, and the quantity is not adjusted from q_0 . Thus, Francel (1997) assumes that revenues remain at p_0q_0 , and that the cost increase of p_1p_0af is the decrease in net farm income, roughly doubling the net income loss. Francel's (1997) analysis is virtually no different from Sparks (1999), coming to the same basic result.

Sparks (1999) estimates that farm revenues would decline \$5.3 billion (2.3 percent). \$1.7 billion is estimated as a decline in domestic agricultural revenue in response to income declines⁵, and \$3.6 billion is from assuming U.S. agricultural export demand declines due to developing countries expanding production and U.S. production costs increasing.⁶ Sparks (1999) estimates that farm input expenditures would increase by \$16.2 billion (8.8 percent).⁷ Sparks (1999) estimates that manufactured input (chemicals, fuels, & electricity) expenditures increase by \$13.0

⁵ Sparks (1999) estimates that domestic food expenditures would decline by \$1.7 billion, by applying an assumed income elasticity of 0.35 percent and 2010 income loss of 2.4 percent to projected 1998 crop and livestock receipts of \$202.7 billion. This \$1.7 billion estimate is overestimated by about \$0.8 billion due to the choice of income elasticity. Sparks (1999) cited income elasticity estimates by Huang for individual items in Table 15 of their report, but did not use Huang's estimated aggregate food income elasticity of 0.28 for this calculation. If they had used the DRI/McGraw Hill (1977) estimate of 1.6 percent GDP loss in 2010 (Sparks (1999) Table 3) and Huang's estimated aggregate food income elasticity of 0.28, their income effect would be \$0.9 instead of \$1.7 billion.

⁶ Sparks (1999) assumes that increased U.S. production costs relative to those in Latin America, Asia, and Africa would result in export losses of 6 to 7 percent. Applied to forecast 1998 U.S. agricultural exports of \$55.0 billion, a loss of \$3.6 billion is estimated. This is inconsistent with the Kyoto Protocol which will not be delivered for ratification unless there is participation from developing countries.

⁷ Sparks (1999) used energy price increases from DRI/McGraw Hill (1977), assumes input energy component and price response (with citations), and calculates net input cost changes. The exception is electricity, or which Sparks (1999) assumes a cost change of 100 percent instead of the DRI/McGraw Hill (1977) increase of 54 percent, thereby increasing the cost impact from \$1.3 billion to \$2.9 billion.

billion (46 percent). Expenditure changes in the other input categories increase by a total of \$3.2 billion.

Sparks (1999) arrives at an estimated income loss of \$21.5 billion (38.9 percent of net cash income) by summing their estimated increases in input expenditures and losses in revenues. Sparks (1999) analyzes the problem as if it were a one period problem, as if farmers would not adjust resource allocation in the face of input price changes and shifts in demand that would lower prices. Sparks (1999) extends the estimated input price increase to typical farms using farm budgets from U.S. Department of Agriculture, Economic Research Service (ERS) and the University of Florida. Sparks (1999) assumes that price reductions of 2.4-2.5 percent would occur for corn, soybeans, hogs, milk, cattle, and tomatoes. The estimated impacts are flawed in the same way the aggregate analysis is flawed, over-stating impacts.

Francel (1977) estimates the effects of higher energy prices on farm input costs, and applies the estimated input cost increases to 1995 U.S. farm production expenses to estimate cost increases of \$10.251 billion (5.8 percent) under the “low” scenario and \$20.537 billion (11.7 percent) under the “high” scenario. Dividing these cost increases by the average 1991-95 U.S. net farm income of \$42.7 billion, Francel estimated decreases in net farm income of 24 percent in the “low” scenario and 48 percent in the “high” energy price increase scenario. Francel does not indicate which method he used to compute input price increases

In contrast to the partial budgeting approaches employed by Francel and Sparks (1999), McCarl, Gowen, and Yeats (1997) use the Agricultural Sector Model (ASMSOIL) to assess the farm sector impacts of carbon permits prices of \$25, \$50, and \$100 per short ton (2,000 lbs) implemented in years 2000, 2005, 2010, 2015, 2020⁸. ASMSOIL is a spatial equilibrium

⁸ The carbon price increases used by McCarl, Gowen, and Yeats (1997) are illustrative and not the result of a macroeconomic analysis, such as DRI/McGraw Hill (1977) or AEA (1998).

nonlinear programming model with multiple input and output regions and thousands of production related variables. The model assumes that economic agents have sufficient time to adjust consumption and production decisions in response price or policy shocks (i.e. adjustment paths are not modeled). The simulation results reflect movements between market equilibriums.

Impacts of carbon permits on the costs of fertilizers and other chemicals are calculated using information in the transactions matrix of the IMPLAN input-output model and incorporating price increases for key energy inputs in the production of farm chemicals. McCarl, Gowen, and Yeats (1997) estimates of energy price increases for diesel, gasoline, and natural gas are consistent with the DRI/McGraw Hill (1977) energy price estimates used in the Sparks (1999) analysis. For various farm chemicals, however, McCarl, Gowen, and Yeats (1997) estimate price increases that are all less than one percent. Hence, for farm chemicals, the cost increases associated with carbon permits in McCarl, Gowen, and Yeats (1997) are significantly less than would be suggested by the embodied fuel or carbon content of the inputs.

McCarl, Gowen, and Yeats (1997) report that the major farm sector adjustment to higher energy costs would be a shift to less energy intensive practices such as conservation tillage. In the \$100 carbon permit simulation, for example, quantities used of cropland, water, and labor all decline by less than one percent as do expenditures for nitrogen, potassium, and phosphorous; expenditures for other chemicals increase less than one percent.

McCarl, Gowen, and Yeats (1997) present welfare impacts associated with the various carbon permit prices in terms of changes in consumer, producer, and foreign surplus relative to a scenario where no taxes are imposed. The results indicate that consumers will pay a significantly larger absolute share of any carbon/energy tax, while producers will pay a larger relative share. For example, the loss in producer surplus associated with a \$100 carbon permit begun in 2000 is \$256 million, while the loss in consumer surplus is \$1.134 billion. In percentage terms, however,

the loss in producer surplus is about five times larger than the loss in consumer surplus (0.09 percent vs 0.50 percent). Producer surplus declines 0.17 percent with \$500 carbon and increases 0.03 percent with \$25.00 carbon.

With respect to the U.S. farm sector, McCarl, Gowen, and Yeats (1997) estimate that carbon permit prices of \$25, \$50, and \$100 per ton would cost (total surplus loss), respectively, \$450 million, \$850 million, and \$1.6 billion annually, for years 2000 through 2020. Given that 1996 gross farm income was \$49 billion, they conclude U.S. agriculture would be relatively insensitive to carbon taxes or permits aimed at reducing U.S. GHG emissions. Additionally, McCarl, Gowen, and Yeats (1997) (unlike Francl (1997) and Sparks (1999)) note that these costs could be largely offset by returning carbon tax revenues collected from the farm sector to producers in the form of lump-sum transfers. For carbon permit prices of \$25, \$50, and \$100 per ton, these revenues are estimated at \$450 million, \$800 million, and \$1.5 billion, respectively.

Summary. Francl (1997) and Sparks (1999) conduct partial budgeting analyses of the effects of carbon permits on the U.S. agriculture sector, and conclude that annual net farm income will decline by 46-48 percent. Sparks (1999) analyzes the effects of carbon permit prices at \$177-\$193 per metric ton. The large projected decline in net farm income is largely the result of assuming that farmers do not respond to changes in input costs and net returns. It is more likely that rising input costs lead to reduced quantities supplied which leads to rising market prices and value of production. The effects of carbon permits on farm income are likely to be overestimated by these studies. McCarl, Gowen, and Yeats (1997) use an agricultural sector model to analyze the effects of carbon permit prices. Their calculation of effects of carbon prices on fuel costs appear to be reasonable, but their calculation of carbon price effects on fertilizer and pesticide costs less than one percent rise, which appears to be low given our knowledge of energy

embodied in these inputs. McCarl, Gowen, and Yeats (1997) allow producers and markets to respond to higher input costs, and project that income declines—about 0.5 percent with a \$100/mt carbon price—would be minimal. They further note that the income effects could be largely offset by returning carbon revenues to the farm sector. Because this analysis seems to underestimate chemical cost increases, their estimated shifts of crop acreage into chemical intensive conservation tillage is likely to be overestimated.

CHAPTER III. USDA ECONOMIC ANALYSIS OF THE KYOTO PROTOCOL ON U.S. AGRICULTURE

Energy-economic models have evaluated the effects of the Kyoto Protocol on energy sectors and the subsequent effect throughout the economy. These models have assumed that a permit trading systems will impute a price for emitting carbon dioxide, which will be translated into changes in energy prices. Producers and consumers will be affected according to how much carbon they are absorbing in production and consumption. Products and inputs containing relatively more carbon are likely to decline in use as producers and consumers respond to price signals.. All sectors of the economy would likely be affected, including agriculture, as the cost of fuels, electricity, fertilizers and chemicals, and transportation services would all be affected.

Because USDA's analysis of the Kyoto Protocol relies on the AEA (1998) carbon price estimates, we provide a review of the AEA (1998): key features, assumptions, and results of the AEA study appear in Table III.1.⁹ The AEA provides a discussion of the flexibility embodied in the Kyoto Protocol across several dimensions. The Protocol's flexibility can be characterized as "when", "what", and "where" flexibility. "When" flexibility refers to freedom in the timing of emissions reductions. For example, the averaging over the five-year commitment period reflects this kind of flexibility. "What" flexibility refers to the opportunities to substitute emissions

⁹ It is worth noting that results reported in the AEA are consistent with results reported in several other macroeconomic assessments of the reducing GHG emissions to levels at or near that required by the Kyoto Protocol. For example, assuming unrestricted international trading of emissions permits Charles River Associates (1998) replicates the AEA carbon permit price of \$14 per mt, while Edmonds et al. (1997) and the Energy Information Agency (1997) obtain prices of \$38 and \$40 per mt, respectively (the latter two studies consider reducing emissions to a level of 1990 minus 10 percent). Other studies, such as DRI/McGraw Hill (1977) and WEFA (1998) do not take into the consideration the flexibility mechanisms and result in larger impacts on energy prices. The energy-economic modeling literature has pointed out the importance of flexibility in abating GHG emissions at least cost (Jacoby *et al.* 1997; Manne and Richels 1997; Interagency Analytical Team 1997).

reductions or sequestration of one kind of GHG for another GHG. “Where” flexibility refers to opportunities to reduce emissions where it is least expensive to do so, for example, through international trading and the Clean Development Mechanism. While no one model can incorporate fully all of these flexibilities, the AEA (1998) did include parts of all three kinds of flexibility. Regarding “when” flexibility, the Administration used the Second Generation Model (SGM) which can evaluate the effects of emissions trading on the economy in 2010 and implicitly averages out the effects of business cycles and weather-induced energy use fluctuations on permit prices and subsequent economic effects. This smoothing out of short-term phenomena is consistent with the averaging provided over 2008 to 2012 in the Protocol. Regarding “what” flexibility, the AEA (1998) included all six GHGs in evaluating emissions targets and abatement opportunities. However, the Administration did not quantitatively assess carbon sequestration. Regarding “where” flexibility, the Administration evaluated various trading blocs and participation by developing countries through the Clean Development Mechanism and trading. It should also be noted that the AEA (1999) analysis did not incorporate the effects of several Administration policies, including proposed electricity restructuring legislation, the Climate Change Technology Initiative, and other Administration initiatives, which could further reduce the cost of meeting greenhouse gas targets.

The AEA (1999) analysis provides a set of scenarios representing various trading blocs. An assessment using the SGM model that accounts for an efficient international trading system and developing country participation yields permit price estimates ranging between \$14/ton and \$23 per metric ton, and resource costs between \$7 billion and \$12 billion per year. The low permit price assumes that the European Union does not engage in international trading, while the high permit price assumes that all Annex I and some key developing countries engage in international

trading.

The key assumption distinguishing the various economic impacts is the degree of international trading in the emissions obligations. Among and within studies, costs are highest when trading does not occur, lowest when all countries participate in emissions trading, and somewhere in between when trading is limited to Annex I countries. The Protocol explicitly provides for trading of emissions obligations among Annex I countries (Article 17) and for project-based agreements between Annex I and non-Annex I countries through the Clean Development Mechanism (Article 12). While the structure and procedures of an international emissions trading system are still under negotiation, scenarios that assume no trading will occur are overly pessimistic regarding the costs of implementing the Kyoto Protocol.

We analyze the effects of the Kyoto Protocol on agriculture in several steps. For our core scenario, we use the AEA (1999) carbon price of \$23 per metric ton (we also estimate the effects for every \$50 increase in carbon prices; these results appear in Appendix 1.) To accurately capture the effects of carbon prices on agricultural inputs, we estimate the carbon embodied in agricultural inputs for crop and livestock production by region. We then introduce the changes in input prices into a detailed model of the U.S. agricultural sector, which estimates the corresponding impacts on agricultural commodity price, supply, demand, income, erosion, nitrogen loss, and other important agriculture sector indicators. We do not examine how the sector might be affected by domestic policy actions to encourage reductions of emissions from agricultural sources. While agricultural sources are an important source of some greenhouse gases, it is premature to anticipate what policy options may be implemented to address these sources.

Input Prices. The increase in input prices due to a \$23 per metric ton carbon price is

calculated by multiplying the carbon embodied in each input by the carbon price. Using the Economic Research Service's Cost of Production (COP) survey data (<http://www.econ.ag.gov/briefing/fbe/car/car.htm>), we calculated the physical quantity of each input used in a production activity and then multiplied this quantity by estimates of the amount of carbon embodied per unit of input. This approach is superior to the more arbitrary approaches used by Francé (1977), Sparks (1999), and McCarl, Gowen, and Yates (1977). Embodied carbon and input price increases are presented in (Table III.2).

Direct carbon costs for crops include expenditures on diesel, gasoline, LP gas, natural gas, lubricants, and electricity used for the operation of machinery, vehicles, irrigation systems, and crop drying. The most important categories of indirect carbon costs are “fertilizer, lime, and gypsum”, “chemicals” (pesticides), and “custom operations”. “Custom operations” includes custom field and other operations (and often involving machinery that farmers contract for), technical services, and commercial drying. Other important indirect carbon costs categories are “other variable cash expenses” which can include purchased irrigation water, baling, etc. Remaining indirect carbon costs categories include “ginning” for cotton and “drying” for rice (see Appendix 2 for a more detailed discussion of energy use in the sector).

Direct energy costs for livestock include expenses for diesel, gasoline, LP gas, natural gas, lubricants, and electricity used for machinery, vehicles, equipment, manure handling systems, feed systems, housing, and dairy parlor operation. Indirect energy cost sources include “hauling,” “marketing,” and “custom services and supplies.”

Modeling Carbon Price Impacts. To capture the full effects of carbon prices on the agriculture sector we employ the USMP model which represents agricultural markets and production enterprises in considerable detail with commodity, spatial, production practice and

other particulars of the model validated to the latest baseline, geographic, and cost of production data sources available (see Appendix 3, for a more detailed description). The USMP model accounts for the most important effects of the carbon charges on U.S. agriculture.¹⁰

USMP models production of 10 crops: corn, sorghum, oats, barley, wheat, rice, cotton, soybeans, hay and silage (fruits and vegetable are not included in the USMP model) accounting for **XX percent** of farm income and **XX percent of farm output. (SOURCE)**. Some 16 primary livestock production enterprises are included, the principal being dairy, swine, beef cattle, and poultry. Several dozen processed and retail products such as dairy products, pork, fed and nonfed beef, poultry, soy meal and oil, livestock feeds, and corn milling products are included. The model incorporates domestic use, imports, exports, and inventory/stock product markets. USMP includes government conservation, acreage, price, and income programs. Production, consumption (demand), trade, and price levels for crop and livestock commodities and most processed or retail products are endogenously determined within the model structure with domestic consumption, commercial stock, export and other demand elasticities from the **FAPSIM model (SOURCE)**.

USMP is a medium term model. We hold the energy efficiency of available production technology constant which means that farmers are not assumed to respond to increased energy costs by adopting new, currently unavailable, technology. Farmer can switch among a wide range

¹⁰ The model results are "partial equilibrium" because they omit effects on agriculture which pertain to interaction between the agriculture sector and the rest of the U.S. economy. These interaction effects are minor enough that they are routinely ignored when evaluating policy impacts on agriculture. They would include, for example, effects of changes in consumer good and production input prices which result from how the carbon permit scenarios affect agriculture and non-agriculture sector producers and consumers. If carbon permits reduce non-agriculture sector income somewhat, specific examples might include declines in non-agriculture sector purchases of, e.g., food and fertilizer for non-agriculture use. These changes would reduce agriculture sector product sales revenue and input expenses somewhat, but the magnitudes are so small relative to the direct impacts that they may be safely ignored.

of tillage practices, crop rotations, etc. We consider this an appropriate, although conservative, assumption given the medium term nature of the USMP model. Because producers are routinely observed to economize on scarce or more expensive inputs, over the longer term we would expect to see increases in the adoption of more energy efficient production practices. We assume that the prices of fuels, electricity, agricultural chemicals, and other inputs will increase by the value of the carbon embedded in each input unit. This in effect assumes a perfectly elastic supply function for each of the inputs. While conservative, our model is not yet capable of modeling the input supply sector more precisely to determine the degree to which energy price increases are passed on the farm customers.

We apply the estimated input prices increases discussed above to each of the nearly 1,000 production systems contained in USMP. We then solve the model to return commodity and input markets to a new equilibrium. The supply, use, acreage, price and other market indicators which result then form the basis for determining the impacts of Kyoto on the agriculture sector. We evaluate the impacts of the emissions reduction policy in 2010, the midpoint of the 2008-2012 period established for compliance with the Kyoto Protocol.

U.S. agriculture sector conditions in 2010 are based on the USDA Long-Term Agricultural Baseline (February 1998). The official USDA baseline provides projections through the year 2007; for this analysis we extended the baseline estimates to 2010 with linear trends (of acreage planted, prices, and other market variables).¹¹ The USMP model is then calibrated to crop and livestock supply, demand, production, acreage, government program, input cost and other conditions for 2010. USMP employs crop multi year rotation system enterprises and livestock enterprise budgets based on the 1996 Economic Research Service's Cost of Production (COP)

¹¹ This procedure to extend the baseline to 2010 was based on recommendations from ERS baseline analysts.

survey data (<http://www.econ.ag.gov/briefing/fbe/car/car.htm>). These costs are indexed to baseline projections of variable costs for 2010.

The analysis is "comparative static" which means that it compares conditions in the initial, base year, equilibrium situation with conditions after the economy has had several years to adjust to a new, medium-run, equilibrium. This analysis follows the Baseline assumptions that no other policy or market changes take place, so we can isolate the unique effects of implementing carbon permit prices. Farmers respond to carbon prices by changing production levels or quantities, by changing products produced, and by shifting among current production practices actually observed in agricultural survey data. Producer response to changes in product and input prices is ultimately determined by all producers adjusting so that the revenue and returns from their last commodities produced just equal one another. Shifts among production practices—for example reducing acreage under conventional tillage and increasing acreage under reduced tillage—incur costs of acquiring new implements and learning new management practices which all enter into the process of adjusting to the new equilibrium¹².

Effects on Crop Prices, Production, and Domestic Use. Increases in carbon prices causes crop costs of production to rise, which reduces quantity demanded, increases crop price and leads to declines in production. Relative crop impacts are influenced on the supply side by carbon intensity in production. The \$23 per metric ton carbon price leads to crop price increases of less than three cents per bushel for feedgrains (corn, sorghum, barley, oats) and wheat (Table III.3). Relative changes among feedgrains on the supply side depend on the relative energy and carbon

¹² Conventional Tillage : use of disc in planting preparation. Moldboard Tillage: conventional plus use of moldboard plow. No-till (slot planting): Soil is left undisturbed prior to planting; weed control is usually accomplished with a combination of herbicides and cultivation. Ridge-till: soil is left undisturbed prior to planting; about one third of the soil surface is tilled with sweeps or row cleaners at planting time; planting is completed on ridges; weed control with herbicides and cultivation. Mulch-till: -total surface is tilled, using tools such as chisels, field cultivators, disks, sweeps, or blades; weed control with herbicides and cultivation.

intensity in production, and on the demand side depend on their relative protein and energy content in constituting animal feed rations. Rice price increase more than other crops (about 11 cent per hundredweight) owing to its greater energy and carbon intensity in production. Soybean prices increase about one cent per bushel owing to lesser carbon intensity in production. Soybean production, in the Corn Belt for example, uses only about 40 percent of the carbon per acre (134 lbs) relative to corn (309 lbs).

Declines in crop production are also relatively small. Production of all 10 USMP crops declines by less than 1.0 percent. Again, soybean production impacts are below those of feedgrains owing to the lesser carbon intensity in production, while rice production declines (about 0.9 percent) are greater due to its greater carbon intensity in production.

Effects on Crop Acreage. Charging a carbon permit price increases crop costs of production and will tend to reduce acreage planted across crops, regions, and cropping practices in proportion to how much carbon is embodied in the production process. The increase in the price of carbon leads to a decline of 1.3 million acres planted to the 10 major field crops (Table III.4. Feedgrain acreage declines about 400 thousand acres, while wheat and hay acreage decline 300 thousand acres each. Soybean acreage declines about 100 thousand acres. Proportionally, acreage declines are larger than average in the Mountain and Pacific regions and are the largest in the South Plains—regions with substantial irrigated acreage. Virtually all of the acreage decline occurs in acres farmed under conventional tillage as opposed to conservation tillage.

Effects on Livestock Price and Production. Charging a carbon permit price affects livestock production on the supply side both through direct energy cost impacts and indirect cost impacts including higher feed costs. Increased carbon prices affect livestock products negligibly, with prices increasing less than a half percent and production declining a tenth of a percent or less

(Table III.5).

Income and expense effects. The value of production and total variable costs are the major components of farm income affected by the carbon charge scenarios. Charging for carbon increases the costs of production, which increases commodity prices. Higher prices

increase value of production, but also reduce quantity demanded and hence produced, which serves to reduce value of production. The net effect on value of production depends on input supply and commodity demand markets, but—given inelastic demand—agricultural product values typically rise when production costs rise.

Total variable costs of production rises 0.6 percent (\$821 million), while value of production increases .2 percent (\$450 million), netting out to a net cash returns decline of 0.5 percent (\$371 million) (Table III.6) assuming that carbon permit revenues are not returned to the agriculture sector.¹³ Regional net cash returns range from a decline of 0.3 percent in the Corn Belt to 2.3

<u>Income Accounting Concepts</u>	
+	Value of Production
+	Conservation Reserve Payments
+	Production Flexibility Payments
-	<u>Total Variable Costs</u>
=	Net Cash Returns

¹³ The redistribution of income resulting from a domestic carbon reduction policy would depend on how the policy was designed and implemented. The value of tradeable carbon permits auctioned by the government, or the revenues collected from sale of permits could be returned entirely to the economy. For example, permit values or revenues could be redistributed to agricultural producers according to historical carbon use, or according to some environmental or stewardship “good,” or on some other basis. Thus, the ultimate impact of the different mechanisms on consumer and producer welfare would depend on how the revenues were employed (returned to consumers or producers, or otherwise used). The specific emissions reduction mechanism used will also affect the calculation of changes in agriculture sector net benefits. We currently treat the increase in input costs paid by agriculture producers as a transfer payment from farmers to the government or permit holders completely outside agriculture. The design of a carbon pricing program goes beyond the agriculture sector. It is possible that under a scheme where carbon permits are allocated to producers based on current carbon emission rates, that agriculture producers could receive transfer payments from other sectors of the economy. These payments could be greater than the associated increases in energy costs, resulting in an increase rather than decrease in producer net benefits.

percent in the Southern Plains.

Effects on Agricultural Inputs A system of carbon permits will increase the prices of agricultural inputs proportionally with carbon content. Farmers' responses to higher input prices will determine the shifts in input uses and the ultimate effects of carbon charges on farmer expenditures. Increased input prices result in reduced input use and reduced carbon embodied in inputs and agricultural production. Over time, carbon charges would stimulate development of new technology that would reduce the energy requirements for agricultural production and its embedded carbon.

The effects of carbon permits on carbon content and energy-intensive input use and on energy expenses by input are reported in Table III.7. Crop and livestock expenses for all energy increase by 2.3 percent. The input industry as a whole, using "crops and livestock all energy" as a proxy¹⁴, incurs a sales volume reduction of 0.6 percent.

Direct fuel and lubricant use by farmers and that embodied in custom use are affected most directly by carbon permits. Direct use of fuel and lubricants by farmers declines by 1.4 percent while custom service use declines by 4.4 percent. Fertilizers, particularly nitrogen, and chemicals are energy intensive inputs. About 1.625 pounds of carbon are embedded in each pound of nitrogen fertilizer and we estimate that about 5.633 pounds of carbon are embedded in each pound of chemical pesticide. Fertilizer use declines by 0.4 percent while chemical (pesticide) use declines by 0.5 percent. Electricity use increases by 1.1 percent reflecting electricity's smaller carbon content relative to fossil fuels.

Changes in surplus measures and net social benefit. An increase in carbon prices causes net

¹⁴For this analysis the carbon content of inputs used in the available technologies (production practices) is fixed, enabling reductions in carbon to be used to estimate reductions in input use. The percent changes in each input's use can be approximated by its percent change in embedded carbon.

social benefit from agriculture to decline, along with consumer and producer surpluses, reflecting the adverse effects the resulting increases in production costs and food prices have on both consumers and agricultural producer welfare (Table III.8).¹⁵ Under the Kyoto Protocol, losses to both consumers and agricultural producers decline by \$791 million (0.04 percent). The losses are split fairly evenly between consumers and producers, with consumer surplus declining by \$374 million and producer surplus declining by \$417 million. Net domestic benefit (consumer surplus plus producer surplus plus revenues transferred out of sector) which measures the net impact on agriculture or deadweight loss, declines by \$67 million. This is considerably less than the direct losses to consumers and agricultural producers, and indicates the potential for significantly reducing agriculture sector losses by recycling revenues transferred out of the sector by the carbon charge back to consumers and agriculture producers in the form of a lump sum transfer.

Changes in environmental indicators. The imposition of carbon permit prices leads to very slight reductions in soil erosion (sheet, rill and wind) and nitrogen loss to water (surface runoff and leach) (Table III.9). The reductions are brought about primarily by declines in acreage planted, rather than substitution of less carbon intensive conservation tillage practices for conventional practices. Both erosion and nitrogen loss decline imperceptibly (less than 0.5 percent) and these losses are fairly uniform across production regions. The insignificant changes in the indicators reflects the negligible impact low carbon prices have on acreage planted and technology (tillage practices) used.

¹⁵The various surplus and social benefit measures used in this analysis represent only partial gains or losses from the imposition of carbon charges. They represent changes in consumer and social welfare caused by changes in the agriculture sector alone. They don't take into account the effect of increased energy prices on consumer income or the prices consumers pay for other goods. As a result, the demand for agriculture products is only affected by changes in agricultural prices. It also assumes that all input prices, excepting land and those directly affected by changes in energy prices remain unchanged. It also leaves out any environmental benefits which may result from reductions in acreage planted and conventional tillage and reduction in GHG emissions.

Societal benefits (improved water quality) from reductions in erosion and nitrogen loss largely accrue downstream (off-site)¹⁶ from the agricultural production activities causing them. As a result, they are not included in calculations of consumer surplus, producer surplus or net social benefits. Declines in the estimated offsite damages from soil erosion are estimated at about \$4 million. These estimates suggest that the added environmental benefits, while important, will not offset the loss to consumers and producers caused by the carbon charge.

Exports and Competitiveness Effects. Commodity exports are determined by the intersection of the supply and demand curves for U.S. agricultural products in international markets. When one or both of these curves shift, there is typically a change in the quantity of U.S. commodities exported. Among the factors that can shift the supply curve of U.S. commodities in world markets are changes in the domestic prices of agricultural inputs. Increases in these prices generally raise the marginal cost of farm production—shifting the supply curve of U.S. commodity exports upwards and decreasing the quantity of commodities exported. Among the factors that can shift the demand curve for U.S. commodities in world markets are changes in the relative costs of crop and livestock production elsewhere in the world. Decreases in the relative costs of farm production in other global regions generally enhance the competitiveness of commodities from these regions resulting in a downward shift of the demand curve of foreign consumers for U.S. agricultural products and a decrease in U.S. commodity exports.

Under the Kyoto Protocol, the prices of energy intensive inputs such as diesel fuel, gasoline,

¹⁶ Reduced water quality has negative effects on navigation, recreational and commercial fishing, and water for drinking, industrial, and irrigation uses. Reduced quality results in costs incurred by individuals in avoiding or treating sub-quality water. Damage in dollar terms per ton of erosion for these categories by agricultural region have been estimated by analysts at ERS using procedures which approximate the physical, chemical, biological and economic links between soil erosion and water quality. The estimates of off-site damage used in this report were derived by multiplying the estimated damage per ton of erosion times tons of erosion for each production region.

electricity, fertilizers, and pesticides will increase. For the agricultural sector, a key question is whether the carbon price would cause input prices to rise sufficiently to affect domestic production and export levels and the degree to which carbon prices increase in the rest of the world. USMP, which accounts for both the effects of increasing input prices and the responses of foreign producers to higher world commodity prices, estimates that exports would decline by less than 2.1 percent (for rice) or less (Table III.2)¹⁷

The USMP model evaluates market impacts over a medium-run time frame. If the higher input prices associated with a carbon charge persist over time, the longer-run impacts could include decreases in the relative costs of farm production in other global regions—particularly vis-a-vis regions that do not implement a carbon charge. Conceptually, this cost advantage could eventually manifest itself in the form of lower prices for commodities from these regions, which in turn would reduce the demand for U.S. commodities in world markets. The USMP model does not account for shifts in demand due to changes in production costs elsewhere in the world.

Whether or not the long-run competitiveness of U.S. farmers in world commodity markets would be hurt by the implementation of a domestic charge on carbon is, at present, speculative. As noted by AEA (1998), energy prices already vary significantly among Annex 1 countries and between Annex 1 and non Annex 1 countries and yet there has not been any large scale migration of energy-intensive industries to take advantage of the potential cost savings. While the prices of some key farm inputs are likely to rise, the long-run effects of a carbon charge on U.S. agriculture would be affected by many factors, most of which are beyond the scope of the present assessment.

¹⁷ Changes in crop exports in USMP are determined by the price change evaluated and the export demand elasticities specified in the model. The export demand elasticities used in this analysis are: corn, -0.53; sorghum, -1.17; barley, -0.65; oats, -0.65; wheat, -1.44; rice, -2.41; soybeans, -0.73; and cotton, -1.26. These capture the medium-run impacts of a shock occurring 10 years in the future.

These factors include differences in the rates and magnitudes of technical change, the relative impacts of the carbon charge on other economic sectors, how long Annex 1 countries accept a carbon charge, how long the global economy takes to fully adjust, and whether or not Annex 1 countries restrict the international migration of key industries.

If, as a result of implementing the Protocol, foreign producers incur smaller carbon charges than domestic producers, U.S. agricultural commodities could become less competitive in global markets and U.S. commodity export demands would fall. On the other hand, if foreign producers incur higher production costs under the Protocol, U.S. competitiveness would be enhanced and U.S. commodity export demands would increase. Lacking accurate estimates of the likely effects of implementing the Protocol on the competitiveness of U.S. agricultural products, we do not shift U.S. export demands from the levels projected in the extended USDA Long-Term Baseline.

At the same time, we acknowledge the concerns that some have expressed about the possibility that increasing energy prices only in Annex-I countries will increase the likelihood of agricultural production (primary and/or processing) shifting to non-Annex-I regions. Recent evidence, however, suggests that the validity of such concerns may depend on the time-frame being considering – specifically, whether or not one is allowing for limited or full adjustments on the part of regional and world economies to the higher energy prices (i.e. a partial versus a general equilibrium framework).

Summary and conclusions. USDA's analysis is consistent with the Kyoto Protocol and the Administration's estimation of the impacts on energy prices when all the key provisions including emission trading, a multi-year commitment period, allowance for forestry carbon sinks, joint implementation, and the Clean Development Mechanism are taken into consideration. Other analyses may arrive at larger energy price impacts but we believe these analyses do not model

energy price increases that are consistent with the Kyoto Protocol's cost-reducing provisions.

We use the U.S. Regional Agricultural Sector Model (USMP), which predicts how changes in energy prices will affect the supply of crops and livestock, commodity prices, consumer demand, use of production inputs, farm income, government expenditures, participation in farm programs, and environmental indicators. USMP is linked with regularly-updated USDA production practices surveys, the USDA multi-year baseline, and geographic information system databases such as the National Resources Inventory. USMP covers 10 crops, livestock, as well as several dozen processed and retail products. Impacts are estimated by commodity for 10 farm production region, and 45 land resource regions.

We take as a starting point that under the Kyoto Protocol, energy prices increase the equivalent of \$23 per metric ton of carbon. These rising energy prices cause the cost of agricultural production to rise slightly and increase crop prices. Higher crop prices increase the value of production, but also reduce quantity demanded of food and fiber. That leads to slightly lower production. So we have a little less production being sold at a little higher prices. The net effect on farm income is a slight decline. Some regions, particularly those more dependent on energy-intensive irrigation, will be more negatively affected.

We also look at how the agricultural sector is affected for every \$50 increase in carbon prices. But even under higher carbon prices—which are not consistent with the Administration's position on climate change—we do not find significant negative impacts of American farmers. This is because farmers respond to slightly higher input prices by changing the mix of inputs, reducing output, and shifting to other commodities. Other analyses that show much larger impacts allow no such adjustment to take place.

We find the \$23 per ton carbon price leads to production declines ranging from 0.1 percent

for soybeans to 0.9 percent for rice. Prices increases range from about two cents per bushel for feedgrains, one cent per bushel for wheat, and 11 cents per hundredweight for rice. Rice prices increase more than other crops owing to its greater energy and carbon intensity in production. Soybean, silage and hay prices rise less than 1 percent owing to lesser carbon intensity in production. We find that the Kyoto Protocol would affect livestock products negligibly, with prices increasing about a half percent or less and production declining a twentieth of a percent or less.

Fertilizers, particularly nitrogen, and chemicals are energy intensive inputs. Under the Kyoto Protocol, farmers' expenditures for fertilizers increase by 2.1 percent. About 75 percent of the changes are attributed to nitrogen, which is higher in carbon content than potash and phosphates. Chemical expenditures increase by 1.2 percent while expenditures on electricity increase by 2.6 percent.

Our analysis suggests that effects on producers and consumers are quite small when the flexibility mechanisms of Kyoto are used. Assuming no income from carbon sequestering activities, net cash returns decline 0.5 percent, and consumer welfare would decline 0.05 percent.

IV. Opportunities for Agriculture

Carbon Sequestration. Land-use change and forestry is an important element of the Kyoto Protocol: Net changes in greenhouse gases and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, are to be used to meet emissions target commitments (Article 3.3) . The Protocol also provides that additional human-induced activities related to change in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories can be added by the Parties to the Protocol (Article 3.4)¹⁸. The studies described in section II do not account for the potential use of these additional activities in helping the U.S. to meet its emissions reduction target under the Kyoto Protocol.

The potential effects of the Kyoto Protocol on U.S. agriculture depend on many factors, including whether certain types of agricultural and forestry activities are ultimately included by the parties and how the Parties decide to handle definitional issues related to sinks. Equally important is the economic potential of carbon sequestration: while there may be significant physical potential to sequester carbon on agricultural lands, the cost of actually sequestering must be taken into consideration. U.S. agriculture could benefit if terrestrial carbon sinks are

¹⁸ The process of including additional human-induced activities occurs under the UN Framework Convention on Climate Change (<http://www.unfccc.de/>). In addition to annual negotiating sessions of the Conference of Parties and the twice yearly sessions of the Subsidiary Bodies that advise the Conference of Parties, there are several technical venues for addressing land use change and forestry issues. The Intergovernmental Panel on Climate Change (IPCC) is tasked with preparing a Special Report on Land Use, Land Use Change, and Forestry (<http://www.uscgrp.gov/ipcc>), which will be released in May, 2000. The Subsidiary Body on Scientific and Technological Advice organized two workshops on land use change and forestry. One workshop was held in Rome (September, 1998). Another workshop was held in Indianapolis, Indiana (April, 1999). Both workshops addressed methodological and technical issues related to Article 3.4 of the Kyoto Protocol.

eventually included in the Protocol.

Carbon Sequestration Potential. Cropland and grassland pasture and range account for almost half of all land in the contiguous 48 states and significant areas could be managed to increase the quantity of carbon stored in the soils and above ground biomass. Numerous studies of agricultural and rangelands sites in North America have documented changes in soil carbon levels with changes in management practices (see Paustian *et al.* (1996); Reicosky, 1995; Reicosky *et al.*, 1995; Kern and Johnson, 1993). For undisturbed soils first brought into production using conventional tillage practices, soil carbon losses typically range from 30–50 percent over the first 20 years of cultivation, after which, soil carbon levels generally stabilize at a new equilibrium. In the Great Plains, soil carbon losses due to cultivation have been estimated to range from 24–60 percent and take as long as 30 to 43 years to stabilize. In studies of sites that have been shifted out of conventional tillage and into permanent grasses or no-till systems, results show rates of soil carbon buildup between 0 and 2,000 lbs. per acre with accumulation typically taking 5 to 12 years to become measurable. Studies of former cropland sites either abandoned or reseeded with natural grasses indicate that about 50 years is needed to return soils to their maximum carrying capacity (Gephart *et al.*, 1994; and Lal *et al.*, 1998).

The rate of carbon accumulation/release in agricultural soils varies with many site specific factors—including chemical and physical characteristics of the soil, precipitation, above- and below-ground biology, temperature, solar radiation, atmospheric chemistry and processes, landscape characteristics, site history (including past management practices), time, and current land use (Johnson and Kern, 1991). Developing a framework that accounts for these influences in a systematic and verifiable fashion across national and international regions is an important step in including agricultural soils under Article 3.4 of the Kyoto Protocol.

Soils having the greatest potential to sequester carbon are those that are below their carbon carrying capacity, meaning young soils and soils that have been depleted of carbon due to management practices (Johnson and Kern, 1991). Because the large majority of U.S. cropland has been in production for several decades, their large initial releases of carbon have already occurred and current releases are now very low—estimates range between 2.7 and 15 MM mt annually (Gephart *et al.*, 1994; and Lal *et al.*, 1998). Collectively then, U.S. agricultural soils have a relatively high potential for being managed to store additional carbon.

Converting agricultural lands to forests. For 1996, EPA estimates that due to improved management practices and regeneration, U.S. forests represented a net carbon sink of about 208.6 MM mt. This is about 14 percent of total U.S. carbon emissions and 12 percent of total emissions of gases (in carbon equivalents) covered in the Kyoto Protocol. The potential to further offset U.S. GHG emissions by shifting millions of acres of marginal cropland and pasture into forests has been analyzed by Moulton and Richards (1990), Adams *et al.* (1993), Parks and Hardie (1995 and 1996), and Stavins (1998). We focus here on the works by Parks and Hardie (1995 and 1996) and by Stavins (1998) because the studies by Moulton and Richards (1990), and, Adams *et al.* (1993), while frequently cited, are now understood to have significantly overstated the amount of carbon sequestered in new forests (Richards, 1992).

Table III.1 (part A) presents selected results from Parks and Hardie (1995). These results suggest that a land retirement program like the current Conservation Reserve Program (CRP), funded at a level of \$456.2 million annually, would sequester about 48.6 MM tons of carbon per year (or 44.2 MM mt) and require some 22.2 million acres. The carbon sequestered is a little over 3 percent of current U.S. carbon emissions and about 7.9 percent of the emissions reduction AEA (1998) estimates will be required to meet our obligations under the Kyoto Protocol in 2010. Also clear in

Table III.1 is that most of the land converted to forests would be pasture land—note that when only cropland is considered, acres enrolled fall to 9.4 million, carbon sequestered drops to 21.6 MM tons, and per acre costs more than double (to \$48.53). Parks and Hardie (1996), consider the goal of sequestering 10 percent of U.S. carbon emissions in new forests. Achieving this level of sequestration by converting marginal croplands and pasture to new forests is estimated to require 116.1 million acres and cost \$8.31 billion annually.

Stavins estimates a marginal cost function for carbon sequestration through forestry that extends to 342 million acres of land sequestering 518 million tons (470 million metric tons) of carbon per year. Stavins' results at lower levels are similar to those of Parks and Hardie. But upon reaching 342 million acres of land, annual average costs are \$106 per acre and \$70 per ton (\$77 per metric ton) of carbon, and marginal costs are \$200 per acre and \$136 per ton (\$150 per metric ton) of carbon. Stavins estimates that marginal costs are roughly linear until reaching about \$66 per ton (\$73 per metric ton) or \$100 per acre, after which marginal costs increase rapidly. Thus, Stavins demonstrates the need for caution in extrapolating costs from relative low levels of land conversions to higher levels.

While forests generally have more primary production and above ground biomass than grasslands, grassland soils often have more carbon than forest soils (Johnson and Kern, 1991). This is because soil carbon in grasslands is mostly a function of root mortality and because the roots of grasses are thin, compact, and often extend to a depth of a meter or more. Carbon in forest soils, on the other hand is primarily a function of fine root turn-over near the surface and tree litter. For areas that were once prairie or are otherwise poorly suited to forests, conversion of cropland to grasses may be a more efficient carbon sink than conversion to trees.

Paustian *et al.* (1996) look at soil carbon accumulation on 25 million acres of CRP land in

Great Plains. Over the 10 year contract period they estimate an aggregate increase in below ground soil carbon (i.e. carbon in soil organic matter, roots, and soil litter) of 57.6 MM mt—or 5.76 MM mt per year. For CRP acres put into grasses at five locations in the Great Plains, Gephart *et al.* (1994) estimate carbon accumulation in the top 120 inches at 1,000 lbs. per acre per year—implying a 25 million acre program would sequester a total of 11.36 MM mt of carbon per year. For the most recent CRP enrollment period, average annual rental payments for land in the Great Plains ranged between \$32 and \$40 per acre. At these rental rates, a land retirement program that shifts 25 million acres of cropland to grasslands would cost between \$0.8 to \$1.0 billion.

Managing crop and pasture lands can also increase soil carbon levels. Management practices include conservation tillage, use of winter cover crops, adding organic amendments to soils, rotational grazing, and re-seeding pastures with improved varieties.¹⁹ Economic analysis on the potential costs and benefits of these practices to mitigate GHG emissions is limited although new analysis is currently underway at USDA and at several universities. Kern and Johnson (1993) estimate changes in soil carbon and energy use for various levels of adoption of minimum tillage and no-till systems for the period 1990-2020. Their results suggest that in moving from 60 million acres in no-till to 80 million acres, soil carbon would increase between 206 MM mt (million metric tons of carbon) and 339 MM mt over a 30 year period. (Table III.1, part B) This suggests that shifting 20 million acres into no-till would result in between 6.9 MM mt and 11.3 MM mt of carbon being sequestered annually—or between 1.2 percent and 2.0 percent of the U.S.

¹⁹ Many of these practices are linked to a variety of environmental benefits such as improved water quality and reductions in soils erosion. For example, the benefits of reduced erosion from switching 22.4 million acres of highly erodible land now under conventional tillage to conservation tillage at is estimated at between \$30.5 million and \$99.1 million U.S. Department of Agriculture, Economic Research Service. 1998a.

target for complying with the Kyoto Protocol in 2010.²⁰

If shifting lands from commodity production to forests or grasses, or moving from conventional tillage to conservation tillage are to be considered carbon sinks in the context of the Kyoto Protocol, the affected lands will have to stay in their new uses for extended periods of time (perhaps a minimum of 20 years). That is, managing land to sequester carbon for a few years and then returning it to production, or resuming conventional tillage in the case of land put into no-till, would quickly release any carbon that had been added to soils or biomass by sequestration activities (Paustian *et al.*, 1996; U.S. Department of Agriculture, Economic Research Service, 1998). A key focus then of policies to promote agricultural carbon sinks will need to be ensuring that conditions exist under which producers are willing to enter relatively long-run commitments regarding the management of land resources.

To assess how government policies might facilitate and encourage such commitments, it is helpful to view land ownership as a bundle of separate interests, each conveying the right to use a parcel of land in a particular way (Weibe, 1996). The set of interests associated with any given parcel may be held by one agent or may be distributed among multiple agents (public and private). From this perspective, the market value of any subset of interests reflects expectations about the present value of all current and future uses that subset allows the holder to legally undertake. Hence, the effect of establishing agricultural GHG sinks within the framework of the Kyoto Protocol would be create a new economic interest in farm land—namely the right to

²⁰ To put this in perspective, conservation tillage increased from 2 percent of U.S. cropland in 1968 to 36 percent in 1996, while acreage over the period 1992-1996 was almost constant—although acres under no-till increased from 9.9 percent of all cropland to 14.5 percent (USDA, ERS, 1998). Conservation tillage is used mostly on soybeans, corn, and small grains, which indicates that conservation compliance has probably been a major factor affecting adoption rates (USDA, ERS, 1997). This suggests that economic incentives would probably be a significant component of any effort to mitigate GHG emissions via the expanded use of conservation tillage.

manage it for increased carbon content. Giving sequestered carbon a positive market value would mean farmers could treat it as another commodity. Profit maximizing producers would then choose to sequestered carbon when the present value of its net returns exceeded similar streams associated with other commodities over some relevant time horizon.

At present, the details of any future market for carbon sequestration are largely uncertain since many of the factors that would define this market are still being debated by the Parties to the Kyoto Protocol. Possibilities include: firms with high emissions reductions costs would mitigate the environmental impacts of their emissions by contracting with farmers to engage in specific sequestration activities. The government's role in this case could be limited to maintaining the legal environment in which sinks are defined, measured, verified, and sequestration contracts enforced.

Other mitigation opportunities. In addition to converting marginal agricultural lands to forests and permanent grasses and adopting production practices that enhance soil carbon levels, a number of other opportunities may exist for agriculture to help mitigate U.S. GHG emissions. These include managing existing forests on U.S. farm lands for increased carbon storage, reducing agricultural methane emissions (via changes in methods of handling animal wastes and changes in livestock feeds), reducing agricultural emissions of nitrous oxide (via altering the use of nitrogen fertilizers and other farm chemicals) and producing biomass crops for energy generation.. Little formal economic analysis has addressed the potential of these opportunities to cost effectively mitigate U.S. GHG emissions (see Bluhm, Conway, Ronigen, and Shapouri, 1995; Brown, Rosenberg, Easterling, and Hays, 1998; and Ternary, Winnett, Shackleton, Hohenstein, 1995 for discussions on the economics of biomass)

Whether or not these alternative GHG mitigation options prove to be economically viable will depend largely on the set of sinks and mitigation practices ultimately permitted in Kyoto Protocol and the set of government policies implemented to achieve U.S. emissions reductions obligations. For example, expanding production of biomass crops could help mitigate U.S. GHG emissions in two ways. First, as discussed above, farmers could produce biomass utilizing practices that increase soil carbon levels. Second, where the energy generated by burning biomass replaces energy generated by fossil fuel combustion, it would represent a shift to recycling atmospheric carbon and thus, over time, a reduction in *net* emissions. Additionally, because of the substitutability between biofuels and fossil fuels in energy generation, any carbon-based charge on fossil fuels would enhance the competitiveness of biofuels. The economic viability of biofuels as a GHG mitigation option then will depend on whether or not agricultural soils are allowed as a carbon sink in the Kyoto framework, whether or not shifting to practices that recycle atmospheric carbon will be counted as a reduction in net emissions, and the magnitude of the carbon charge needed to meet U.S. emissions reductions obligations.

Table I.1: Greenhouse Emissions from the Agriculture Sector, million metric tons of carbon equivalent (MMTCE), 1990-96

Gas/Source	1990	1991	1992	1993	1994	1995	1996
Total U.S. Emissions	1632.7	1620.2	1645.7	1678.0	1715.3	1731.1	1788.0
Methane (CH ₄)	169.9	171.1	172.5	171.9	175.9	179.2	178.6
Nitrous Oxide (N ₂ O)	92.3	94.4	96.8	97.1	104.9	101.0	103.7
Carbon	1348.3	1333.2	1353.2	1385.6	1408.5	1419.2	1471.1
Total Ag. Emissions	105.7	107.5	109.3	110.9	114.8	114.4	114.0
CH₄	50.3	50.9	52.2	52.5	54.4	54.8	53.7
Enteric Fermentation	32.7	32.8	33.2	33.6	34.5	34.9	34.5
Manure Management	14.9	15.4	16.0	16.1	16.7	16.9	16.6
Rice Cultivation	2.5	2.5	2.8	2.5	3.0	2.8	2.5
Agricultural Residue	0.2	0.2	0.2	0.2	0.2	0.2	0.2
N₂O, total	55.4	56.5	57.1	58.5	60.4	59.7	60.3
Manure Management	3.3	3.5	3.5	3.6	3.7	3.6	3.7
Ag. Soil Management	52.0	52.9	53.5	54.8	56.6	55.9	56.5
Ag. Residue Burning	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Agricultural Emissions as percent of Total U.S.	6.5	6.6	6.6	6.6	6.7	6.6	6.4

Source: U.S. Environmental Protection Agency. 1998. *Inventory of U.S. Greenhouse Gas Emission and Sink: 1990-1996*. (USEPA 236-R-98-006, March 1998), Washington, DC.

Table II.1: Assumptions, Features, and Results of Selected Farm-Level Studies on Reducing U.S. Carbon Emissions

Study	Emissions targets*	Price of Carbon (\$ permit)	Key Assumptions and Features	Key Results
Franci (1997) results in 1994 \$'s	1990	Low scenario: \$0.25 per gallon of fuel. High scenario: \$0.50 per gallon of fuel.	1. Estimates how fuel taxes would affect input prices and production cost of selected commodities. 2. Tax rates based on a literature review 3. All price changes occur in year 1. 4. Effects relative to 1994 5. No producer supply response that would raise commodity prices.	1. Total farm production expenses increase 5.8% in the low scenario and 11.7% in the high scenario. 2. See Table II.4 for impacts on agricultural input prices
Sparks (1999): results in 1995 \$'s	See DRI study (table II.2)	See DRI study.	1. Uses DRI model to define baseline and assess macroeconomic impacts of each scenario. No phase-in period. 2. Estimates how carbon tax would affect the prices energy intensive farm inputs. 3. Input cost increase reflects producer response to higher prices; domestic consumer response limited to income effect. 4. Technology, commodity production patterns, and systems of food processing and marketing assumed constant through 2010. 5. No producer supply response that would raise commodity prices.	1. Higher energy costs would: a. increase farm production costs \$16.2 billion (8.8%) and food processing and marketing costs \$18 billion (2.6%). b. reduce domestic food demand 0.8% c. decrease farm income nearly 53% from 1998 d. increase farm consolidation e. increase food imports and decrease food exports.
McCarl et al. (1997)	No specific target	Considers taxes of 25, \$50, and \$100 per short ton of carbon	1. taxes put in place all at once & all economic adjustments occur immediately 2. Changes in relative prices of diesel, natural gas, fertilizer and electricity are estimated exogenously and imposed on the model. 3. Considers imposing carbon tax in 2000, 2005, 2010, 2015, and 2020.	1. U.S. agriculture is not very sensitive to carbon taxes. 2. Carbon taxes of \$25, \$50, and \$100 / ton would cost the farm sector, respectively, \$450, \$850, and \$1,600 million annually. Annual tax revenues from the farm sector would be \$450, \$800, and \$1,500 million. 3. Farmers would pass most of any input price increases on to consumers.

Table II.2: Agricultural Input Cost Increases Estimated in Various Studies, by Carbon Tax Scenario

Study	Input	Policy Scenario		
Francel		Fuel Price Increase Scenario		
		Low	High	
		--percent--		
	Fuel and electricity	25	50	
	Pesticides/chemicals	20	40	
	Fertilizer	15 to 20	30 to 40	
	Custom operations/hauling	15	30	
	Other Expenses	5	10	
Sparks, Inc.		Emissions Permit Price (1997 \$'s per metric ton of Carbon)		
		\$177-193		
		--percent--		
	Fuels and Oil	30		
	Electricity	100		
	Fertilizer and lime	100		
	Pesticides	50		
McCarl et al.		Carbon Permit Price (1997 \$'s per short ton of Carbon)		
		\$25	\$50	\$100
		--percent--		
	Gasoline	4.52	9.04	18.08
	Diesel	8.26	16.53	33.06
	Natural Gas	13.13	26.26	52.53
	Electricity	8.26	16.53	33.06
	Nitrogen	0.22	0.44	0.87
	Phosphorous	0.08	0.16	0.33
	Potassium	0.22	0.44	0.87
	Chemicals	0.08	0.16	0.33

Table III.1: Summary of AEA (1998) Analysis of Implementing the Kyoto Protocol

Emissions Target:

U.S. greenhouse gas (GHG) emissions target is set 7% below 1990 levels between 2008 and 2012. Gases covered are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF₆).

Methodology :

1. Construct regional "business as usual" (BAU) GHG emissions scenarios for 2010.
2. Develop regional marginal abatement cost curves for reducing GHG emissions.
- Use the Second Generation Model (SGM) to calculate the world GHG permit prices that equates marginal abatement costs across regions for various trading scenarios. For each scenario, assess the impacts on U.S. energy prices, energy consumption, GDP, investment, and consumption. (SGM is a 12 region - 9 sector computable general equilibrium model designed to analyze energy markets).

Key Assumptions:

1. Efficient trading of emissions allowances within regions and across specified trading blocs
2. Carbon sinks not considered
3. Autonomous gain in energy efficiency for the US economy set at 0.96% annually
4. No banking of emissions allowances for later periods
5. No emissions mitigation related to electricity sector restructuring, the Climate Change Technology Initiative, the Energy Efficiency Initiative, or voluntary industry actions
6. GHG emissions target is, on average, 600 MMTCE below projected "business as usual" emissions levels for 2008-2012.
7. Specified trade blocs:
 - Annex 1: Unrestricted trade of emissions credits among Annex 1 countries.
 - Umbrella 1: Unrestricted trade of emissions credits among Annex 1 countries minus Eastern Europe and the European Union (EU).
 - Umbrella 2: Unrestricted trade of emissions credits among Annex 1 countries minus the EU.
 - CDM: Developing countries sell emissions credits via Clean Development Mechanism.
 - KDC: Key developing countries adopt emissions targets equal to their 2010 baseline and participate in normal trading:

Scenario results (% reductions relative to case where all countries reduce emissions domestically):

Scenario	reduction in permit price	reduction in U.S. economic cost	Permit Price (1996 \$/t)	U.S. Economic Cost (1996 \$/yr)
Annex 1	72%	57%		
Umbrella 1	75%	61%		
Umbrella 2	85%	74%		
Annex 1+KDC	88%	80%	\$23/metric ton	\$12 billion/year
Umbrella 1+KDC	91%	83%		
Umbrella 2+KDC	93%	87%	\$14/metric ton	\$ 7 billion/year
Annex 1+CDM	79%	66%		
Umbrella 1+CDM	82%	71%		
Umbrella 2+CDM	88%	80%		

Results for permit price = \$14 per metric ton (relative to the BAU scenario in 2010)

- a. raise household energy prices 3% and annual household energy costs \$70,
- b. raise both electricity and gasoline prices 3% (for gasoline this is about 4 cents per gallon);

Results for permit price = \$23 per metric ton (relative to the BAU scenario in 2010)

- a. raise household energy prices 5% and annual household energy costs \$110,
- b. raise electricity prices 5% and gasoline prices 4% (about 6 cents per gallon)

Source: AEA (1998)

Table III.2: Inputs under the Kyoto Protocol : embodied carbon and input prices

Item	Unit	Input Price (2010) \$ / unit	Carbon Content pounds / unit	Input Price Increase* \$ / unit percent	
Fuels			1,2/		
Diesel fuel	Gallon	1.21	6.026	0.063	5.2
Gasoline	Gallon	1.65	5.233	0.055	3.3
LP gas	Gallon	1.06	3.200	0.033	3.2
Natural gas	100 Cu.Ft.	0.45	3.300	0.034	7.7
Electricity			3/		
Northeast	Kwh.	0.11	0.087	0.001	0.9
Lake States	Kwh.	0.06	0.150	0.002	2.6
Corn Belt	Kwh.	0.06	0.150	0.002	2.8
Northern Plains	Kwh.	0.06	0.150	0.002	2.8
Appalachian	Kwh.	0.08	0.105	0.001	1.4
Southeast	Kwh.	0.06	0.129	0.001	2.3
Delta	Kwh.	0.05	0.135	0.001	2.9
Southern Plains	Kwh.	0.05	0.127	0.001	2.5
Mountain	Kwh.	0.06	0.127	0.001	2.4
Pacific	Kwh.	0.07	0.042	0.000	0.6
Chemicals			4/		
Nitrogen	Pound	0.38	1.420	0.015	3.9
Phosphate	Pound	0.29	0.296	0.003	1.1
Potash	Pound	0.17	0.236	0.002	1.4
Pesticides	Pound	3.49	5.633	0.059	1.7

* Input price change in USMP model run with carbon permit price of \$23 per metric ton.

Sources:

1/ USDOE/EIA. 1997. *Annual Energy Outlook*, p. 222. (Volume/Btu conversions)

2/ USDOE/EIA, 1997. *Emissions of Greenhouse Gases in the United States -1996*, USDOE/EIA-0573(96), Oct. 1997. Table B1, p.100. Adjustments for incomplete combustion per personal communication with Susan Holte, EIA emissions specialist. (Btu/Carbon conversions)

3/ Wiese, AM. 1998. *Impacts of Market-Based Greenhouse Gas Emission Reduction Policies on U.S. Manufacturing Competitiveness*, Research Study #090 American Petroleum Institute. Citing USDOE, EIA. 1995. "Annual Electric Generator Report," in *The Electric Power Annual*, Vol.1, tables 6-8.

4/ Helsel, Z.R. 1992. "Energy and Alternatives for Fertilizer and Pesticide Use," Chapter 13 in *Energy in Farm Production*, ed. RC Fluck. Elsevier, 1992.

Table III.3: 2010 crop price, production, domestic use and exports under the Kyoto Protocol

Crop			Price		Production		Domestic use		Exports	
			Base	\$23/mt	Base	\$23/mt	Base	\$23/mt	Base	\$23/mt
			2010		2010		2010		2010	
			--dollars per unit--		--million units--					
Corn	Bushel		3.20	3.22	11,776.2	11756.5	1675.0	1674.3	3250.6	3240.0
		Change								
		% change		0.02		-19.7		-0.7		-10.6
Sorghum	Bushel		3.00	3.02	770.0	766.1	35.0	34.8	335.0	331.9
		Change		0.02		-4.0		-0.2		-3.1
		% change		0.78		-0.5		-0.7		-0.9
Barley	Bushel		2.85	2.88	450.0	447.3	172.0	171.5	70.0	69.0
		Change		0.03		-2.7		-0.5		-1.0
		% change		1.13		-0.6		-0.3		-1.4
Oats	Bushel		1.90	1.91	293.7	292.8	102.0	101.9	2.0	2.0
		Change		0.01		-1.0		-0.1		0.0
		% change		0.65		-0.3		-0.1		-0.4
Wheat	Bushel		4.65	4.66	2,828.0	2821.6	1146.0	1145.8	1625.0	1619.3
		Change		0.01		-6.4		-0.2		-5.8
		% change		0.22		-0.2		0.0		-0.4
Rice	Hundred-weight		12.87	12.98	206.4	204.4	7.0	7.0	85.4	83.7
		Change		0.11		-2.0		0.0		-1.8
		% change		0.85		-0.9		-0.3		-2.1
Soybeans	Bushel		7.55	7.56	3,144.2	3140.9	152.2	152.1	1149.7	1149.0
		Change		0.01		-3.3		-0.1		-0.8
		% change		0.09		-0.1		0.0		-0.1
Cotton	Bale		NA ¹	NA	21.3	21.2	13.2	13.2	8.0	8.0
		Change		1.25		-0.1		-0.1		0.0
		% change		0.34		-0.4		-0.3		-0.4
Silage	Ton		21.66	21.67	95.6	95.4	27.5	27.4	0.0	0.0
		Change		0.01		-0.2		-0.1		0.0
		% change		0.04		-0.3		-0.3		0.0
Hay	Ton		60.53	60.61	155.6	154.9	79.2	78.7	0.0	0.0
		Change		0.08		-0.7		-0.6		0.0
		% change		0.13		-0.4		-0.7		0.0

¹ USDA is prohibited from publishing cotton price projections.

Table III.4: 2010 acreage planted and acreage change under the Kyoto Protocol

	Base/ Change	North East	Lake States	Corn Belt	North Plains	Appa- lachia	South East	Delta States	South Plains	Moun- tain	Pacific	US Total
Selected crops												
-- million acres --												
Feed- grains	2010 base	3.97	15.49	43.59	24.55	4.78	2.18	1.00	6.39	4.36	1.42	107.72
	Change	-0.02	-0.02	-0.02	-0.13	-0.01	-0.01	0.00	-0.10	-0.05	-0.02	-0.38
	% change	-0.40	-0.10	0.00	-0.50	-0.20	-0.20	-0.40	-1.60	-1.20	-1.30	-0.30
Wheat	2010 base	0.73	3.89	6.46	28.97	1.45	0.38	0.71	21.42	10.69	2.83	77.50
	Change	0.00	-0.01	-0.01	-0.09	0.00	0.00	0.00	-0.18	-0.03	0.00	-0.31
	% change	-0.20	-0.10	-0.10	-0.30	-0.30	-0.20	-0.10	-0.80	-0.20	0.20	-0.40
Soybeans	2010 base	1.08	8.38	36.11	8.36	4.99	2.87	8.19	0.30	0.00	0.00	70.27
	Change	0.00	-0.01	-0.02	-0.02	-0.01	-0.01	-0.03	0.00	0.00	0.00	-0.09
	% change	-0.10	-0.10	0.00	-0.20	-0.20	-0.30	-0.30	-0.80	0.00	0.00	-0.10
Hay	2010 base	7.81	10.53	11.38	10.94	6.33	1.05	0.76	1.19	9.31	3.20	62.50
	Change	-0.01	-0.02	-0.01	-0.07	0.00	0.00	0.00	-0.02	-0.14	0.00	-0.26
	% change	-0.20	-0.20	-0.10	-0.60	0.00	0.00	0.00	-1.30	-1.50	0.10	-0.40
10 major crops	2010 base	15.04	40.04	98.61	74.29	19.00	7.61	17.01	36.40	25.14	9.00	342.15
	Change	-0.04	-0.07	-0.05	-0.31	-0.03	-0.02	-0.04	-0.44	-0.22	-0.05	-1.26
	% change	-0.20	-0.20	-0.10	-0.40	-0.20	-0.20	-0.20	-1.20	-0.90	-0.50	-0.40
Tillage Types												
Conven- Tional	2010 base	3.28	16.01	45.20	37.24	7.66	6.56	15.55	27.97	13.51	5.39	178.37
	Change	-0.03	-0.05	-0.02	-0.34	-0.01	-0.02	-0.04	-0.43	-0.24	-0.05	-1.23
	% change	-0.90	-0.30	0.00	-0.90	-0.10	-0.20	-0.20	-1.50	-1.80	-0.90	-0.70
Mold- board	2010 base	8.31	13.34	12.22	15.03	6.17	1.05	0.80	6.41	8.78	3.37	75.47
	Change	0.01	-0.01	0.00	0.10	0.00	0.00	0.00	-0.07	0.03	0.00	0.06
	% change	0.10	-0.10	0.00	0.60	0.10	0.00	-0.10	-1.10	0.30	0.00	0.10
Mulch	2010 base	1.33	7.57	20.71	15.68	1.71	0.00	0.00	2.02	2.86	0.24	52.12
	Change	-0.01	-0.02	-0.03	-0.02	-0.01	0.00	0.00	0.06	-0.01	0.00	-0.03
	% change	-0.50	-0.20	-0.10	-0.20	-0.70	0.00	0.00	3.00	-0.30	0.70	-0.10
No-Till	2010 base	2.12	3.02	20.48	4.99	3.46	0.00	0.66	0.00	0.00	0.00	34.73
	Change	-0.01	0.01	-0.01	-0.05	-0.01	0.00	0.00	0.00	0.00	0.00	-0.07
	% change	-0.40	0.30	0.00	-0.90	-0.30	0.00	0.10	0.00	0.00	0.00	-0.20
Ridge-Till	2010 base	0.00	0.11	0.00	1.35	0.00	0.00	0.00	0.00	0.00	0.00	1.46
	Change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	% change	0.00	0.10	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.10
All Tillage Types	2010 base	15.04	40.04	98.61	74.29	19.00	7.61	17.01	36.40	25.14	9.00	342.15
	Change	-0.04	-0.07	-0.05	-0.31	-0.03	-0.02	-0.04	-0.44	-0.22	-0.05	-1.26
	% change	-0.20	-0.20	-0.10	-0.40	-0.20	-0.20	-0.20	-1.20	-0.90	-0.50	-0.40

Conventional Tillage : use of disc in planting preparation. Moldboard Tillage: conventional plus use of moldboard plow. No-till (slot planting): Soil is left undisturbed prior to planting; weed control is usually accomplished with a combination of herbicides and cultivation. Ridge-till: soil is left undisturbed prior to planting; about one third of the soil surface is tilled with sweeps or row cleaners at planting time; planting is completed on ridges; weed control with herbicides and cultivation. Mulch-till: -total surface is tilled, using tools such as chisels, field cultivators, disks, sweeps, or blades; weed control with herbicides and cultivation.

Table III.5: Selected 2010 livestock price and production under the Kyoto Protocol

Item	Unit		Price		Production	
			Base 2010	\$23/mt	Base 2010	\$23/mt
			--dollars per unit--		--million units--	
Milk	Hundred-weight		15.25	15.29	1,705.0	1,703.2
		Change		0.03		-1.8
		% change		0.23		-0.1
Hog slaughter	Hundred-weight*		49.8	49.94	255.2	255.1
		Change		0.14		0.0
		% change		0.27		0.0
Beef yearlings	Hundred-weight*		90.64	91.17	185.9	185.7
		Change		0.53		-0.2
		% change		0.58		-0.1
Fed beef	Hundred-weight*		80.61	81.08	329.5	329.0
		Change		0.47		-0.5
		% change		0.58		-0.2
Broilers	Pounds		0.39	0.39	37,863.5	37,853.2
		Change		0		-10.3
		% change		0.22		0.0

* live weight.

Table III.6: 2010 Income and expenses: base level, change and percent change under Kyoto Protocol

	Base/ Change	North East	Lake States	Corn Belt	North Plains	Appa- lachia	South East	Delta States	South Plains	Moun- tain	Pacific	US Total
-- million dollars --												
Crops												
Value	2010 base	3,503	11,034	38,477	16,835	5,595	2,496	7,577	6,299	5,218	3,497	100,530
Of	Change	3	30	127	0	9	4	18	-29	-19	-9	135
Production	% change	0.10	0.30	0.30	0.00	0.20	0.20	0.20	-0.50	-0.40	-0.30	0.10
Conserva-	2010 base	5	104	268	214	29	30	20	118	108	38	933
Tion	Change	0	0	0	0	0	0	0	0	0	0	0
Reserve	% change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Payments												
Production	2010 base	92	357	1,029	857	152	83	411	642	227	160	4,010
Flexibility	Change	0	0	0	0	0	0	0	0	0	0	0
Payments	% change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	2010 base	2,485	5,868	16,580	10,141	3,498	1,516	4,272	5,409	3,049	2,220	55,038
Variable	Change	13	60	208	86	31	15	48	2	-9	-6	448
Costs	% change	0.50	1.00	1.30	0.90	0.90	1.00	1.10	0.00	-0.30	-0.30	0.80
Net	2010 base	1,115	5,627	23,195	7,764	2,278	1,093	3,736	1,649	2,505	1,474	50,435
cash	Change	-10	-30	-81	-86	-23	-10	-30	-31	-10	-3	-314
Returns	% change	-0.90	-0.50	-0.30	-1.10	-1.00	-0.90	-0.80	-1.90	-0.40	-0.20	-0.60
Livestock												
Value	2010 base	8,816	11,676	17,889	18,416	8,488	8,156	5,741	19,701	8,901	9,545	117,329
Of	Change	6	10	157	87	4	2	2	-183	139	92	315
Production	% change	0.10	0.10	0.90	0.50	0.00	0.00	0.00	-0.90	1.60	1.00	0.30
Total	2010 base	5,163	7,882	15,398	18,306	6,293	5,082	3,558	17,370	8,035	6,464	93,550
Variable	Change	18	27	155	87	10	8	6	-122	112	71	373
Costs	% change	0.30	0.30	1.00	0.50	0.20	0.20	0.20	-0.70	1.40	1.10	0.40
Net	2010 base	3,653	3,794	2,491	109	2,195	3,074	2,184	2,331	866	3,081	23,780
cash	Change	-12	-17	2	0	-6	-7	-5	-60	26	21	-58
Returns	% change	-0.30	-0.40	0.10	-0.30	-0.30	-0.20	-0.20	-2.60	3.00	0.70	-0.20
Crops and Livestock												
Value	2010 base	12,319	22,710	56,366	35,250	14,083	10,652	13,318	26,000	14,120	13,042	217,859
Of	Change	9	40	285	87	12	6	20	-211	120	83	450
Production	% change	0.10	0.20	0.50	0.20	0.10	0.10	0.10	-0.80	0.80	0.60	0.20
Total	2010 base	7,648	13,750	31,977	28,447	9,790	6,598	7,830	22,778	11,084	8,685	148,587
Variable	Change	31	86	363	173	42	23	54	-120	103	65	821
Costs	% change	0.40	0.60	1.10	0.60	0.40	0.30	0.70	-0.50	0.90	0.70	0.60
Net	2010 base	4,768	9,422	25,686	7,874	4,474	4,167	5,919	3,981	3,371	4,555	74,215
cash	Change	-22	-47	-79	-87	-29	-17	-35	-91	17	18	-371
Returns	% change	-0.50	-0.50	-0.30	-1.10	-0.70	-0.40	-0.60	-2.30	0.50	0.40	-0.50

Table III.7: Carbon embedded and energy expenses under the Kyoto Protocol ¹

Item	Carbon embodied in production		Energy expenses in production	
	Base2010	\$23/mt	Base2010	\$23/mt
-- Crops --	-- million mt --		-- million dollars --	
Fuel	11	10.8	5,210.9	5,404.0
Change		-0.2		193.1
% Change		-1.4		3.7
Electricity	0.5	0.5	446.3	453.8
Change		0		7.5
% Change		-0.7		1.7
Custom	1.4	1.3	655.5	657.9
Change		-0.1		2.4
% Change		-4.4		0.4
Fertilizer	13	12.9	12,275.3	12,528.1
Change		-0.1		252.8
% Change		-0.4		2.1
Chemicals	5.9	5.8	8,007.9	8,102.5
Change		0		94.6
% Change		-0.5		1.2
Crops all energy	31.7	31.4	26,595.8	27,146.2
Change		-0.3		550.4
% Change		-1		2.1
-- Livestock --				
Fuel	8.4	8.3	4,075.4	4,216.9
Change		-0.1		141.4
% Change		-1.4		3.5
Electricity	0.4	0.4	483.6	499.8
Change		0		16.2
% Change		1.1		3.4
Livestock all energy	8.8	8.7	4,559.0	4,716.7
Change		-0.1		157.7
% Change		-1.3		3.5
--Crops and livestock--				
Fuel	19.4	19.1	9,286.3	9,620.9
Change		-0.3		334.6
% Change		-1.4		3.6
Electricity	0.9	0.9	929.8	953.6
Change		0		23.7
% Change		0.2		2.6
Custom	1.4	1.3	655.5	657.9
Change		-0.1		2.4
% Change		-4.4		0.4
Fertilizer	13	12.9	12,275.3	12,528.1
Change		-0.1		252.8
% Change		-0.4		2.1
Chemicals	5.9	5.8	8,007.9	8,102.5
Change		0		94.6
% Change		-0.5		1.2
All energy	40.5	40	31,154.8	31,862.9
Change		-0.4		708.1
% Change		-1		2.3

¹ These estimates pertain to the 10 major field crops and major livestock enterprises included in the USMP model and cover most significant carbon use in agriculture. USMP does not model fruit, vegetable and other horticultural production which are energy intensive and use relatively more electricity than field crops. Horticultural electricity uses include irrigation, refrigeration and greenhouse operation.

Table III.8: Social benefit measures under Kyoto Protocol

Measure			U.S. Total
			million dollars
Producer Surplus	Base		1,096,957
	\$23/mt	Change	-417
		% change	-0.04
Net farm cash Returns ¹	Base		74,215
	\$23/mt	Change	-371
		% change	-0.5
Consumer surplus	Base		822,239
	\$23/mt	Change	-374
		% change	-0.05
Consumer and producer surplus	Base		1,919,196
	\$23/mt	Change	-791
		% change	-0.04
Revenue transfers out of agriculture sector²			N/A
	\$23/mt	Change	724
Net social benefit	Base		1,919,196
	\$23/mt	Change	-67
		% change	-0.00
Net foreign surplus	Base		54,409
	\$23/mt	Change	-127
		% change	-0.46

¹ Crop and live animal producers. Processing (food, feed and meat) not included.

² Revenues transferred out of agriculture sector based on carbon tax rate implied by carbon permit price.
Equal to tax revenues from imposition of a carbon tax.

Δ Net social benefit

= Δ Consumer surplus + Δ Producer surplus + Tax revenue

Δ Net foreign surplus = Δ Export surplus + Δ Import surplus

Table III.9: Changes in erosion and water related nitrogen losses¹

Indicator			North East	Lake States	Corn Belt	North Plains	Appa- Lachia	South East	Delta States	South Plains	Moun- tain	Pacif ic	U.S. Total
			--- million tons---										
Soil	Base		48.9	224.3	471.7	307.1	102.2	47.0	85.3	285.2	326.4	89.5	1987.7
Erosion	\$23/mt	change	-0.073	-0.538	-0.200	-1.322	-0.174	-0.091	-0.157	-0.556	0.207	-0.027	-2.928
		% change	-0.149	-0.240	-0.042	-0.430	-0.170	-0.193	-0.184	-0.195	0.064	-0.031	-0.147
Nitrogen-	Base		0.23	0.36	1.96	1.10	0.46	0.17	0.47	0.63	0.17	0.09	5.63
Loss to	\$23/mt	change	0.000	0.000	-0.001	-0.005	0.000	0.000	-0.001	-0.005	0.000	-0.001	-0.016
Water		% change	-0.311	-0.249	-0.055	-0.428	-0.164	-0.199	-0.221	-0.842	-0.107	-1.376	-0.288
Nitrogen-	Base		0.019	0.075	0.664	0.229	0.046	0.021	0.037	0.273	0.049	0.041	1.453
Loss to	\$23/mt	change	0.000	0.000	0.000	-0.001	0.000	0.000	0.000	-0.003	0.000	0.000	-0.006
Air ²		% change	-0.242	-0.114	-0.067	-0.467	-0.232	-0.160	-0.196	-1.276	-0.126	-0.779	-0.393
			--- million dollars---										
Offsite	Base		228.8	377.4	579.3	152.4	346.9	108.2	265.8	175.1	170.0	208.1	2612.0
Damages	\$23/mt	change	-0.339	-0.713	-0.199	-0.486	-0.590	-0.209	-0.489	-0.777	-0.025	-0.198	-4.024
From		% change	-0.148	-0.189	-0.034	-0.319	-0.170	-0.193	-0.184	-0.444	-0.015	-0.095	-0.154
Erosion													

¹ The environmental indicators reported in this table do not measure environmental quality, but rather changes in factors which influence environmental quality.

² Nitrogen loss to air includes nitrogen losses from denitrification and volatilization.

Table IV.1: Potential Carbon Sequestration on U.S. Agricultural Lands

A. Selected Features of a Land Retirement Program to Sequester Carbon on Marginal Cropland and Pasture

Lands Targeted:	---- Cropland and Pasture ----		----- Cropland -----	
Objective:	Minimize Cost per Acre	Minimize Cost per Ton C	Minimize Cost per Acre	Minimize Cost per Ton C
Total land enrolled (million acres)	23.1	22.2	10.3	9.4
Annual Carbon Sequestered (million metric tons)	40.9	44.2	15.3	19.6
Annual cost (\$/acre)	19.75	20.54	44.29	48.53
Annual cost (\$/metric ton)	11.15	10.33	29.88	23.23
Length of Program:	10 years (assumes forests would then be highest value use)			
Total Program Cost:	\$3.7 billion total			
Annual Program Cost:	\$456.2 million			

Source: Parks and Hardie (1995)

► **Estimated Changes in SOC and Fossil Fuel Use to the year 2020 for Select Changes in the Use of Minimum Tillage and No-Till systems in the United States**

Tillage System	----- Scenario 1 -----					----- Scenario 2 -----					----- Scenario 3 -----				
	Mean	Min.	Max.	Fuel		Mean	Min.	Max.	Fuel		Mean	Min.	Max.	Fuel	
	----- MMT C -----														
a. Conventional	-41	-31	-52	-121	-24	-18	-30	-87	-13	-9	-16	-67			
b. Minimum	0	0	0	-30	0	0	0	-52	0	0	0	-66			
c. No-till	0	0	0	-6	105	80	129	-10	377	286	468	-13			
d. Totals	-41	-31	-52	-157	80	62	99	-149	364	277	452	-146			
Net gain/loss	-198	-188	-209		-69	-87	-50		218	131	306				

Scenarios:

1. 27% of current cropland is in conservation tillage 27% (20% in minimum till and 7% in no-till)
2. Conservation tillage increases to 57% of all cropland (=> 60 million acres in conserv- tillage).
3. Conservation tillage increases to 76% of all cropland (=> 80 million acres in conserv- tillage).

Source: Kern and Johnson (1993)

Table IV.2: Relative Carbon Gain and Potential Policy Actions for Selected Management Practices

Management Practice	Relative Carbon Gain (per unit area)*	Possible Policy Actions**
Cultivated Land		
Adoption of reduced- or no-till	M	CS, E&TA, CC
Use of winter cover crops	L	CS, E&TA
Elimination of summer fallow	M	CS, E&TA
Use of forages in rotations	M	CS, E&TA
Use of improved varieties	M	CS, E&TA
Use of organic amendments	M	CS, E&TA
Irrigation	H	CS
Set-Aside Lands		
Establish perennial grasses	H	CS, LR,
Soil/water conservation measures	H	CS, E&TA, CC
Establish forest	H	CS, LR
Restore wetlands	H	CS
Pastureland		
Improved grazing methods	M	CS, E&TA
Fertilizer applications	M	CS, E&TA
Use of improved species/varieties	M	CS, E&TA
Irrigation	M	CS

Source: Except for restoring wetlands, assessments of relative carbon gain are from Bruce et al. (1998)

* H = high, M = medium, L = low

** CS = cost share (paying all or part of the costs of implementing the practice – cost could be defined to include lost income).

CC= conservation compliance (requires land owner to participate in a market transition, commodity support, or other government program with economic benefits). E&TA = education and technical support (requires that the practice be profitable). LR = land retirement (providing payments, usually annual, for land to be put into specific uses).

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Appendix 1: Impacts under Alternative Carbon Prices

Several studies reported in Chapter 2 conclude carbon prices will be greater than those predicted in the Administration's Economic Analysis (AEA, 1998). While these analyses are not consistent with the provisions of the protocol, these higher carbon prices have been used in the several analysis of the agricultural sector. For comparison, we provide multipliers for interested readers to compute the agricultural sector impacts for a range of carbon prices. Appendix tables A1.1 to A1.4 report multipliers which can be used to calculate the economic impacts for selected variables for every \$50.00 increase in the price of carbon.

Using the multipliers. For example, in table A1.3, Net Cash Returns for Crops and Livestock projected to be \$74,214.9 million in 2010. Using the multiplier, Net Cash Returns with a \$50 carbon permit price would be \$73,450.9 million (which is the base level \$74,214.9 million plus the multiplier, -\$763.3 million). Or, assuming a \$10 carbon permit price we can estimate that Net Cash Returns would decline by \$152.66 million to \$74,062.24 million ($\$74,214.9 - (\$10/\$50) * \763.3 million). Multipliers are presented for crop prices and production, crop domestic use and exports, income, total expenses, and welfare measures.

While the impacts on the sector increase as carbon prices increase, even with higher carbon prices, the impacts on the agricultural sector remain far below those predicted in recent studies such as Sparks (1999). This is because our analysis more accurately reflects the carbon content in farm production inputs and takes into consideration market adjustments.

Stavins estimates a marginal cost function for carbon sequestration through forestry that extends to 342 million acres of land sequestering 518 million tons (470 million metric tons) of carbon per year. Stavins' results at lower levels are similar to those of Parks and Hardie. But upon reaching 342 million acres of land, annual average costs are \$106 per acre and \$70 per ton (\$77 per metric

ton) of carbon, and marginal costs are \$200 per acre and \$136 per ton (\$150 per metric ton) of carbon. Stavins estimates that marginal costs are roughly linear until reaching about \$66 per ton (\$73 per metric ton) or \$100 per acre, after which marginal costs increase rapidly. Thus, Stavins provides demonstrates the need for caution in extrapolating costs from relative low levels of land conversions to higher levels.

Appendix 1, Table 1: 2010 key variables under Kyoto Protocol and multipliers for alternate carbon permit price

Item	Unit	2010 base level	\$23/ton permit price	change per \$50 permit price change ¹
Supply and Use Indicators				
Commodity Price			–dollars/unit–	
Corn	Bushel	3.20	3.22	0.04137
Sorghum	Bushel	3.00	3.02	0.04985
Barley	Bushel	2.85	2.88	0.04955
Oats	Bushel	1.90	1.91	0.02900
Wheat	Bushel	4.65	4.66	0.02717
Rice	Hundred-	12.87	12.98	0.23135
	weight			
Soybeans	Bushel	7.55	7.56	0.01361
Cotton	Bale	NA ²	NA	3.00029
Silage	Ton	21.66	21.67	0.01776
Hay	Ton	60.53	60.61	0.08300
Production			–million units–	
Corn	Bushel	11776.2	11756.5	-43.64565
Sorghum	Bushel	770	766.1	-8.46810
Barley	Bushel	450	447.3	-4.16688
Oats	Bushel	293.7	292.8	-2.28620
Wheat	Bushel	2828	2821.6	-17.17149
Rice	Hundred-	206.4	204.4	-4.14855
	weight			
Soybeans	Bushel	3144.2	3140.9	-7.24297
Cotton	Bale	21.3	21.2	-0.20408
Silage	Ton	95.6	95.4	-0.52743
Hay	Ton	155.6	154.9	-0.83345
Domestic Use			–million units–	
Corn	Bushel	1675.04	1674.32	-1.5148
Sorghum	Bushel	35.00	34.77	-0.4892
Barley	Bushel	172.00	171.50	-0.7778
Oats	Bushel	102.00	101.93	-0.1559
Wheat	Bushel	1146.00	1145.77	-0.6035
Rice	Hundred-	7.00	6.98	-0.0420
	weight			
Soybeans	Bushel	152.17	152.12	-0.10410

Item	Unit	2010 base level	\$23/ton permit price	change per \$50 permit price change ¹
Cotton	Bale	13.20	13.16	-0.1090
Silage	Ton	27.52	27.43	-0.2079
Hay	Ton	79.22	78.66	-0.59850
Exports				
Corn	Bushel	3250.56	3239.95	-22.2636
Sorghum	Bushel	335.01	331.94	-6.5183
Barley	Bushel	70.00	69.00	-1.5433
Oats	Bushel	2.00	1.99	-0.0240
Wheat	Bushel	1625.04	1619.25	-15.32570
Rice	Hundred-	85.40	83.65	-3.73210
	weight			
Soybeans	Bushel	1149.74	1148.99	-1.5206
Cotton	Bale	8.00	7.97	-0.0749
Silage	Ton	0.00	0.00	0.0000
Hay	Ton	0.00	0.00	0.0000
Income/expense Indicators				
--million dollars --				
-- Crops --				
Value of Production		100,530.10	134.90	276.93
Conservation Reserve		933.10	0.00	0.00
Payments				
Production Flexibility		4,009.70	0.00	0.00
Payments				
Total variable costs		55,037.70	448.40	940.42
Net cash returns		50,435.20	-313.50	-663.49
-- Livestock --				
Value of Production		117,329.30	314.70	657.34
Total variable costs		93,549.60	372.50	757.15
Net cash returns		23,779.70	-57.80	-99.81
-- Crops and Livestock --				
Value of Production		217,859.40	449.60	934.28
Total variable costs		148,587.30	820.90	1,697.57
Net cash returns		74,214.90	-371.40	-763.29
Welfare Measures				
Producer Surplus		1,096,957	1,096,540	-888.81
Net farm cash returns		74,215	73,844	-764.24
Consumer surplus		822,239	821,865	-798.90

Item	Unit	2010 base level	\$23/ton permit price	change per \$50 permit price change ¹
Consumer and producer surplus		1,919,196	1,918,405	-1690.10
Revenue transfers out of agriculture		442	3,082	1511.33
Net social benefit		1,919,196	1,919,129	-189.18
Net foreign surplus		54,409	54,281	-277.03

¹ Amount by which the selected variable changes for each \$50 change in carbon permit price.

² USDA is prohibited from publishing cotton price projections.

Appendix 2. Energy Use in Agriculture

Agricultural energy uses comprise on-farm direct uses of fuels and electricity to operate vehicles, machinery, irrigation, and drying systems; indirect uses of energy in manufactured fertilizers and pesticides; and uses of energy in hired or purchased services. Energy is included in smaller proportion in other expenses including commodity transportation, hired custom and machine work, and purchased feed. Agricultural fossil fuel use peaked in 1978, declining in response to the oil price shocks of the 1970s and early 1980s (TableA.1). By 1993, fossil energy use declined by 25 percent, but electricity use increased by about 17 percent (ERS, 1997).

Major factors in agricultural use of refined petroleum products and electricity use are planted acreage and irrigated acreage (ERS, 1997; and Uri and Gill;). Irrigated land in farms increased from 46.4 to 53.3 million acres between 1987 and 1996 (TableA.2). Planted acres in 1990-96 averaged 337 million acres with a low of 330 million acres in 1993 and a high of 346 million acres in 1996. More energy efficient diesel machinery and reduced tillage systems have allowed diesel use to be maintained at about 1978 levels while reducing gasoline use by over half. Estimated electricity use increases are consistent with increased irrigated acres. Uses of nitrogen fertilizer, the most energy intensive nutrient, increased by about 10 percent, phosphorous declined by a similar amount. Potash and pesticide use levels show little change until 1994, with pesticides increasing by 14 percent in one year.

U.S. Farm Sector Income and Energy Expenses. U.S. agriculture commodity cash receipts are about \$203 billion (1996 through the 1998¹), about 53 percent from crops and 47

¹Values for 1998 are USDA-ERS forecasts.

from livestock (Table A.3). The crop proportion is slightly higher than the 51 percent share from 1989 through 1998. Energy related expenses are about \$40-41 billion per year (1996 through 1998). The energy-related share of the U.S. farm sector cash expenses averaged about 24 percent from 1989 through 1998, showing a slight increase since 1994. This increase is consistent with the increases in planted and irrigated crop land.

Manufactured inputs include fuels, oils, and fertilizers and other agricultural chemicals. Annual manufactured input expenses are around \$29 billion (1996 through 1998). Manufactured inputs accounted for about 17 percent of U.S. farm cash expenses from 1989 through 1998, and with a slight increase since 1994. This increase is driven by rising expenditures for fertilizer and pesticides. The direct energy share of cash expenses has declined slightly since 1994 to about 5.5 percent. Expenditures for other energy intensive inputs have averaged about \$12 billion per year since 1994. This category includes "machine hire and custom operations" and "marketing, storage, and transportation."

Adjustments can be expected in input usage with long-run shifts in relative prices and changes in technology. Machine hire and custom work can substitute for farm owned and operated machinery and its attendant direct energy expenditures. Past and future shifts in custom expenditures could be associated with greater efficiency in the use of machinery, labor, and energy. The shift to reduced tillage has reduced direct energy expenditures and increased pesticide expenditures. The extent of irrigated acres and quantity of irrigation water applied is related to costs of pumping and the returns to irrigation, and over time efficiency gains have occurred with irrigation (ERS, 1997).

Crop Enterprises. Expenditures for direct energy, chemicals, and on other energy intensive inputs range between about 30 and 75 percent of total crop cash expenses (Table A.4).

As a share of total cash expenditures, this sum is quite stable across each crop's reporting regions. Of three input groups, chemical expenditures show the least variation in expenditure shares, followed by direct energy. Corn and wheat are cases in point, with significant variation in direct energy and chemical expenditures, but with little variation in the energy-intensive share of total expenditures.

Irrigation accounts for higher magnitude expenses and revenues for Plains States corn and Pacific wheat, but the energy share of total cash expenses is similar to other regions. Revenues can be affected by both yields and regional price variation. The regional variation in direct energy and chemical expenditures and shares of total cash expenses reflect the differences in production techniques and possibilities across the country. Further, the data presented are regional averages--considerable variation would be expected within regions, driven by land quality, farm type, land tenure and other factors. The regional stability of the share of direct, chemical, and other energy including expenses of total cash expenses for each crop, is hypothesized to reflect competitive profit maximizing relationships among commodity and input prices and land productivity.

The complexity and the difficulty in using cost of production budgets and returns alone to predict the effects of energy price increases on regional crop production is illustrated by corn, wheat, and soybean production in the Southeast. The high Southeastern expenditures on fertilizer and pesticides are offset by yields or prices, to generate average or higher ratios of expenses to revenues for wheat and corn. While the ratio is higher than average for soybeans (at least for 1996), Southeast soybeans are often double cropped with wheat in rotation with corn. Further, the livestock industry in the Southeast and the eastern ports contribute to higher grain prices than in the Midwest markets. Thus it is not at all clear from budgets alone what the effects

of higher energy costs will be on regional production patterns.

Livestock Enterprises. Energy related expenses as a share of total cash expenses range between about 6 and 33 percent for livestock and poultry (Tables A.5). Energy related expenses include expenditures on fuel, lubrication, and electricity; marketing and hauling; and custom services and supplies. Feed expenditures, broken out separately in ERS cost of production tables, range from 50 to 75 percent of total cash expenses. Broiler farms stand out with energy expenses ranging from 28 to 33 percent of total cash expenses, attributed to heating and cooling requirements for broiler houses. The energy share of hog expenses is 6 percent, but the animal feed expenses are 73 percent of cash expenses. Hog feed is primarily composed of feed grains and soybeans, among the highest in energy expenses.

Dairy, with cooling and milking equipment power requirements, follows with energy shares averaging about 15 percent of total cash expenses. Northeast and Southeast energy shares stand out at 19 percent, resulting from higher marketing and hauling expenses. Feed expenses as a percent total cash expenses increase with reliance on feeding grains and concentrates as opposed to forage, with the upper Midwest and Pacific regions below average. The Pacific region stands out as well with lower direct energy expenditures, consistent with its lower feed expenditures.

Cow-calf regional feed expenditure differences are mainly due to harvested forage and pasture expenses, which in turn are related to direct energy, chemical and irrigation expenses. Somewhat offsetting the South's lower feed expenditures is a higher marketing and hauling expenditure. Similarly, lower direct energy expenses in the West are more than offset by higher feed expenses. Noting the losses per bred cow in 1996 and the cyclical nature of the cattle industry, the beef industry faces longer term competitive problems with respect to pork and

broilers as background for any potential energy increases (ERS, 1998).

Appendix 3, Table 1: Use of Energy Inputs in U.S. Agriculture; 1978 and 1990-94.

Year	Gasoline billion gallons	Diesel billion gallons	LP gas billion kWh	Electricity billion kWh	Nitrogen	Phosphate million pounds	Potash	Pesticide
1978*	3.6	3.2	1.3	47.6	10	5.1	5.5	0.29
1990	1.5	2.7	0.6	48.9	11.1	4.3	5.2	0.27
1991	1.4	2.8	0.6	47.9	11.3	4.2	5	0.27
1992	1.6	3.1	0.9	54.6	11.5	4.2	5	0.29
1993	1.4	3.3	0.7	55.6	11.4	4.4	5.1	0.28
1994	1.4	3.5	0.9	56.2	12.6	4.5	5.3	0.32

* 1976 pesticide value; 1980 electricity value.

Sources:

Electricity: estimated from farm expenditures data in USDA, ERS (1997; table 3.3.3, p.138) and electricity price data for industrial users in USDOE, EIA (1996; table 8.11, p. 247).

All other inputs see USDA, ERS (1997, table 3.1.1, p. 100; table 3.2.2, p.119; and table 3.3.1, p. 136).

Appendix 3, Table 2: Factors in U.S. farm demand for refined fuel, electricity, fertilizer, and pesticides

Item	1978	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
Cropland							million acres				
Cropland used for crops \1	na	331	327	341	341	337	337	330	339	332	346
Irrigated cropland \2	50.3	46.4	na	na	na	na	49.4	49.8	51.8	52	53.3
Farm Fuel Prices, U.S. Ave. \3							dollars per gallon				
Gasoline	0.6	0.92	0.93	1.05	1.17	1.19	1.15	1.14	1.08	1.11	1.26
Diesel	0.46	0.71	0.73	0.76	0.95	0.87	0.82	0.82	0.77	0.77	0.92
LP gas	0.4	0.59	0.59	0.58	0.83	0.75	0.72	0.78	0.72	0.73	0.8
Electricity (Retail industrial rate) \4							cents per Kwh.				
	2.8	4.8	4.7	4.7	4.7	4.8	4.8	4.8	4.8	4.7	4.6
Fertilizer \5							dollars per ton				
Anhydrous ammonia (82%)	177	187	208	224	199	210	208	213	243	330	303
N solutions (30%)	118	109	137	142	132	138	141	137	137	169	182
Urea (45-46%)	169	161	183	212	184	212	198	202	207	266	278
Ammonium Nitrate (33%)	140	157	166	189	180	184	178	186	196	223	233
Ammonium Sulfate (21%)	109	144	140	154	154	151	151	157	170	182	184
Superphosphate (44-46%)	151	194	222	229	201	217	206	190	212	234	258
Potassium chloride (60% pot.)	96	115	157	163	155	156	150	146	146	155	153
Chemicals \6							index (1990-92 = 100)				
Chemicals price indices						101	103	107	112	115	
Herbicides						101	102	106	110	113	
Insecticides						101	104	110	117	120	
Fungicides and others						101	105	111	109	117	

\1 USDA-ERS Ag. Resources and Environmental Indicators, 1996-97, Ag. HB 712 - Table 1.1.5 Major uses of cropland, U.S. 1986-96 , p6.; and Cropland Use in 1997, AREI update No. 5 Aug. 1997, Table 1.

\2 USDA-ERS Ag. Resources and Environmental Indicators, 1996-97, Ag. HB 712 -Table 2.1.3 Irrigated land in farms, by region and crop, selected years 1969-96, p.74.

\3 USDA-ERS Ag. Resources and Environmental Indicators, 1996-97, Ag. HB 712 - p. 137, Table 3.3.2 - Avg. U.S. farm fuel prices, 1974-95.

\4 Energy Info. Admn. Annual Energy Review - Table 8.11 Retail prices of Electricity Sold by Electricity Utilities, 1960-1996, p. 247.

\5 USDA-ERS Ag. Resources and Environmental Indicators, 1996-97, Ag. HB 712 - p.109,Table 3.1.8 - Average U.S. farm prices of selected fertilizers, 1960-96.

\6 USDA-ERS Ag. Resources and Environmental Indicators, 1996-97, Ag. HB 712 - p. 127, Table 3.2.6 Selected April pesticide prices, 1991- 1995.

Appendix 3, Table 3: Income statement and energy-related expenses for U.S. farm sector 1989-1998

Item	Unit	1989	1990	1991	1992	1993	1994	1995	1996	1997P	1998F	Ave.	St. Dev.
Cash income statement:													
1. Cash receipts	\$ Bil.	160.8	169.5	167.9	171.3	177.7	181.2	188.1	199.6	208.3	200.6	182.5	16.1
Crops 1/	\$ Bil.	76.9	80.3	82.1	85.7	87.5	93.1	101.0	106.6	111.7	105.8	93.1	12.4
Livestock	\$ Bil.	83.9	89.2	85.8	85.6	90.2	88.2	87.0	93.0	96.6	94.8	89.4	4.2
Livestock share	Pct.	52.2	52.6	51.1	50.0	50.8	48.6	46.3	46.6	46.4	47.3	49.2	2.5
2. Direct Government payments	\$ Bil.	10.9	9.3	8.2	9.2	13.4	7.9	7.3	7.3	7.5	7.4	8.8	2.0
3. Farm-related income 2/	\$ Bil.	8.6	8.2	8.2	8.2	9.0	9.2	10.1	10.9	11.8	11.5	9.6	1.4
4. Gross cash income (1+2+3)	\$ Bil.	180.3	187.0	184.3	188.7	200.1	198.3	205.4	217.8	227.6	219.5	200.9	16.4
Cash expenses 3/	\$ Bil.	127.5	134.2	134.0	133.6	141.2	147.6	153.6	161.4	166.9	166.2	146.6	14.7
Net cash income	\$ Bil.	52.8	52.8	50.3	55.1	58.9	50.7	51.8	56.4	60.7	53.4	54.3	3.5
Farm income statement:													
Total gross income 4/	\$ Bil.	192.0	198.2	191.9	200.5	203.7	215.8	210.1	235.8	237.9	230.0	211.6	17.6
Total expenses	\$ Bil.	146.7	153.4	153.3	152.9	160.5	167.4	174.0	182.3	188.0	187.4	166.6	15.5
Net farm income	\$ Bil.	45.3	44.8	38.6	47.6	43.2	48.3	36.1	53.5	49.9	42.5	45.0	5.2
Energy-related Expenses													
<u>Manufactured inputs</u>													
Fuels and oils	\$ Bil.	4.8	5.8	5.6	5.3	5.4	5.3	5.4	6.0	6.2	6.2	5.6	0.4
Electricity	\$ Bil.	2.6	2.6	2.6	2.6	2.7	2.7	3.0	3.2	3.0	2.9	2.8	0.2
Direct Energy Expenses	\$ Bil.	7.4	8.4	8.2	7.9	8.1	8.0	8.4	9.2	9.2	9.1	8.4	0.6
Share of Cash Expenses	Pct.	5.8	6.3	6.1	5.9	5.7	5.4	5.5	5.7	5.5	5.5	5.7	0.3
Share of Total Expenses	Pct.	5.0	5.5	5.3	5.2	5.0	4.8	4.8	5.0	4.9	4.9	5.0	0.2
Fertilizer & lime	\$ Bil.	8.2	8.2	8.7	8.3	8.4	9.2	10.0	10.9	10.9	11.0	9.4	1.2
Pesticides	\$ Bil.	5.0	5.4	6.3	6.5	6.7	7.2	7.7	8.5	8.8	8.8	7.1	1.4
Chemical Expenses	\$ Bil.	13.2	13.6	15.0	14.8	15.1	16.4	17.7	19.4	19.7	19.8	16.5	2.5
Share of Cash Expenses	Pct.	10.4	10.1	11.2	11.1	10.7	11.1	11.5	12.0	11.8	11.9	11.2	0.6
Share of Total Expenses	Pct.	9.0	8.9	9.8	9.7	9.4	9.8	10.2	10.6	10.5	10.6	9.8	0.6
Total Manufactured Inputs	\$ Bil.	20.6	22.0	23.2	22.7	23.1	24.4	26.2	28.7	29.0	28.9	24.9	3.1
Share of Cash Expenses	Pct.	16.2	16.4	17.3	17.0	16.4	16.5	17.1	17.8	17.4	17.4	16.9	0.5
Share of Total Expenses	Pct.	14.0	14.3	15.1	14.8	14.4	14.6	15.1	15.7	15.4	15.4	14.9	0.6
<u>Other expenses</u>													
Machine hire & custom work	\$ Bil.	3.4	3.6	3.5	3.8	4.4	4.8	4.8	4.7	4.9	4.9	4.3	0.6
Marketing, storage, & transport.	\$ Bil.	4.2	4.2	4.7	4.5	5.6	6.8	7.2	6.8	7.0	7.1	5.8	1.3
Total Other expenses	\$ Bil.	7.6	7.8	8.2	8.3	10.0	11.6	12.0	11.5	11.9	12.0	10.1	1.9
Share of Cash Expenses	Pct.	6.0	5.8	6.1	6.2	7.1	7.9	7.8	7.1	7.1	7.2	6.8	0.8
Share of Total Expenses	Pct.	5.2	5.1	5.3	5.4	6.2	6.9	6.9	6.3	6.3	6.4	6.0	0.7
<u>Total Energy Related Expenses</u>		28.2	29.8	31.4	31.0	33.2	36.0	38.1	40.1	40.8	40.9	35.0	4.8
Share of Cash Expenses	Pct.	22.1	22.2	23.4	23.2	23.5	24.4	24.8	24.9	24.5	24.6	23.8	1.0
Share of Total Expenses	Pct.	19.2	19.4	20.5	20.3	20.7	21.5	21.9	22.0	21.7	21.8	20.9	1.0

P = preliminary. F = forecast.

1/ Includes commodities placed under CCC loans and profits made on loans redeemed.

2/ Income from custom work, machine hire, recreational activities, forest product sales, and other farm sources

3/ Cash expenses exclude capital consumption, perquisites to hired labor, and farm household expenses from total expenses.

4/ Total gross income includes gross cash income, nonmoney income, and value of inventory change.

Source: Adapted from Tables 29 and 34 Agricultural Outlook USDA-ERS March 1998 for 1989-1993, and ERS website July 1998 update for 1994-1998.

Appendix 3, Table 4: Cash Expenses that Include Energy for U.S. Field and Horticultural Crops, 1996

Commodity	Region	Direct Energy		Chemicals		Other Inputs ^{V2}		Dir., Chem., Oth.		T. Cash	Revenue	Expense
		\$/plt.ac.	Percent of total	\$/plt.ac.	Percent of total	\$/plt.ac.	Percent of total	\$/plt.ac.	Percent of total	\$/plt.ac.	Expns. ^{V1} \$/plt.ac.	/Revenue Percent
Corn	United States	21.14	12.9	82.95	50.7	9.76	6.0	113.85	69.5	163.77	388.73	42.1
	Northeast	13.07	8.9	75.34	51.2	9.03	6.1	97.44	66.2	147.27	252.73	58.3
	Southeast	15.38	8.7	97.86	55.6	4.23	2.4	117.47	66.7	176.07	385.29	45.7
	North Central	13.98	9.2	83.15	54.4	9.1	6.0	106.23	69.5	152.74	370.55	41.2
	Plains States	42.67	22.1	80.53	41.6	12.67	6.6	135.87	70.3	193.4	453.78	42.6
Wheat	United States	9.71	13.9	27.34	39.1	5.35	7.6	42.40	60.6	70.01	146.94	47.6
	North Central	5.77	6.8	46.26	54.5	4.04	4.8	56.07	66.0	84.95	141.90	59.9
	Southeast	6.51	6.9	45.63	48.6	7.35	7.8	59.49	63.3	93.97	219.66	42.8
	Northern Plains	7.12	12.0	23.9	40.4	2.72	4.6	33.74	57.0	59.18	143.56	41.2
	Cen. & So. Plains	10.95	17.5	19.78	31.6	7.79	12.4	38.52	61.5	62.59	105.09	59.6
	Pacific	22.34	17.0	50.74	38.7	7.9	6.0	80.98	61.7	131.25	332.18	39.5
Soybeans	United States	9.45	11.8	35.4	44.3	3.65	4.6	48.50	60.6	80	256.36	31.2
	North Central	8.22	10.5	35.88	45.7	4.04	5.1	48.14	61.3	78.54	265.55	29.6
	Northern Plains	12.51	18.2	23.61	34.3	2.41	3.5	38.53	55.9	68.87	254.69	27.0
	Southeast	10.55	10.7	50.35	50.9	2.38	2.4	63.28	64.0	98.88	214.76	46.0
	Delta	14.06	16.3	30.49	35.3	3.88	4.5	48.43	56.1	86.37	232.47	37.2
Cotton	United States	35.67	11.9	97.51	32.6	71.76	24.0	204.94	68.6	298.78	383.84	77.8
	Southeast	24.76	8.0	138.97	45.1	74.86	24.3	238.59	77.4	308.16	536.61	57.4
	Delta	30.17	8.2	145.47	39.6	88.15	24.0	263.79	71.8	367.16	566.19	64.8
	Southern Plains	39.33	18.4	50.1	23.4	41.12	19.2	130.55	61.0	214.04	189.19	113.1
	Southwest	48.98	8.3	139.38	23.5	168.42	28.4	356.78	60.1	593.2	634.70	93.5
Rice	United States	73.03	19.7	123.96	33.4	75.71	20.4	272.70	73.4	371.61	592.70	62.7
	Ark. Non-Delta	77.04	22.8	116.83	34.6	61.72	18.3	255.59	75.7	337.58	630.01	53.6
	Miss. River Delta	77.36	24.3	116.44	36.6	46.97	14.8	240.77	75.7	318.2	588.32	54.1
	Gulf Coast	69.03	18.7	120.87	32.7	70.39	19.0	260.29	70.4	369.79	543.08	68.1
	California	65.96	13.1	150.81	30.0	144.81	28.8	361.58	71.8	503.27	744.96	67.6
Sorghum	United States	17.95	21.9	30.27	37.0	5.26	6.4	53.48	65.3	81.85	170.91	47.9
	Central Plains	12.31	16.3	32.72	43.2	4.69	6.2	49.72	65.7	75.72	193.37	39.2
	Southern Plains	25.24	28.1	27.11	30.2	5.99	6.7	58.34	65.0	89.76	141.80	63.3
Oats	United States	7.41	14.2	18.87	36.2	4.33	8.3	30.61	58.7	52.17	128.26	40.7
	Northeast	12.38	15.1	33.26	40.7	4.91	6.0	50.55	61.8	81.77	125.37	65.2
	North Central	4.19	8.2	21.38	42.0	5.75	11.3	31.32	61.6	50.85	119.06	42.7
	Northern Plains	9.78	22.2	12.55	28.5	2.42	5.5	24.75	56.2	44.06	115.37	38.2
Peanuts	United States	40.31	11.6	143.83	41.6	25.73	7.4	209.87	60.6	346.1	635.14	54.2
	VA - NC	40.05	9.8	195.14	47.8	10	2.4	245.19	60.0	408.38	832.06	49.1
	Southeast	29.7	8.2	170.14	47.0	27.13	7.5	226.97	62.6	362.3	680.56	53.2
	Southern Plains	61.09	21.7	64.93	23.1	31.5	11.2	157.52	56.1	280.97	481.58	58.2
Sugar Beets	United States	41.64	9.6	144.8	33.3	42.15	9.7	228.59	52.5	435.18	746.61	58.2
	Great Lakes	22.77	7.7	131.49	44.2	28.35	9.5	182.61	61.4	297.2	439.68	67.0
	Red River Valley	21.87	6.7	112.8	34.7	24.88	7.6	159.55	49.0	325.43	698.52	46.0
	Great Plains	53.53	11.1	167.75	34.8	38.86	8.1	260.14	54.0	481.49	692.29	69.0
	Northwest	95.71	14.0	208.57	30.4	49.18	7.2	353.46	51.6	685.53	1017.37	67.4
	Southwest	65.27	8.1	197.3	24.4	195.95	24.3	458.52	56.8	807.69	1246.62	64.1
Sugarcane	United States	29.80	4.3	135.26	19.6	70.30	10.2	235.36	34.1	690.16	979.40	70.2
	Florida	23.79	3.1	119.15	15.7	104.81	13.8	247.74	32.6	760.95	1040.40	73.2
	Hawaii	93.51	3.7	450.15	17.8	62.57	2.5	606.23	24.0	2526.63	2645.37	95.2
	La/Texas	29.73	7.2	119.48	29.1	31.89	7.8	181.09	44.1	410.67	727.00	56.2
		\$ mil.	percent	\$ mil.	percent	\$ mil.	percent	percent	percent	\$ mil.	\$ mil.	percent
Horticultural	United States	2386	9.8	2275	9.4	2874	11.8	7535.31	31.0	24308	38497	63.2

^{V1} Total cash expenses for commodities include cash expenses as reported in ERS Cost of Production tables.

^{V2} Other expenses that embody energy include custom costs for all commodities, cotton ginning, rice and peanut drying, and marketing, storage, and transport costs for horticultural products.

^{V3} Expenses including energy as a proportion of cash expenses.

^{V4} Revenue per acre is yield times price. Revenue for horticultural farms is gross cash income, of which \$38540.9 mil. (95 percent) is generated by vegetable, fruit, greenhouse, and nursery sales.

Sources: USDA-ERS webpage, <http://www.econ.ag.gov/briefing/fbe/car/car.htm>, and USDA-ERS-RED-FSP.

Appendix 3, Table 5: Cash Expenses that Include Energy for U.S. Livestock Enterprises (1996) and Broiler Farms (1995)

Enterprise	Region	Fuel, Lub., & Elec. Expense Share of Total		Marketing & Hauling Expense Share of Total		Custom Serv. & Sup. Expense Share of Total		Energy ^{\2} Share of Total	Animal Feed Expense Share of Total		Total Cash Expenses	Revenue
		\$ per cwt. milk	percent	\$ per cwt. milk	percent	\$ per cwt. milk	percent	percent	\$ per cwt. milk	percent	\$ per cwt. milk	\$ per cwt. milk
Dairy	United States	0.53	4.6	0.80	7.0	0.42	3.7	15.2	7.53	65.5	11.49	14.78
	Northeast	0.7	5.6	1.13	9.0	0.54	4.3	18.9	7.46	59.6	12.51	15.19
	Southeast	0.34	2.6	1.49	11.2	0.65	4.9	18.7	8.12	61.2	13.27	17.41
	Upper Midwest	0.62	5.5	0.50	4.5	0.34	3.0	13.0	7.17	64.1	11.19	14.74
	Corn Belt	0.58	4.7	0.74	5.9	0.38	3.0	13.6	8.35	67.0	12.47	14.88
	Southern Plains	0.49	4.0	0.85	6.9	0.31	2.5	13.4	9.09	74.1	12.27	15.10
	Pacific	0.28	2.8	0.83	8.2	0.40	4.0	15.0	7.25	71.9	10.08	13.89
		\$ per bred cow	percent	\$ per bred cow	percent	\$ per bred cow	percent	percent	\$ per bred cow	percent	\$ per bred cow	\$ per bred cow
Cow-calf	United States	23	6.7	8.34	2.4	0.00	0.0	9.2	212.17	62.2	341.28	287.42
	North Central	28.2	10.0	5.28	1.9	0.00	0.0	11.9	157.99	56.1	281.41	281.43
	South	22.76	8.2	10.97	4.0	0.00	0.0	12.2	140.66	50.9	276.23	216.17
	Great Plains	24.95	6.8	7.45	2.0	0.00	0.0	8.9	232.23	63.6	365.30	319.70
	West	17.54	4.5	8.93	2.3	0.00	0.0	6.9	266.69	69.1	386.12	298.98
		\$ per cwt. gain	percent	\$ per cwt. gain	percent	\$ per cwt. gain	percent	percent	\$ per cwt. gain	percent	\$ per cwt. gain	\$ per cwt. gain
Hogs	United States	1.83	3.8	0.59	1.2	0.51	1.1	6.1	35.48	74.1	47.86	60.16
	North	1.84	3.8	0.56	1.2	0.47	1.0	6.0	35.62	74.3	47.97	59.58
	South	1.78	3.7	0.70	1.5	0.64	1.3	6.6	34.98	73.6	47.50	62.12
		\$ per farm ^{\4}	percent	\$ per farm ^{\5}	percent	\$ per farm	percent	percent	\$ per farm ^{\6}	percent	\$ per farm	\$ per farm
Broiler Farms ^{\3}	Appalachia	9871	22.3	na	na	1450	3.3	25.6	na	na	44225	78543
	Southeast	17731	28.1	na	na	3213	5.1	33.2	na	na	63055	93076
	Delta	11024	26.0	na	na	2694	6.4	32.4	na	na	42325	77041
	Other regions	8515	13.5	na	na	917	1.5	15.0	na	na	63027	95165
	United States, with gross cash income ≥ \$50,000	12529	23.4	na	na	2713	5.1	28.5	na	na	53446	84048

^{\1} Total cash expenses for enterprises include cash expenses as reported in ERS Cost of Production tables for 1996.

^{\2} Energy-related expenses as a proportion of cash expenses.

^{\3} Broiler farm revenues are 1995 gross cash income, including other livestock and crop-related income.

Broilers comprise 74 percent of Appalachia gross cash income, 76 percent of Southeast, 89 percent of Delta, and 77 percent of U.S. farms with income over \$50,000.

^{\4} Broiler farm fuel, lub, and electricity includes telephone expenses.

^{\5} Marketing and hauling is included as "Other variable expenses", defined as "Supply, transportation, storage, and general business expenses, and registration fees."

For the U.S. farms, "Other variable cost" is \$2483 about 20 percent of fuel, lube, and electricity.

^{\6} Sufficient detail not available for feed cost presentation.

Sources: USDA-ERS webpage, <http://www.econ.ag.gov/briefing/fbe/car/car.htm>, and Perry, Janet, David Banker, Robert Green, Broiler Farms': Organization, Management, and Performance, AIB 748, USDA, ERS, March, 1999, Table 10.

Appendix 3. USMP Regional Agricultural Model

The U.S. Regional Agricultural Sector Model (USMP) is designed for general purpose economic, environmental, and policy analysis of the U.S. agriculture sector². USMP is linked with regularly-updated USDA production practices surveys, the USDA multi-year baseline (USDA, WAOB, 1997), and geographic information system (GIS) databases such as the National Resources Inventory (USDA, NRCS). USMP predicts how changes in farm, resource, environmental, or trade policy, commodity demand or technology will affect regional supply of crops and livestock, commodity prices and demand, use of production inputs, farm income, government expenditures, participation in farm programs, and environmental indicators (such as erosion, nutrient and pesticide loadings, greenhouse gases and others). An agriculture sector spatial equilibrium model (as described in McCarl and Spreen), USMP incorporates agricultural commodity supply, use, and policy measures (House), as well as natural resource and environmental impacts derived through biophysical models (Faeth).

Baseline validation; demand and supply response. USMP does not make dated forecasts or projections. Instead, acreage, supply/use, prices, production practices, environmental loadings and so forth are validated exactly to any USDA baseline year or recent historical year (e.g. between 1988 and 2005) and corresponding geographic information. For example, for scenario analysis with a 2001 base year, USMP's base U.S. corn acreage planted equals the USDA

² USMP is designed and maintained by Robert House, Mark Peters, and Howard McDowell of the USDA/Economic Research Service/Resource Economics Division. USMP is modeled in the General Algebraic Modeling Language (GAMS) as a nonlinear programming problem with solutions obtained using the MINOS nonlinear optimizer solver. USMP consists of some 2000 equations (of which 550 are nonlinear) and 5400 variables (900 nonlinear). Links with geographic information system (GIS) databases on the input data and output results sides of USMP further disaggregate the economic and environmental impact analyses supported by USMP.

baseline's 2001 projection (80.5 million acres), and corn acreage in each model region/practice strata is determined by share information from NRI and USDA Cropping Practices Survey (CPS) regional data. From there, comparative static adjustments to the scenario "shock" (e.g. a policy change) explain how the sector changes (through both aggregate indicators such as U.S. farm income and detailed indicators such as acreage in corn-bean rotation using mulch tillage in the central Corn Belt) between the base period and several years later when the change has worked itself out and the sector returns to equilibrium. USMP acreage planted/commodity supply response uses a positive mathematical programming (PMP) formulation (Howitt) with U.S. aggregate commodity supply response calibrated to supply response elasticities from the FAPSIM econometric simulation model (Green and Price)³. Responses in individual region, tillage practice, rotation and other strata follow nested adjustment functions which are part of the PMP calibration, and sum up to aggregate response. No bounds or flexibility constraints are used.

Commodity coverage. USMP models production of 10 crops: corn, sorghum, oats, barley, wheat, rice, cotton, soybeans, hay and silage. Fruits and vegetables are not modeled in USMP. Some 16 primary livestock production enterprises are included, the principal being dairy, swine, beef cattle, and poultry. USMP commodity coverage comprises about 75 percent of the value of U.S. agricultural production, about 55 percent of the value of crop production, and about 95 percent of the value of livestock and poultry production (USDA, ERS, 1999). Several dozen processed and retail products are included in the model structure, the principal being dairy

³The Food and Agricultural Policy Simulator (FAPSIM) is an annual econometric model of the U.S. farm sector, designed and maintained by J. Michael Price of the USDA's Economic Research Service.

products, pork, fed and nonfed beef, poultry, soy meal and oil, livestock feeds, and corn milling products. Additionally, the model incorporates domestic use, imports, exports, and inventory/stock product markets. USMP includes government conservation, acreage, price, and income programs. Production, consumption (demand), trade, and price levels for crop and livestock commodities and most processed or retail products are endogenously determined within the model structure with domestic consumption, commercial stock, export and other demand elasticities from the FAPSIM model.

Integrated economic and resource/environmental analysis. USMP's crop production enterprises include both economic items (e.g. yield, nitrogen cost, etc.) and environmental indicator coefficients corresponding to the specific rotation and tillage practices (e.g. soil erosion, nitrogen leaching, etc.). Economic coefficients in the enterprise budgets were developed from USDA data including the National Resources Inventory, Cropping Practices Survey (USDA, ERS, 1992), the Farm Costs and Returns Survey (FCRS) and the Agricultural Resources Management Survey (ARMS) (USDA, ERS), and calculations (of e.g. machinery costs) standard to crop budget generators. Most environmental measures were estimated using the USDA Erosion/Productivity Impact Calculator (EPIC) model (Williams *et al.*) For each "baseline" solution or alternative scenario, the model tallies associated levels of selected agricultural environmental indicators and acreage under various rotation/tillage practices. Impacts are determined within USMP for the national level, 10 farm production regions, and 45 land resource regions. Environmental impacts, using Geographic Information System databases such as the National Resources Inventory, are further disaggregated depending on the analysis.

USMP has been applied to project the effects on U.S. national and regional agriculture of changes in export levels and variability (Miller *et al.*), trade agreements (Burfisher *et al.*),

imports (Spinelli *et al.*), input taxes (Peters *et al.*), irrigation policy (Horner *et al.*), ethanol production (House *et al.*), wetlands policy (Heimlich *et al.* 1997a), and various other policy and program scenarios.

Crop System Biophysical Calibration. Crop system calibration is performed to ensure that the EPIC simulations of each crop system in the model correctly represent yield and other characteristics. Representative soil type and weather conditions are inputs to the biophysical model, as are the crop(s) grown, multi-year rotation of crops, and cultural practices of production. A representative soil was selected for each region from the NRI and Soils5 databases using a multidimensional similarity measure to regional average Universal Soil Loss Equation variables capturing slope, hydrological, and erodability characteristics. Representative weather conditions are specified as distributional information on temperature, rainfall, and other variables (NOAA). County yield data for the 10 crops are aggregated into the 45 regions to estimate average crop yields (USDA, NASS).

Each crop system is specified as a sequence of crops with dated field operations including cultivation, planting, harvesting, and application of specific fertilizer formulas and pesticides. Biological parameters in the biophysical are validated in each production region to ensure calibration of the model's simulated yield to regional yield statistics and to ensure the yield-nitrogen response is consistent with observed nitrogen application rates and rational use of nitrogen. The 60-year average results of the calibrated EPIC simulations are entered as environmental coefficients for the crop system in the USMP system budget.

Talking Points on EIA's Analysis of Implementation of the Kyoto Protocol

September 1998

The EIA Analysis Fails to Model the Kyoto Protocol's Flexibility

- ***The EIA analysis fails to model international trading.*** EIA's model is not capable of modeling international emissions trading, even though this is a critical feature in reducing the cost of compliance for the United States and other countries. By contrast, the Administration explicitly modeled international trading, as has every modeling team participating in the exercise assessing Kyoto conducted under Stanford's Energy Modeling Forum -- which includes virtually all of the leading energy economic modelers in the world. These models have demonstrated that international trading among industrialized countries could lower costs of emissions reductions by as much as half.

EIA does attempt to include scenarios which assume an amount of domestic reductions intended to mirror the level of domestic reductions implied in the model used by the Administration. However, these EIA scenarios still overstate the cost of permits because they fail to take into account the way that an international market, bidding to a single international permit price, lowers cost.

- ***The EIA analysis fails to account for all six types of greenhouse gases.*** The EIA study assumes that the United States would achieve its target only through carbon dioxide reductions. In fact, the Kyoto Protocol covers all six major greenhouse gases, and permits countries to achieve their targets through reductions made in any of these gases. This flexibility allows countries and companies to make reductions in the most cost-effective manner possible, reducing the cost of compliance.

EIA Assumes Firms Take Little or No Action to Address Climate Change before 2005

- ***EIA assumes most firms do not anticipate climate change policies.*** In EIA's study, most businesses do not take action to address climate change until 2005, and therefore only have a short time until the 2008-2012 budget window to reduce emissions. Studies have demonstrated that the amount of lead time a company takes has dramatic economic implications. For example with EIA's model, a 5-year "ramp-up" (starting in 2005) would result in economic costs 65% greater than that associated with a 10-year "ramp-up" (starting in 2000). Thus, EIA's assumption that many businesses would fail to plan for the future results in higher projected costs.

- Already businesses are taking action to address climate change. For example, on September 18, British Petroleum announced its plan to reduce emissions of greenhouse gases worldwide by 10% below 1990 levels by the year 2010. In July, United Technologies announced their plan to reduce its worldwide energy consumption by 25% by the year 2007.

The EIA Analysis Does Not Include Policy Elements That Will Lower Costs

- In the Administration's analysis, additional elements of policy were recognized as having the potential to significantly decrease the costs of compliance and increase the amount of reductions that might be accomplished at home. These policies were not factored into the illustrative model the Administration cited, but were qualitatively taken into account in reaching the conclusion that the United States could meet its Kyoto target for a relatively modest cost. The EIA analysis, however, ignores elements such as forestry activities (covered under the Kyoto Protocol) and the Administration's electricity restructuring proposal, which could significantly lower compliance costs.



EXECUTIVE OFFICE OF THE PRESIDENT
COUNCIL OF ECONOMIC ADVISERS
WASHINGTON, D.C. 20500

CHIEF OF STAFF

September 15, 1998

Dear Senator Hagel:

I am writing to provide information that is responsive to a question in your September 9 letter to Under Secretary of State Eizenstat regarding the economic assumptions the Administration used during the Kyoto Protocol negotiations. Because you have asked specific and technical questions about economic analysis conducted by Council of Economic Advisers (CEA) staff, the State Department forwarded your request to CEA to provide answers.

In your September 9 letter, you asked for the model or analysis used during the negotiations in Kyoto. During the Kyoto Conference, CEA staff worked with Treasury staff in providing economic analysis used by the U.S. delegation.

In conducting this analysis, CEA drew from modeling results derived from the Second Generation Model (SGM). CEA developed cost curves for Annex I countries and five developing country regions from SGM model outputs for carbon dioxide and assessed the marginal cost of compliance based on required emissions targets necessary to comply with various targets under consideration. (The approach used is comparable to the methodology used for the illustrative modeling analysis in the Administration Economic Analysis.)

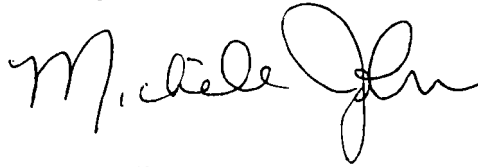
Most analyses focused on the economic effects of various trading regimes. For example, we assessed the permit prices and efficiency losses associated with constraints on purchasing permits as well as with constraints on selling permits. These analyses provided results for the United States, and in most cases, results for all other Annex I countries (or regions) represented in SGM. Further, we assessed the economic implications of an umbrella trading group, with and without developing country participation through "joint implementation" (as CEA termed it during Kyoto). We considered permutations that included both trading constraints and variations of umbrella trading that provided more information on the economic effects of these proposals. Finally, there were some analyses that considered various trading arrangements with different emissions targets.

CEA staff have compiled the memoranda, tables, and modeling data produced by CEA staff for use by the U.S. delegation during the Kyoto negotiations. Given your specific interest in the economic assumptions used at the Kyoto negotiations and your important role as a member of the Senate Observer Group on climate change, we are willing to make these materials available to you or your staff. In the event that these materials reflect internal policy

deliberations or ongoing international negotiations, we are willing to make appropriate accommodations for you to review the materials while protecting the Executive Branch's interest in maintaining confidentiality in the policymaking process.

If you or your staff are interested in reviewing these materials, please ask your staff to contact me at (202)395-5084.

Sincerely,

A handwritten signature in black ink, appearing to read "Michele Jolin". The signature is fluid and cursive, with the first name "Michele" written in a larger, more prominent script than the last name "Jolin".

Michele Jolin

The Honorable Chuck Hagel
Chairman
Subcommittee on International Economic
Policy, Export and Trade Promotion
Committee on Foreign Relations
United States Senate
Room 450, Dirksen Senate Office Building
Washington, D.C. 20510-6225