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Economic Analysis of U.S. Agriculture and the Kyoto Protocol

Economic Analysis of U.S. Agriculture and the Kyoto Protocol. This analysis was prepared by the Office of Chief Economist, Global Change Program Office with technical input from the Economic Research Service.

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EXECUTIVE SUMMARY

In this analysis, we examine the potential costs and benefits for U.S. agriculture resulting from U.S. compliance with the Kyoto Protocol. We conclude that, if proper advantage is taken of the Protocol's flexible, market-based mechanisms, the impact on American farmers would be relatively modest. Further, we conclude that various studies purporting to demonstrate more severe impacts on farm income are flawed because they fail to take adequate account of the adjustments that farmers would make to changes in production costs. When these flaws are corrected, it becomes apparent that, even if tradable emission permit prices turned out to be a good deal higher than we project them to be, the impact on farm income would be just a fraction of what these studies estimate. Finally, we note that addressing climate change could create opportunities for farmers to supplement their income through sequestering carbon or producing biomass that can be used to make fuels, energy, and chemicals.

The Scientific Rationale for Taking Action on Climate Change

There is a broad scientific consensus that the threat of climate change is real and could lead to serious adverse consequences, such as intense floods and droughts, disease, and rising sea levels. There is thus a clear rationale for taking prudent, common sense measures to reduce our greenhouse gas emissions. For agriculture, the picture is mixed. Climate change will likely mean changes in growing seasons, water availability, soil moisture, precipitation, and the incidence and distribution of pests and pathogens. Most studies indicate that given the requisite time and resources to adapt, total U.S. and world food production will not be substantially altered. There will, however, be regional and sectoral winners and losers and more research on this is clearly needed. Current studies, for example, have tended to ignore adjustment costs, which could be significant as the need arises for new varieties of crops and expanded irrigation and flood control systems.

The Kyoto Protocol

The Kyoto Protocol commits industrialized nations to take on binding targets for greenhouse gas emissions for the period 2008-2012. Thanks largely to U.S. leadership, the Protocol contains several provisions that provide flexibility in meeting those targets, and thus reduce costs. These include: 1) a five year commitment period beginning in 2008, allowing countries or firms to delay or accelerate reductions within the agreed upon time frame; 2) inclusion of all six greenhouse gases, allowing emissions reductions of one gas to be substituted for increases in emissions of another; 3) coverage of certain so-called carbon "sinks " (activities that absorb carbon, such as planting trees); 4) international emissions trading and joint implementation of projects among countries with binding targets; and, 5) a "Clean Development Mechanism" that will allow industrial countries or firms to earn credits for emission reducing projects in the developing world. These elements, particularly emissions trading, can significantly reduce the costs of meeting the Protocol's emissions targets.

The Kyoto Protocol, however, does not include adequate participation by developing countries. President Clinton has made clear that he will not submit the Protocol to the Senate without meaningful participation from key developing countries in efforts to address global warming. The United States is currently engaged in a vigorous effort to secure such participation.

Taking Action—the Costs and Opportunities for Agriculture

While agriculture is directly responsible for less than 10 percent of annual U.S. greenhouse gas emissions, efforts to mitigate emissions could naturally affect agricultural production and income, owing especially to the sector's sensitivity to energy prices. Our analysis concludes, however, that the impacts on agriculture of meeting the United States' Kyoto target will be relatively small assuming efficient and global implementation of the Protocol's flexibility mechanisms. Importantly, this result does not factor in the benefits to agriculture of avoiding the consequences of climate change. Moreover, even under more pessimistic assumptions— higher tradable permit prices and higher energy prices—the effects on agriculture are far less than asserted by other analyses released over the past two years. We also review the potentially significant economic opportunities for agriculture in efforts to mitigate net greenhouse gas emissions.

Economic impacts of Kyoto. We take as a starting point the Administration's economic analysis of the Kyoto Protocol released in July 1998. Like other analyses, the Administration's analysis assumed that a permit trading system will impute a price for emitting greenhouse gases, including carbon dioxide, which will be translated into changes in energy prices. Taking into account the Protocol's essential flexibility measures, this analysis arrived at a tradable emissions permit price of $14 to $23 per metric ton in 2010, depending on the scale of international emission trading assumed. This analysis also suggests that the direct resource costs of attaining the Kyoto targets for emission reductions might amount to $7 to $12 billion per year in 2008-2012, or just 0.1 percent of projected U.S. Gross Domestic Product. These results are consistent with those reported in a variety of other macroeconomic assessments of the cost of reducing emissions to the levels required by the Protocol through efficient global implementation.

We then introduce the permit price of $23 per metric ton of carbon into USDA's U.S. Regional Agricultural Sector Model (USMP). The USMP predicts how changes in energy prices resulting from a tradable permit system 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. The resulting impacts on the U.S. agricultural sector are small and, in some cases, negligible.

Production declines, for example, range from 0.1 percent for soybeans to 0.9 percent for rice. Livestock production would decline a twentieth of a percent or less. These small declines in production are partially offset by increased commodity prices, which mean that net cash returns to farmers fall by only 0.5 percent. Consumer welfare declines by 0.05 percent. Our study also found minimal effects on competitiveness. Because the overall costs of compliance will be low, incentives to shift production to countries having no, or less stringent, emission targets will be similarly small. With an efficient international emissions trading system, all countries participating in international trading would face approximately the same price for carbon, and thus the energy price effects of complying with the Kyoto Protocol would be comparable across all these countries.

We also look at how the agricultural sector is affected for every $50 increase in tradable emissions permit prices. We find that even with higher permit prices, which we do not anticipate based on Administration policy, the effects on American farmers will still be relatively modest. This is because farmers respond to changes in input prices by changing the mix of inputs, modifying production practices, and reducing output.

In many ways, this analysis is conservative. First, the econometric model used in the Administration's analysis does not, by its terms, account for the potential for any other domestic policy measures (aside from emissions trading) to further reduce costs, such as the President's package of R&D investments and new tax incentives to promote energy efficiency and renewable energy included in his FY 2000 budget, or restructuring of the electricity industry. In addition, in our use of the USMP model, we make very conservative assumptions about the rate at which farmers adopt new, more efficient technology in response to higher energy prices. We further assume that revenues generated from the sale of tradable permits are transferred out of the agricultural sector and not recycled back to agricultural producers. Finally, neither the Administration's model nor the USMP model make any attempt to measure the potential revenues to farmers from carbon sequestration (see below) or the long term benefits of avoiding the consequences of climate change.

Limitations of other agricultural analyses. The results of our analysis vary considerably from those of several other non-governmental studies in broad circulation, which evaluate the potential impacts of limiting greenhouse gas emissions on U.S. agriculture.

Studies by both Sparks (1999) and Francl (1997) take as their starting points high tradable permit prices inconsistent with efficient implementation of the Kyoto Protocol. Sparks, for example, uses permit prices of $177 to $193 per metric ton, which are derived from the DRI/McGraw Hill (1997) macroeconomic model. Unlike the model used by the Administration, however, the DRI/McGraw Hill model does not analyze cost-saving provisions in the Kyoto Protocol. Instead, it models the effect of the emissions targets contained in the Protocol, but assumes away or ignores all of the Protocol's flexibility mechanisms, including emissions trading, the Clean Development Mechanism, and opportunities to meet targets by abating greenhouse gases other than carbon dioxide. The DRI/McGraw Hill model also implicitly assumes no participation on the part of developing countries–even though this is inconsistent with the Administration's condition for submission of the Protocol to the Senate for ratification.

The Sparks and Francl studies also employ analytical techniques that are inappropriate to analyzing the long term impacts of climate change mitigation on the entire agricultural sector. Both studies use the partial budgeting approach, which assumes that farmers are unable to pass on any increase in their costs and do not respond to changes in production costs. Partial budgeting is a reasonable approach when looking at a single production period for a small number of farms whose production will not affect market quantities and prices. It will, however, overstate impacts over the longer term for the entire sector because it fails to take adjustments into account. Sparks' and Francl's use of this methodology leads them to overstate the impacts on farm income of mitigating climate change.

Another study by McCarl, Gowen, and Yeats (1997) uses an agricultural sector model more appropriate to estimating the impacts of higher energy prices on U.S. agriculture. Their approach is similar to the one used here and produces results that are consistent with ours. The McCarl analysis, however, appears to use unreasonably low prices for fertilizer and pesticides. As a result, it calculates an impact on farm income that we believe is too low.

Potential opportunities for agriculture. As noted above, none of the economic models considered here, including the USMP and the Administration's, explicitly account for the potential effects of carbon sinks in reducing net greenhouse gas emissions.

Under the Kyoto Protocol, net emissions resulting from afforestation, reforestation, and deforestation are counted toward a country's target. In addition, the Parties can add additional sink activities, such as those related to agricultural soils and other forestry management activities. Following the submission of a Special Report on this topic by the Intergovernmental Panel on Climate Change in the spring of 2000, the Parties will be in a position to consider further decisions on the scope and use of carbon sinks under the Protocol.

A number of studies reviewed here make a persuasive case that improved management practices such as conservation tillage, use of winter cover crops, and rotational grazing can significantly and cost-effectively increase the carbon stored in U.S. agricultural soils. Studies also indicate that converting marginal agricultural lands to forests can be a cost-effective means of sequestering significant quantities of carbon. In addition, bioenergy–using trees, crops, and agricultural wastes to produce power, fuels or chemicals–represents a potentially significant opportunity to both reduce net greenhouse gas emissions and supplement farm income.

The challenge for policymakers in the years to come will be to develop the institutions and promote the conditions that will allow the private sector to take advantage of these and other sequestration opportunities that in many instances are far more cost-effective than equivalent emissions reductions in the energy sector.

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 (GHGs) at safe levels. The Kyoto Protocol, which requires the advice and consent of the Senate, calls for industrialized nations to reduce their average national emissions over 2008-2012 to about five percent below 1990 levels.

Key elements of the Protocol include: a five-year commitment period (2008-2012); comprehensive coverage of all six major GHGs (carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs), enabling substitution of reduction among gases; international emissions trading and joint implementation among countries that agree to take on binding targets; a Clean Development Mechanism, providing opportunities for industrialized countries and their firms, to earn certified emissions reductions for investment in projects in developing countries; and a subset of land-use change and forestry activities that sequester carbon, commonly referred to as "sinks". These elements, particularly international emissions trading, could significantly reduce the costs of meeting emissions reduction targets.

The incorporation of land-use change and forestry is an important element of the Kyoto Protocol. Net changes in GHG emissions and removals by sinks resulting from direct human-induced land-use change and specified forestry activities (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 GHG 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. Most studies conclude that while climate change is unlikely to impair the ability of the United States to produce enough food to feed itself and others through the next century, there are several important limitations in the current understanding of the impacts of climate change on agriculture. For example, in existing economic models water resources are poorly linked with agronomic and economic processes. Hence, our understanding of climate-related impacts on flooding, water-logging of soils, and irrigation water availability is limited. Changes in climate variability and extreme weather events are also poorly understood. Many of the climate-sensitive interactions that crops and livestock have 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 GHG emissions. Direct contributions result from emissions of CH_4, N_2O, and CO_2 due to ruminant animals, decomposition of soil organic carbon from tillage practices, rice cultivation, fertilizer application, use of manure, and degradation of wetlands. Indirect contributions, which account for most of agricultural GHG emissions, are attributed to emissions of CH_4 and other gases from concentrated livestock operations and from microbial activities in soil and water following fertilizer and manure applications.

We then turn to a discussion of economic analyses of the Kyoto Protocol. We review recent analyses of the impacts of limiting greenhouse gas emissions on agriculture noting that some studies reach unreasonable conclusions either due to assumptions regarding permit prices that are inconsistent with the Kyoto Protocol or because agricultural markets are not modeled appropriately.

Drawing from key provisions of the Kyoto Protocol, we analyze the effects of a tradable permit system on U.S. agriculture. Specifically, we trace the effects of the permit system through agriculture's use of carbon-containing inputs, such as fuel and fertilizer. For our core scenario, we use the Administration Economic Analysis (AEA), 1998 permit price of $23 per metric ton of carbon equivalent[1]. We estimate the carbon embodied in agricultural inputs for crop and livestock production, calculate the corresponding changes in input prices implied by the permit price, and introduce the input price change into a model of the U.S. agricultural sector. The model estimates the impacts on agricultural prices, supply, demand, income, and other important agricultural indicators. We also estimate the effects for every $50 increase in the permit price. We do not look at contributions of agricultural activities to GHG sources. While agricultural contributions are an important source of some GHGs, it is premature to anticipate what policy options may be implemented to address these contributions. Moreover, we do not include in our model the

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[1] The permit price, derived from a general equilibrium model, reflects adjustments that would likely occur across sectors.

potential opportunities to supplement farm income through carbon sequestering activities but we do discuss this potential in a subsequent chapter.

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 practice surveys, the USDA multi-year baseline, and geographic information system databases such as USDA's National Resources Inventory (USDA, 1987, 1992). USMP predicts how changes in farm policy (resource, environmental, or trade), commodity demand or technology will affect regional supplies 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 links with biophysical models.

USMP is a medium-term model. We hold the energy efficiency of available production technology constant which means that farmers, by assumption, do not respond to increased energy costs by adopting new, currently unavailable, technology. However, farmers can adjust energy use by choosing from a wide range of currently used technology (tillage practices, crop rotations, etc.) which offer a variety of energy efficiencies. 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 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, again a conservative assumption.

We take as a starting point that energy price increases reflect a permit price of $23 per metric ton. Rising energy prices increase production costs, which increase commodity prices. Higher prices in a market with inelastic demand result in higher revenues and lower quantities demanded. The effect on net farm income depends on the relative supply and demand elasticities in the input and output markets. Given the inelastic demand for food, higher farm production costs will to be partially offset by higher revenues.

We find the $23 per ton permit price leads to small production declines ranging from 0.1 percent for soybeans to 0.9 percent for rice[2]. Price increases range from about two cents per bushel for corn (0.6 percent), one cent per bushel for wheat (0.2 percent), one cent per bushel for soybeans (0.09 percent), and 11 cents per hundredweight for rice (0.9 percent). Rice prices increase more than the prices of other crops owing to rice's greater energy and carbon intensity in production. Soybean prices rise less than 1 percent owing to lesser carbon intensity in production. We find that the Kyoto Protocol would affect livestock markets negligibly, with prices rising 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 permit prices. These higher permit prices are not consistent with Administration's policies on climate change. However, we do not find significant impacts on American farmers because higher input

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[2] All reported USDA results are relative to a 2010 baseline.

prices cause changes in the mix of inputs, reductions in output, and shifts to other commodities.

Our analysis also looks at the potential for including agricultural carbon sequestration activities in the Kyoto Protocol, the role of biomass, and other GHG 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 CO_2 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) and the world (Darwin, 1999 and 1998a; Darwin *et al.*, 1995; Rosenzweig and Parry, 1994). These studies and others indicate that[3]: climate-induced shifts in agricultural possibilities and other effects of rising concentrations of atmospheric CO_2 are unlikely to impair the ability of the United States to produce enough food to feed itself and others through the next century. Climate-induced shifts are likely to reduce the ability of some communities to obtain their livelihoods from agriculture.

Climate change and agriculture. Climate is a major factor in agricultural production and farming is located in those areas where potential value of agricultural production is consistently high. The two most important climate-related indicators of agricultural production 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

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

extend the length of the natural growing season. The source of the water used in such localities may depend on local precipitation, precipitation in some distant location, or precipitation from the distant past (i.e., supplies of ground water). Climate also affects livestock production. Temperatures that are too high or too low can generate stress that lowers livestock production. Livestock production also requires 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 production. Extreme weather events involving heavy precipitation are especially important because 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 CO_2 effects. The level of CO_2 in the atmosphere affects agricultural output directly. Plants combine solar energy with water (generally from the soil) and CO_2 from the air to photosynthesize glucose, a simple sugar. Stomata, primarily on the leaves, control the passage of water vapor and other gases to the plant from the atmosphere and vice versa. The size of the stomatal openings are negatively correlated with the atmospheric concentration of CO_2, that is, the higher the level of CO_2, the smaller the stomatal openings and the slower the rate of transpiration (the loss of water vapor from the plant). Hence, elevated CO_2 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 CO_2 is incorporated during photosynthesis. Experimental yield responses for C3 crops (which include wheat, rice, barley, oats, and potatoes) to 700 ppmv of atmospheric CO_2 (approximately double the current concentration) averages +30 percent, with a range of -10 to +80 percent (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 CO_2 is lower (IPCC, 1996). A commonly used estimate for corn's yield response to 555 ppmv of atmospheric CO_2 (double the pre-industrial concentration) is seven percent (Rosenzweig *et al.*, 1993).

There remains considerable debate about whether such CO_2-induced increases will be observed under commercial conditions. First, estimates of CO_2 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 CO_2 benefits (Darwin, 1997 and 1998b). Third, although higher levels of atmospheric CO_2 may have a beneficial effect on plant growth—also known as the CO_2 fertilization effect—other gases released by burning fossil fuels (particularly ozone, sulfur dioxide, and nitrogen dioxide) have detrimental effects on plant growth. Fourth, 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 CO_2 is doubled ($2xCO_2$ 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 GHGs 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 CO_2 (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 (0.0, 1.5, 2.5, and 5.0°C) with four precipitation changes (-10, 0, 7, and 15 percent) and four levels of atmospheric CO_2 (355, 440, 530, and 600 ppmv) on 1990 and 2060 agricultural economies.

Agricultural impacts. Global analyses of climate change indicate that agricultural production is likely to increase at higher latitudes and in alpine areas where current 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 production are also offset by the direct effects of rising concentrations of atmospheric CO_2 (Rosenzweig and Parry, 1994; Darwin, 1998a). The net effects on world agricultural production, accordingly, has been shown to be relatively small, i.e., plus or minus three percent for world cereal production in $2xCO_2$ scenarios with CO_2 fertilization and limited adaptation (Rosenzweig and Parry, 1994), plus or minus one percent for crop production and livestock production in $2xCO_2$ scenarios without CO_2 fertilization but with extensive adaptation (Darwin, 1995), and less than plus four percent for crop and livestock production in transient scenarios with CO_2 fertilization and moderate adaptation (Darwin, 1998a)[4]. 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 CO_2 fertilization is included in the scenarios (Rosenzweig and Parry, 1994; Darwin, 1998a).

The effects of climate change on U.S. agricultural output are similar to those on world output—agricultural output 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 $2xCO_2$ scenarios with CO_2 fertilization and limited adaptation (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 $2xCO_2$ scenarios

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[4] Limited adaptation includes the following responses to climate change: shifting planting dates, increasing fertilizer adaptation, installing irrigation systems, and developing new crop varieties. Moderate adaptation includes all limited adaptation responses, plus shifting crop and livestock production systems, and limiting expansion of crop and livestock production into new areas. Extensive adaptation includes all limited adaptation responses, shifting crop and livestock production systems, and broad, no-cost expansion of crop and livestock production into new areas.

without CO_2 fertilization and extensive adaptation (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 CO_2 fertilization and moderate adaptation (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 CO_2 fertilization and moderate adaptation (Darwin, 1998a).

The effects of climate change on U.S. prices are larger than those on world prices. U.S. prices tend to move in the opposite direction of production (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 CO_2 fertilization is included in the scenarios (Adams *et al.*, 1995 and 1999; 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 production. 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 scenario[5].

Implications. These results suggest that, barring any unforseen catastrophic events, climate-induced shifts in agricultural possibilities and other effects of rising concentrations of atmospheric CO_2 are unlikely to impair the ability of the United States to feed itself through the next century. Much depends, however, on how well farmers can 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 will be determined, in part, by the predictability of the climatic future, the costs of adapting, and the effects of government policies and 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 the future climate will be in a given location; changes could occur relatively rapidly and the transition may be erratic. For example, 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.

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[5] 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 studies evaluated here generally ignore adjustment costs such as those associated with converting forests into agricultural land, adding or expanding irrigation and flood control systems, or establishing new cropping systems. The costs associated with these adaptations will be negligible only if climate changes 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. Were this not the case, then adaptation might be hampered. Government policies and programs ranging from crop insurance and disaster assistance to the level 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 available technological options.

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, the availability of irrigation water, and sea level rise. Second, changes in climate variability and extreme weather events are not explicitly included in existing models which limit our knowledge of how climate change might affect the probability of crop failure in a given area. Third, many of the climate-sensitive interactions that crops and livestock have with pests and diseases are excluded from existing models. It is important to recognize that current understanding of the impacts of climate change on agriculture will continue to develop as additional research on this topic becomes available.

Agriculture's Contribution to Greenhouse Gas Emissions

Agricultural activities contribute to GHG emissions both directly and indirectly. Direct contributions result from emissions of CH_4, N_2O, and CO_2 that are due to machinery operation, other energy use, 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 CO_2 emissions from cropland soils. Indirect contributions, which account for most of agricultural GHG emissions, are attributed to emissions of N_2O 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 114.1 million metric tons of carbon equivalent (MMTCE) or between 6 and 7 percent of total U.S. GHG emissions (Table I.1)[6]. Agricultural activities contribute CO_2 emissions primarily through combustion of fossil fuels, SOC decomposition, and biomass burning. In the U.S., CO_2 emissions from deforestation are small. Emissions of CH_4 from agricultural activities are primarily from enteric fermentation in ruminant animals, rice cultivation, and biomass burning. The principal sources of N_2O emissions are soils, fertilizers, and manures, and biomass burning.

The current EPA inventory also includes CO_2 flux caused by changes in forest carbon stocks (trees, understory, forest floor, forest soils, wood products, and landfilled wood), and a preliminary assessment of the net CO_2 flux caused by changes in forest soil carbon stocks. Not

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[6] Methane emissions from wetlands, grassland, and forestlands are also not included in the current inventory due to an inadequate scientific basis for estimating net emissions from these sources. Further research and methodological research is needed to accurately include these sources in the national inventory of GHG emissions.

yet included in the annual inventories are net emissions of CO_2 from agricultural soils (croplands, rangelands, and pasturelands).

Cropland and grassland pasture and range account for almost half of all land in the contiguous 48 states and significant portions could be managed to increase the quantity of carbon stored in the soils and above ground biomass. Numerous studies of agricultural and rangeland 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 pounds 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).

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 million metric tons of carbon (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.

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

This chapter reviews several studies which evaluate the potential impacts on the agricultural sector of limiting GHG emissions. The common approach in these studies is to specify a permit price (either arbitrarily or selected from a macroeconomic or energy model) and estimate the effects of that price on energy intensive farm inputs, agricultural production costs, supply, prices, and farm income. This chapter focuses on three recent studies: Francl (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. Francl and Sparks conduct partial budgeting analyses of the effects of carbon permits on the U.S. agriculture sector, and conclude that annual net farm income declines by 46-48 percent. These large projected declines are primarily the result of the partial budgeting approach which assumes 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 increased value of production. Consequently, the partial budgeting approach overstates the impact of higher energy prices on the agricultural sector. McCarl, Gowen, and Yeats estimate income declines of about 0.5 percent (under $100 per metric ton permit prices); their analysis uses an agricultural sector model that assumes producers and markets respond to higher input costs.

A positive permit price affects the total cost of using energy, thereby increasing input prices and subsequently increasing these variable production costs. The effect on commodity supplies, market prices, and farm income depends critically on the degree to which: 1) input prices increase, which in turn depends on the ability of input suppliers to pass on higher energy prices to their agricultural customers; 2) farmers adjust to higher energy prices by reducing output and/or adopting less energy intensive cropping systems; 3) consumers respond to higher output prices; and 4) any revenues resulting from the domestic emissions reduction program are recycled back to agricultural producers through reductions in some taxes these producers pay. Consequently, the impact of the permit price depends on the supply and demand elasticities for primary and intermediate inputs, and final goods, which can vary over the short, medium, and longer term. Assumptions made regarding permit prices, elasticities of supply and demand, rates of technological change, and market adjustments are crucial to an accurate assessment of the impacts of the Kyoto Protocol on the agricultural sector.

Neither the studies reviewed here nor the USDA analysis actually estimates the value of carbon, i.e. the permit price of carbon dioxide and other GHGs that would emerge from the Kyoto commitments. Sparks uses an estimate from the DRI/McGraw Hill (1997) macroeconomic model while McCarl, Gowen, and Yeats and Francl assume a range of different values and estimate the impacts for various levels within that range. The USDA analysis (Chapter III) uses the permit price in the AEA; this price reflects key elements of the Protocol and is consistent with Administration policy[7].

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 consists of on-farm direct uses of fuels and electricity to operate vehicles, machinery, irrigation, and drying systems; indirect uses of energy in manufactured

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[7] 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 use is included to a lesser degree in other farm expenses such as commodity transportation, hired custom and machine work, and purchased feed.

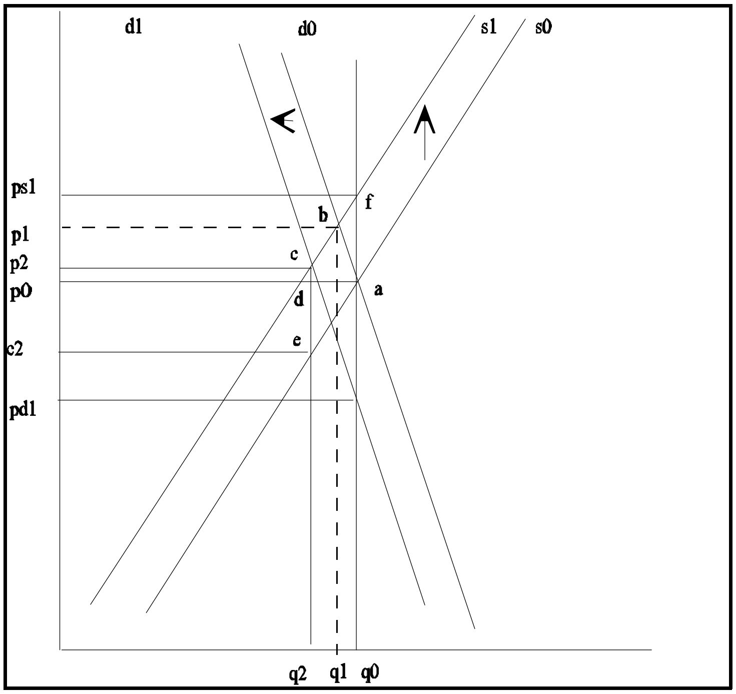
Sparks and Francl use the partial budgeting technique to analyze the impact of a tradable permit price on the agricultural sector. Partial budgeting focuses on an enterprise's revenue and cost components, and then calculates the difference between these to compute net returns. It is partial in the sense that if some 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, that farmers are unable to pass on any increase in costs to consumers, and farmers 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 over longer periods 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.

It is generally accepted that when faced with rising production costs, producers reduce supply which leads to increased market prices. In the case of agricultural commodities generally, demand is "inelastic." As a result, increases in production costs are at least partially offset by higher revenues. Because farmers would likely respond to higher energy prices by 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.

Francl estimates the Kyoto Protocol’s impact on farm income by calculating and summing the increased production costs and comparing them with average farm revenues. Sparks estimates the Kyoto Protocol’s impact on farm income by calculating and summing up the increase in 1998 production costs and the declines in 1998 revenues due to shifts in demand. Both studies substantially overestimate the impacts because they leave out important farmer and market responses.

The response of the agricultural sector to permit prices is shown graphically in Figure 1. Agricultural markets are initially in equilibrium at point *a* where the aggregate supply function, *s0*, intersects the aggregate demand function *d0*. The price level is *p0* and the quantity is *q0*. Increased input prices increase variable production costs and the agricultural supply function shifts from *s0* to *s1*. Farmers adjust to the higher cost structure by producing less and the market reaches a new equilibrium at point *b* with a higher price *(p1)* and lower quantity *(q1)*.

Figure 1. Market Effects of Supply and Demand Shifts



Demand could shift (as assumed in the Spark’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* (i.e. *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*[8]. The increased costs are distributed between producers and consumers according to their relative price elasticities. The Sparks analysis does not include any adjustment to quantity supplied by farmers and the market to reach an equilibrium solution such as *c*. Quantity remains at *q0* while supply and demand shift, thus their analysis overestimates the income loss by *p0ps1fa*.

Francl assumes that costs increase would be represented by the upward shift in the supply function from *s0* to *s1* in Figure1. But by assuming that revenues are an average of past revenues, producers are assumed to not respond to higher input prices, and the quantity is not adjusted from *q0.* Thus, Francl assumes that revenues remain at *p0q0*, and that the cost increase of *ps1p0af* is the decrease in net farm income, which overstates the net income loss. The Sparks and Francl analyses are virtually equivalent, coming to the same basic result.

Sparks estimates that farm revenues would decline $5.3 billion (2.3 percent). Of this, $1.7 billion is estimated as a decline in domestic agricultural revenue in response to income declines[9],

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[8] 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*.

[9] Sparks concludes 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 cited income elasticity estimates by Huang

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[10]. Sparks estimates that farm input expenditures would increase by $16.2 billion (8.8 percent)[11], of which, $13.0 billion reflects higher expenditures for manufactured inputs (chemicals, fuels, and electricity) and $3.2 billion reflects higher expenditures for other inputs.

Sparks estimates an 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 analyzes the problem as if it were a one–period problem, such that farmers would not adjust resource allocation in the face of input price changes and shifts in demand that would lower prices. Sparks extends the estimated input price increase to typical farms using farm budgets from the U.S. Department of Agriculture's, Economic Research Service (ERS) and the University of Florida. Sparks assumes that price reductions of 2.4-2.5 percent would occur for corn, soybeans, hogs, milk, cattle, and tomatoes. The estimated impacts are overstated in the same way the aggregate

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(1993) 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 estimate of 1.6 percent GDP loss in 2010 (Sparks, 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.

[10] Sparks 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. Again, this assumption is inconsistent with the Kyoto Protocol, which the Administration has stated will not be delivered for ratification until there is meaningful participation from key developing countries.

[11] Sparks used energy price increases from DRI, assumes input energy component and price response (without citations), and calculates net input cost changes. The exception is electricity, for which Sparks assumes a cost change of 100 percent instead of the DRI increase of 54 percent, thereby increasing the cost impact from $1.3 billion to $2.9 billion.

analysis overstates impacts.

Francl 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 a “low” impact scenario and $20.537 billion (11.7 percent) under a “high” impact scenario. Dividing these cost increases by the average 1991-95 U.S. net farm income of $42.7 billion, Francl estimated decreases in net farm income of 24 percent in the “low” scenario and 48 percent in the “high”energy price increase scenario. Francl does not indicate which method he used to compute input price increases

McCarl, Gowen, and Yeats use the Agricultural Sector Model (ASMSOIL) to assess the farm sector impacts of carbon permit prices of $25, $50, and $100 per short ton of carbon (2,000 pounds) implemented in years 2000, 2005, 2010, 2015, 2020[12]. ASMSOIL is a spatial equilibrium 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 to price or policy shocks (i.e., adjustment paths are not modeled). The simulation results reflect movements between market equilibriums.

Impacts of tradable 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’ estimates of energy price increases for diesel, gasoline, and natural gas are

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[12] The permit price increases used by McCarl, Gowen, and Yeats are illustrative and not the result of a macroeconomic analysis.

consistent with the DRI energy price estimates used in the Sparks analysis. For various farm chemicals, however, McCarl, Gowen, and Yeats estimate prices increases that are less than one percent for carbon permits of $100 per ton. Hence, for farm chemicals, the cost increases associated with permit prices permits in McCarl, Gowen, and Yeats are significantly less than would be suggested by the embodied fuel or carbon content of the inputs.

McCarl, Gowen, and Yeats 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 present welfare impacts associated with the various permit prices in terms of changes in consumer, producer, and foreign surplus relative to a scenario where no tradable permit system is implemented. The results indicate that consumers pay a significantly larger absolute share of any cost associated with a tradable permit system, while producers pay a larger relative share. For example, the loss in producer surplus associated with a $100 permit price 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 versus 0.50 percent). Producer surplus declines 0.17 percent with $50 permit price and increases 0.03 percent with $25 permit prices.

With respect to the U.S. farm sector, McCarl, Gowen, and Yeats estimate that permit prices of $25, $50, and $100 per ton of carbon 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 a tradable permit system aimed at reducing U.S. GHG emissions. Additionally, McCarl, Gowen, and Yeats note that these costs could be largely offset by returning revenues from a tradable permit reduction auction to agricultural producers.

Summary. Francl and Sparks conduct partial budgeting analyses of the effects of tradable permits on the U.S. agriculture sector, and conclude that annual net farm income will decline by 46-48 percent. The $21.5 billion 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 use an agricultural sector model to analyze the effects of permit prices. Their calculation of the effects of permit prices on fuel costs appears to be reasonable, but their calculations of permit price effects on fertilizer and pesticide costs appear to be low given current knowledge of energy embodied in these inputs. McCarl, Gowen, and Yeats allow producers and markets to respond to higher input costs, and project that income declines—about 0.5 percent with a $100 per metric ton permit price—would be minimal. They further note that the income effects could be largely offset by returning permit revenues to the farm sector.

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

Various macro energy-economic models have evaluated the effects of permit prices on energy sectors and the subsequent effects throughout the economy. These models have assumed that a system of tradable emissions permits will impute a value/cost for emitting CO_2, which will be translated into changes in energy prices. Producers and consumers will be affected according to how much carbon they are emitting and 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, including agriculture, would be affected as the cost of fuels, electricity, fertilizers and chemicals, and transportation services increase.

USDA's analysis of the Kyoto Protocol relies on the AEA permit price. Key features, assumptions, and results of the AEA study appear in Table III.1[13]. 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

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[13] It is worth noting that results reported in the AEA are consistent with results reported in several other macroeconomic assessments of reducing GHG emissions to levels at or near that required by the Kyoto Protocol. For example, assuming unrestricted international emissions trading to achieve the Kyoto targets, Charles River Associates, 1998 replicates the AEA carbon permit price of $14 per metric ton under umbrella trading and developing country trading. In addition, in assessing global trading, the AEA finds a 2010 permit price of $23 per metric ton, while van der Mensbrugghe, 1988 finds a permit price of $27 per metric ton. MacCracken *et al*, 1999. finds a permit price of $29 per metric ton, and McKibben *et al.* (1998) finds a permit price of $13 per metric ton (all permit prices are reported in 1997 dollars).

over the first five-year commitment period (2008-2012) reflects this kind of flexibility. “What” flexibility refers to the opportunities to substitute emissions 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 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 cycle-induced energy fluctuations on permit prices and subsequent economic effects. This smoothing out of short-term phenomena is consistent with the averaging in the 2008 to 2012 commitment period in the Protocol. Regarding “what” flexibility, the AEA included all six GHGs in evaluating emissions targets and abatement opportunities. However, the AEA 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. The AEA did not incorporate the effects of several Administration policies, including proposed electricity restructuring legislation, the Climate Change Technology Initiative, other Administration initiatives, all of which could further reduce the cost of meeting GHG targets.

The AEA analyzes a set of scenarios representing various international trading blocs. An assessment using the SGM model that accounts for a well–functioning international emissions trading system and developing country participation yields permit price estimates ranging between

$14 and $23 per metric ton, and U.S. direct 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 Protocol explicitly provides for emissions trading among Annex I countries (Article 17) and for project-based investment 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 and are not analyzing the costs of implementing the Kyoto Protocol.

Drawing from key provisions of the Kyoto Protocol, we analyze the effects of a tradable permit system on U.S. agriculture. Specifically, we trace the effects of the permit system through the sector's use of carbon-containing inputs, such as fuel and fertilizer. For our core scenario, we use the Administration Economic Analysis (AEA) (1998) permit price of $23 per metric ton of carbon equivalent[14]. First, we estimate the carbon embodied in agricultural inputs for crop and livestock production. Second, we introduce the corresponding changes in input prices —using the AEA permit price—into a model of the U.S. agricultural sector. The model estimates the corresponding impacts on agricultural prices, supply, demand, income, and other important agricultural indicators. We also estimate the effects for every $50 increase in permit prices (Appendix 1). Because our analysis is input based, we do not look at emissions from agricultural

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[14] The permit price, derived from a general equilibrium model, reflects adjustments that would likely occur across sectors. We use this price as a proxy for the implicit value of carbon.

sources directly. While agricultural sources are an important source of some GHGs, it is premature to anticipate what policy options may be implemented to address these sources. Moreover, we do not include in our model the potential opportunities to supplement farm income through the use of carbon sequestration activities, but we discuss this potential in Chapter IV.

Input prices. We estimate the increase in input prices by multiplying the $23 per metric ton permit price by the carbon embodied in each input. This captures the variation in impacts on input prices caused by differences in their carbon content. This is particularly important for estimating the increase in electricity prices because electricity is generated from a variety of power sources that have widely disparate rates of carbon use.

Estimates of the increases in input prices used for this analysis are reported in detail in Table III.2. A $23 per metric ton permit price increases the price of diesel fuel by 5.2 percent, and the price of gasoline by slightly less (3.3 percent). The price of diesel fuel increases more than the price of gasoline increases because diesel fuel has a higher level of embodied carbon than gasoline. Increases in electricity prices vary considerably across the United States ranging from less than one percent in the Northeast and Pacific to nearly three percent in the Corn Belt, Northern Plains and Delta. The variation the impact of a permit price on electricity prices is caused by the variation in power sources used to generate it. In regions where high carbon-intensity power sources (e.g. coal, natural gas or oil) predominate, the price of electricity increases considerably more than in regions where low carbon-intensity power sources(such as nuclear or hydro) predominate. Of the major agriculture chemicals, nitrogen fertilizer increases nearly four percent while phosphate increases by around one percent.

Modeling permit price impacts. To capture the full effects of permit 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). The USMP model accounts for the most important effects of a tradable permit system on U.S. agriculture[15].

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 75 percent of the value of U.S. agricultural production (USDA, ERS, 1999). Some 16 primary livestock production enterprises are modeled, including 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 (Green and Price, 1987).

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[15] The model results are "partial equilibrium" because they omit the effects that changes in consumer income, whether originating in the agriculture sector (farm incomes, wages paid to hired labor and sales of agriculture inputs) or in the non-agriculture sector income, have on the demand for agriculture commodities. If, for example, permit prices reduce non-agriculture sector income, then non-sector purchases of agricultural commodities, like food, could fall. This would in turn reduce agriculture sales revenue and input use. These effects are usually insignificant.

USMP is a medium-term model. We hold the energy efficiency of available production technology constant which means that farmers, by assumption, do not respond to increased energy costs by adopting new, currently unavailable, technology. Farmers can, however, reduce their energy use by choosing from a wide range of currently used tillage practices, crop rotations, etc. which offer a variety of energy efficiencies. This is 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 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. Again, this is a conservation assumption.

For this analysis the USMP model is calibrated to crop and livestock supply, demand, production, acreage, government program, input cost and other conditions for 2010, which is the midpoint of the first commitment period for the Kyoto Protocol. U.S. agriculture sector conditions in 2010 are based on the USDA Long-Term Agricultural Baseline (February 1998). The USDA baseline provides projections through the year 2007. For this analysis the baseline estimates are extended to 2010 with linear trends of acreage planted, prices, and other market variables[16]. 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 multi–year rotation enterprises and livestock enterprise budgets based on the ERS 1996

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[16] The procedure to extend the baseline to 2010 is based on recommendations from baseline analysts at USDA's ERS.

cost-of-production (COP) budgets (USDA, ERS, 1998b). These costs are indexed to baseline projections of variable costs for 2010.

The effects of permit prices are determined by applying the estimated changes in energy and chemical prices to each of the nearly 1,000 production systems contained in USMP. The model is then solved to return commodity and input markets to a new equilibrium. The supply, use, acreage, price and other market indicators which result form the basis for determining the impacts of permit prices on the agriculture sector.

Direct carbon costs represented in USMP crop production activities include those for diesel, gasoline, LP gas, natural gas, lubricants and electricity used for the operation of machinery, vehicles, irrigation systems, and crop drying. Other sources of direct carbon costs include expenditures for nitrogen, phosphates, potash, and pesticides. Major categories of indirect carbon costs represented in USMP production activities include custom operations, ginning for cotton, drying for rice, and other variable expenditures (includes purchased irrigation water, baling, etc.). Custom operations includes custom field operations (often involving machinery that farmers contract for), technical services, and commercial drying.

Direct carbon costs represented in livestock production activities include those for diesel, gasoline, LP gas, natural gas, lubricants, and electricity for machinery, vehicles, equipment, manure handling systems, feed systems, housing, and dairy parlor operation. Indirect carbon costs represented include hauling, marketing and custom services, and supplies.

Increases in expenditures on inputs listed in the direct carbon cost category are calculated directly from estimated increases in input prices. Increases in expenditures on inputs in the indirect cost carbon cost category, such as custom operations, are calculated by multiplying the estimated increase in direct carbon cost input's price by that input's share of total expenditures on the indirect carbon cost input.

The is a "comparative static" analysis, 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 permit prices. Farmers respond to permit 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 items produced equal one another. Shifts among production practices, such as reducing acreage under conventional tillage to reduced tillage, incur costs of acquiring new implements and learning new management practices which all enter into the process of adjusting to the new equilibrium[17].

Effects on crop prices and supply. The $23 per metric ton permit price causes crop production costs to rise, shifting crop supply functions upwards. A new market equilibrium

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[17] Conventional tillage: use of disc in planting preparation. Moldboard Tillage: conventional plus use of moldboard plow. Reduced tillage systems include no–till, ridge–till, and mulch–till. 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 (USDA, 1997a).

occurs with smaller quantities produced and demanded at higher prices[18]. The supply side impacts vary across the carbon intensity of production inputs. Crop prices increase less than three cents (about one per cent or less) per bushel for feedgrains (corn, sorghum, barley, oats) and wheat (Table III.3). Changes among feedgrains on the supply side depend on their relative carbon intensity in production, and on the demand side their relative protein and energy content in animal feed rations. The price of rice increases more than other crops (about 11 cent per hundredweight or 0.85 percent) owing to its greater energy and carbon intensity in production. Soybean prices increase about one cent per bushel (0.09 percent) owing to its lesser carbon intensity in production. Soybean production, in the Corn Belt for example, uses only about 40 percent of the carbon per acre (134 pounds) of corn (309 pounds).

Declines in crop production are also relatively small. Production of all 10 USMP crops declines by less that one 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. Permit prices increase crop production costs and 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 permit price leads to a decline of 1.3 million acres planted (0.40 percent) for the 10 major field crops (Table III.4). Feedgrain acreage declines 380 thousand acres (0.30 percent), while wheat and hay acreage decline by about 300 thousand acres each (0.40 percent). Soybean acreage declines about 100 thousand acres (0.10

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[18] All reported changes are relative to the 2010 baseline.

percent). 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. Permit prices affect livestock production on the supply side both through direct energy cost impacts and indirect cost impacts including higher feed costs. Permit prices affect livestock products negligibly, with livestock 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 (market revenues) and total variable costs are the major components of farm income affected by permit prices. Permit prices increase production costs , which increases commodity prices. Higher commodity prices in inelastic markets more than offset the negative effect of smaller quantities on the value of production or market revenues. The net effect on net cash returns depends on input supply and commodity demand markets, but, given inelastic demand, agricultural revenues or value of production typically increase and partially offset production declines.

Total variable costs of production rise 0.6 percent ($821 million), while the value of production increases 0.2 percent ($450 million), netting out to a net cash returns decline of 0.5 percent ($371 million) (Table III.6) assuming that permit revenues are not returned to the agriculture sector[19]. Regional net cash returns range from a decline of 0.3 percent in the Corn

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[19] The redistribution of income resulting from a domestic carbon reduction policy would depend on how the policy was designed and implemented. There are many ways in which such design and implementation could occur. If tradable permits were auctioned or sold by the government, the value of those permits or any revenue collected from their sale could be returned entirely to the

Belt to 2.3 percent in the Southern Plains.

Effects on agricultural inputs. Farmers' responses to higher input prices will determine the shifts in input uses and the ultimate effects of permit prices on farmer expenditures. Increased input prices result in reduced input use and reduced carbon embodied in inputs and agricultural production. Over time, permit prices would stimulate development of new technology that would reduce the energy requirements for agricultural production.

The effects of permit prices on carbon content 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 proxy[20], incurs a sales volume reduction of one percent.

Direct fuel and lubricant use by farmers and that embodied in custom use are affected most directly by permit prices. 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

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economy. For example, such permit values or revenues could be redistributed to agricultural producers (and others in the economy) according to historical carbon use, or according to some environmental or stewardship "good," or by reducing existing payroll, income, and corporate taxes. Thus, including 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). By not including the potential for recycling some revenues back to agricultural producers, our estimates of agricultural producer welfare losses may be higher than they otherwise would be.

[20] For this analysis the carbon content of inputs used in the available 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.

pound of chemical pesticide. Fertilizer use declines by 0.4 percent while chemical (pesticide) use declines by 0.5 percent.

Changes in surplus measures and net social benefit. Tradable permits cause the net social benefit from agricultural activity to decline, reflecting the adverse effects that increases in production costs and food prices have on both consumers and agricultural producer welfare (Table III.8)[21]. Reductions in surpluses accruing to both consumers and agricultural producers amount to about $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) declines by $67 million. The change in net domestic benefit (commonly referred to by economists as dead weight loss) is important because it measures the gains or losses to society from changes in the agriculture sector which are not balanced off by transfers to other sectors of the economy. This is considerably less than the direct loses to consumers and agricultural producers and indicates the potential for significantly reducing agricultural sector losses by recycling permit revenues back to consumers and agricultural producers in the form of lump sum transfers or reductions in payroll, income, or corporate taxes. Net foreign surplus, surpluses accruing to consumers of U.S. agricultural exports and producers

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[21] The various surplus and social benefit measures used in this analysis represent only partial gains or losses from permit prices. Specifically, 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, area in conventional tillage, and emissions of GHG.

of agricultural commodities imported into the United States, declines by $127 million.

Changes in environmental indicators. Permit prices lead to slight reductions in soil erosion (sheet, rill and wind) and nitrogen loss to both water (surface runoff and leach) (Table III.9) and the atmosphere. 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 losses decline by less than 0.5 percent and these losses are fairly uniform across production regions. These changes in the indicators reflect the relatively small impact permit prices have on acreage planted and tillage practices.

Societal benefits (improved water quality) from reductions in erosion and nitrogen loss largely accrue downstream (off-site)[22] from agricultural production activities. As a result, they are not included in calculations of consumer surplus, producer surplus, or net social benefits. The benefits associated with reductions in offsite damages from soil erosion are $4.0 million. This suggests that added environmental benefits associated with reduced damages from agricultural production, while important, probably will not completely offset the loss to consumers and producers caused by tradable permits.

Exports and competitiveness effects. Commodity exports are determined by the intersection of the supply and demand curves for U.S. agricultural products in international

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[22] Improved water quality has positive effects on navigation, recreational and commercial fishing, and water for drinking, industrial and irrigation uses. Improved quality reduces the costs incurred by individuals to avoid or treat sub-quality water. The costs, in dollar terms per ton of erosion, incurred by individuals to avoid or treat sub-quality water resulting from agriculture activities for these categories have been estimated by analysts at the ERS production region 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 are derived by multiplying the estimated damage per ton of erosion times tons of erosion for each production region.

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 relative farm production costs 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, electricity, fertilizers, and pesticides will increase. For the agricultural sector, a key question is whether the permit price would cause input prices to rise sufficiently to affect domestic production and export levels, and the degree to which permit prices increase in the rest of the world. With an efficient international trading system, all countries participating in international trading would face the same price for carbon, and thus the energy prices of complying with the Kyoto Protocol would be comparable across all these countries. Thus, international trading eliminates the potential for producers in one country to gain a competitiveness edge over producers in another country, so long as both countries are participants in the trading system. USMP, which accounts for both the effects of increasing U.S. input prices and the responses of foreign producers to higher commodity prices, estimates that the decline in U.S. exports ranges from 2.1 percent for rice to 0.1 percent for soybeans (Table III.2)[23].

The USMP model evaluates market impacts over a medium-run time frame. If the higher input prices associated with a tradable permit system persist over time, the longer-run impacts could include decreases in the relative costs of farm production in other global regions, particularly those regions that do not implement a tradable permit system or other policies to abate carbon dioxide. 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 permit prices is, at present, speculative. As noted by AEA, energy prices already vary significantly among Annex I countries and between Annex I and non–Annex I 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 tradable permit system on U.S. agriculture would be affected by many factors, most of which are beyond the scope of the present assessment. These factors include differences in the rates and magnitudes of technical change, the relative impacts of the permit price on other economic sectors, and how long the global economy takes to fully adjust. If, as a result of implementing the Protocol, foreign producers face lower costs from

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[23] 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.

achieving their Kyoto targets relative to domestic producers, U.S. agricultural commodities could become less competitive in global markets and U.S. commodity export demands would fall. 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.

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 countries. At the same time, the Administration has made it clear that it will not send the Protocol to the Senate without meaningful participation from developing countries.

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 international emissions trading, a multi-year commitment period, allowance for forestry carbon sinks, joint implementation, and the Clean Development Mechanism are taken into consideration. Other analyses arrive at larger energy price impacts, partially because they 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 price 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, and the major livestock commodities comprising about 75 percent of the value of U.S. agricultural production.

The increase in energy prices predicted in the AEA cause the cost of agricultural production to rise slightly, which shifts commodity supply functions upward. The market adjusts with the new supply functions to a higher price with slightly lower quantities produced and consumed. The generally “inelastic” demands for agricultural commodities result in increased value of production (revenues) that partially offsets the increased production costs. Farm income declines slightly as a result of all these changes. Some regions, particularly those more dependent on energy-intensive irrigation, are more negatively affected than other regions.

We also estimate how the agricultural sector is affected for other permit prices (Appendix 1). Even under higher permit prices—which are not consistent with the Administration’s policies on climate change—we do not find significant negative impacts on American farmers. This is because farmers respond to 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 $23 permit 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 (0.2 to 1.1 percent), one cent per bushel for wheat (0.2 percent), and 11 cents per hundredweight for rice (0.9 percent). Rice prices increase more than the prices of other crops owing to rice’s greater energy and carbon intensity in production. Soybean, silage and hay prices rise less than one percent owing to lesser carbon intensity in production. Implementing the Kyoto Protocol has a negligible effect on livestock products 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 modest when the flexibility mechanisms of the Kyoto Protocol are used. Assuming no income from carbon sequestering activities, nor benefits from new technology, net cash returns decline 0.5 percent, and consumer welfare declines 0.05 percent.

CHAPTER IV. OPPORTUNITIES FOR AGRICULTURE

Carbon sequestration. Carbon sequestration could play a critical role in helping meet the challenge of climate change. Under the Kyoto Protocol, carbon sinks(e.g. activities that absorb carbon, such as planting trees) can be used as offsets against emissions of greenhouse gases. Net changes in GHG emissions 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 changes in GHG 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)[24]. The studies described in Chapter II and the USDA economic analysis do not account for the potential use of these additional activities in helping the United States meet its emissions reduction target under the Kyoto Protocol.

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[24] The United States strongly supports the broadest inclusion of sinks that is supported by sound science. Broad inclusion of sinks has the capacity to help cost effectively address the risks of climate change and provide opportunities for the agriculture and forestry sectors to be a part of the solution. 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 Articles 3.3and 3.4 of the Kyoto Protocol.

Carbon sequestration refers to the storage of carbon dioxide from the atmosphere by soils, trees, crops, and other plants. Carbon “sinks” such as farmland, rangeland, and forests can make a great contribution to reducing net greenhouse gas emissions. Conservation activities such as planting trees on marginal lands, restoring degraded soils, and adopting best management practices that improve water quality, soil quality, and habitat protection also have the added benefit of absorbing carbon.

Carbon sequestration potential. The potential effects of the Kyoto Protocol on U.S. agriculture depend on many factors, such as which types of agricultural and forestry activities are ultimately included by the Parties and how these activities are defined. 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 sequestration must be taken into consideration.

Cropland, grassland pastureland, and rangeland account for almost half of all land in the contiguous 48 states. Significant portions of these areas could be managed to increase the quantity of carbon stored in the soils or in above ground biomass such as trees and plants. Numerous studies of agricultural and rangeland sites in North America have documented how changes in management practices can change levels of soil carbon (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 to 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 to 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 pounds 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 MMT (million metric tons) of carbon 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 MMT. 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 pastureland 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).

Parks and Hardie (1995) provide an assessment of the costs of converting pastureland and cropland to forest cover to sequester carbon dioxide. The authors conduct a simulation of a hypothetical carbon sequestration policy patterned after the Conservation Reserve Program (CRP). In this simulation, land owners would offer bids for setting aside some of their agricultural land to promote carbon sequestration. Land owners whose bids are accepted would receive rental payments for ten years and cost-sharing for establishing forest cover. Land owners would only participate in this hypothetical program if doing so makes them better off economically than not participating. Table IV.1 presents selected results from the simulation.

The Parks and Hardie analysis finds that the average cost of sequestering 44 MMT of carbon annually could be slightly above $10 per metric ton. This sequestered carbon is approximately equivalent to eight percent of the emissions reduction AEA (1998) estimates will be required to comply with the United States' Kyoto target. The analysis also finds that most of the land converted to forests would be pastureland. When the authors only consider cropland, the average cost increases more than 100 percent to over $23 per metric ton and annual sequestration falls by 50 percent to under 20 MMT of carbon.

Stavins (1998) estimates a marginal cost function for carbon sequestration for the United States based on an analysis of land use decisions between 1935 and 1984 for the Delta counties of Mississippi, Arkansas, and Louisiana. This marginal cost function essentially represents the value of a ton of carbon a land owner would need to receive in order to convert land over to the forestry activities necessary to deliver that ton of carbon. Stavins found that, on an annualized basis, approximately 150 MMT of carbon could be sequestered in the United States at a marginal cost of $25 per mt. More carbon could be sequestered, but the cost of sequestration increases at an increasing rate. Stavins also compares his results with the estimated marginal costs of reducing carbon dioxide emissions from fossil fuel combustion from several U.S. energy models. While his sequestration cost curve is generally above the estimated marginal costs from the energy models, the total and marginal costs of sequestering 100 MMT are much less than the total and marginal costs of, for example, moving from 500 MMT of reductions to 600 MMT of reductions in the energy models.

These two studies illustrate several key points. First, modest levels of forestry-related sequestration can occur at very low costs. Forest carbon sinks can serve as an important cost-effective alternative to higher cost emissions abatement in the energy sector, as illustrated by the Stavins analysis. Second, promoting a broad set of sequestration activities and lands is important for cost-effectiveness. As Parks and Hardie found, limiting sequestration activities only to croplands increases the costs per ton while decreasing total sequestration relative to promoting carbon sinks on pastureland and croplands. Third, these studies provide assessments of the sequestration potential by simulating policies that would provide an economic incentive to land owners to convert pastureland and cropland to forest cover. The challenge for policymakers is to design the appropriate institutions and conditions that will allow private sector firms to take advantage of the potentially low cost sequestration opportunities. If well-functioning institutions can be designed, then the marginal cost of sequestering carbon would be approximately the same as the marginal cost of abating emissions from fossil fuel combustion in the U.S. and approximately the same as the price of an internationally-traded emissions permit.

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 of more. Carbon in forest soils, on the other hand is primarily a function of fine root turn-over near the surface and tree litter. In 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 the 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 MMT—or 5.76 MMT 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 pounds per acre per year—implying a 25 million acre program would sequester a total of 11.36 MMT of carbon per year.

Land Management Activities. Managing crop and pasturelands 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[25]. Economic analysis on the potential costs and benefits of these practices to mitigate GHG emissions is limited although new analysis is currently underway at the 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 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 MMT and 339 MMT over a 30 year period (Table IV.1, part B). This suggests that shifting 20 million acres into no-till would result in between 6.9 MMT and 11.3 MMT of carbon being sequestered annually—or between 1.2 percent and 2.0 percent of the U.S. target for complying with the Kyoto Protocol in 2010[26].

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[25] Many of these practices are linked to a variety of environmental benefits such as improved water quality and reductions in soil 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, ERS, 1998a).

[26] To put this in perspective, conservation tillage increased from 2.0 percent of U.S. cropland in 1968 to 36 percent in 1996, while acreage over 1992 to 1996 was almost constant—although acres under no-till increased from 9.9 percent of all cropland to 14.5 percent (USDA, ERS, 1998b). 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, 1997a). This suggests that economic incentives would probably be a significant component of any

A key focus of policies to promote agricultural carbon sinks will be to address permanence issues. Managing land to sequester carbon for a few years and then returning it to production, or resuming conventional tillage, 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, ERS, 1998b). To assess how policies might facilitate and encourage long term carbon sequestration activities, 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 (Wiebe *et al*, 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, establishing agricultural GHG sinks within the framework of the Kyoto Protocol creates a new economic interest in farm land, namely the right to 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 sequester carbon when the present value of its net returns exceeded similar income streams associated with other commodities over some relevant time horizon.

At present, however, the details of any future market for carbon sequestration are largely uncertain because many of the factors that would define this market are still being debated by the Parties to the Kyoto Protocol. The design of domestic policy will at least partially depend on the outcome of this debate.

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effort to mitigate GHG emissions via the expanded use of conservation tillage.

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 CH_4 emissions through changes in methods of handling animal wastes and changes in livestock feeds, reducing agricultural emissions of N_2O through altering the use of nitrogen fertilizers and other farm chemicals, and producing biomass crops for fuels, chemicals, and energy generation.

Expanding production of biomass crops could help mitigate U.S. GHG emissions in two ways. First, farmers could produce biomass utilizing practices that increase soil carbon levels. Second, biomass can be used to create fuels, chemicals, and energy. Energy generated by burning biomass replaces energy generated by fossil fuel combustion, and represents 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, a tradable permit system for greenhouse gas emissions would enhance the competitiveness of biofuels. Furthermore, 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 permit price needed to meet U.S. emissions reductions obligations. 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 Turnere, Winnett, Shackleton, and Hohenstein, 1995 for discussions on the economics of biomass).

Summary. Under the Kyoto Protocol, net emissions resulting from afforestation, reforestation and deforestation are counted towards a country's target. In addition, the Parties can add additional sink activities, such as those related to agricultural soils and other forestry management activities. Numerous studies suggest that improved management practices such as conservation tillage, use of winter cover crops, and rotational grazing can significantly and cost-effectively increase the carbon stored in U.S. agricultural soils. Studies also indicate that converting marginal agricultural lands to forests can be a cost-effective means of sequestering significant quantities of carbon. In addition, bioenergy – using trees, crops, and agricultural wastes to produce power, fuels or chemicals – represents a potentially significant opportunity to both reduce net greenhouse gas emissions and supplement farm income.

The challenge for policymakers in the years to come will be to develop the institutions and promote the conditions that will allow the private sector to take advantage of these and other potentially low cost sequestration opportunities. 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 the Kyoto Protocol and the set of government policies implemented to achieve U.S. emissions reductions obligations.

Table I.1: Agricultural sources of greenhouse gas emissions, 1990-96 (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_2O)	92.3	94.4	96.8	97.1	104.9	101.0	103.7
Carbon Dioxide (CO_2)	1348.3	1333.2	1353.2	1385.6	1408.5	1419.2	1471.1
Agricultural Emissions (CH_4 N_2O)	**105.7**	**107.5**	**109.3**	**110.9**	**114.8**	**114.4**	**114.0**
CH_4, total	**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
N_2O, 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
Agricultural Soil Management	52.0	52.9	53.5	54.8	56.6	55.9	56.5
Agricultural Residue Burning	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Agricultural Emissions (CH_4 N_2O) 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.

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
Francl (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 permit prices would affect input prices and production cost of selected commodities. 2. Permit prices 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 percent in the low scenario and 11.7 percent in the high scenario. 2. See Table II.2 for impacts on agricultural input prices.
Sparks (1999): results in 1997 dollars	1990, 7 percent.	$177-193 per metric ton.	1. Uses DRI model to define baseline and assess macroeconomic impacts of each scenario. No phase-in period. 2. Estimates how carbon permits 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 percent) and food processing and marketing costs $18 billion (2.6 percent). b. reduce domestic food demand 0.8 percent c. decrease farm income nearly 53 percent from 1998 d. increase farm consolidation e. increase food imports and decrease food exports.
McCarl et al. (1997); results in 1997 dollars	No specific target.	Considers permit prices of $25, $50, and $100 per short ton of carbon.	1. Permit prices occur all at once and 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 tradable permit system in 2000, 2005, 2010, 2015, and 2020.	1. U.S. agriculture is not very sensitive to 2. Permit prices. 3. Permit prices of $25, $50, and $100 / ton would cost the farm sector, respectively, $450, $850, and $1,600 million annually. Annual permit price 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: Comparison of input cost increases across agricultural sector analyses.

Study	Input	Policy Scenario		
Francl		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 $ per metric ton of carbon)		
		$177 to193		
		--percent--		
	Fuels and Oil	30		
	Electricity	100		
	Fertilizer and lime	100		
	Pesticides	50		
McCarl *et al.*				
		Permit Price (1997 $ 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 analysis of the Kyoto Protocol.

Emissions Target:

U.S. greenhouse gas (GHG) emissions target is set 7 percent below 1990 levels between 2008 and 2012. Gases covered are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydroflurocarbons (HFCs), perfluocarbons (PFCs), and sulfur hexafloride (SF_6).

Methodology:

1. Construct regional "business as usual" (BAU) GHG emissions scenarios for 2010.
2. Develop regional marginal abatement cost curves for reducing GHG emissions.
3. 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 percent annually.
4. No banking of emissions allowances for later periods.
5. No emissions mitigation related to electricity sector restructuring, the Climate Change Technology 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 I:	Unrestricted trade of emissions permits among Annex I countries.
Umbrella 1:	Unrestricted trade of emissions permits among Annex I countries minus Eastern Europe and the European Union (EU).
Umbrella 2:	Unrestricted trade of emissions permits among Annex I 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 international trading.:

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

Scenario	Reduction in permit price (percent)	Reduction in U.S. direct resource costs (percent)
Annex1	72	57
Umbrella1	75	61
Umbrella2	85	74
Annex1+KDC *	88	80
Umbrella1+KDC	91	83
Umbrella2+KDC **	93	87
Annex1+CDM	79	66
Umbrella1+CDM	82	71
Umbrella2+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 percent (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 percent and annual household energy costs $110.
b. raise electricity prices 5 percent and gasoline prices 4 percent (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)	Carbon Content	Input Price Increase*	
		$ / unit	pounds / unit	$ / 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 analysis with carbon permit price of $23 per metric ton.

[1] U.S. Department of Energy, Energy Information Agency, 1997b.
[2] U.S. Department of Energy, Energy Information Agency, 1997c.
[3] Wiese, 1998.
[4] Helsel, 1992.

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

Crop	Unit		Price		Production		Domestic use		Exports	
			Base 2010	$23/mt	Base 2010	$23/mt	Base 2010	$23/mt	Base 2010	$23/mt
			--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		0.02		-19.7		-0.7		-10.6
		% change		0.62		-0.2		0.0		-0.3
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	Hundredweight		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
Crops						-- million dollars --						
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 Payments	% change	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
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
		40.5	40	31,154.8	31,862.9
All energy	Change		-0.4		708.1
	% Change		-1.0		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 the Kyoto Protocol.

Measure			U.S. Total
			million dollars
Producer Surplus	Base		1,096,957
	$23/mt	Change	-417
		% change	-0.04
Net farm cash	Base		74,215
Returns[1]	$23/mt	Change	-371
		% change	-0.5
Consumer surplus	Base		822,239
	$23/mt	Change	-374
		% change	-0.05
Consumer and	Base		1,919,196
producer surplus	$23/mt	Change	-791
		% change	-0.04
Revenue transfers out of agriculture sector[2]			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] Equal to revenues from a permit auction or the value of permits grand fathered up the energy stream of agricultural energy users.

Δ Net social benefit = Δ Consumer surplus + Δ Producer surplus + Permit revenue

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

Table III.9: Changes in erosion and water related nitrogen losses[1].

Indicator			North East	Lake States	Corn Belt	North Plains	Appa-lachia	South East	Delta States	South Plains	Moun-tain	Pacific	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	-.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 volitization.

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 Pastureland

Lands Targeted:	---- Cropland and Pasture ----		----------- Cropland -------------	
Objective:	Minimize Cost per Acre	Minimize Cost per Ton Carbon	Minimize Cost per Acre	Minimize Cost per Ton Carbon
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

, Parks and Hardie, 1995.

B. 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						
Conventional	-41	-31	-52	-121	-24	-18	-30	-87	-13	-9	-16	-67
Minimum	0	0	0	-30	0	0	0	-52	0	0	0	-66
No-till	0	0	0	-6	105	80	129	-10	377	286	468	-13
Total	-41	-31	-52	-157	80	62	99	-149	364	277	452	-146
Net Gain or Loss	-198	-188	-209		-69	-87	-50		218	131	306	

Scenario 1: 27 percent of current cropland is in conservation tillage 27 percent (20 percent in minimum till and 7 percent in no-till)
Scenario 2: Conservation tillage increases to 57 percent of all cropland (implies 60 million acres in conservation tillage).
Scenario 3: Conservation tillage increases to 76 percent of all cropland (implies 80 million acres in conservation 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 PERMIT PRICES

Several studies (such as Charles Rivers Associates, 1998 and DRI/McGrawHill, 1997) conclude that permit prices will be greater than those predicted in the AEA. While these analyses are not consistent with the provisions of the Kyoto Protocol, the higher permits prices have been used in several analyses of the agricultural sector. For comparison, we provide multipliers to compute the agricultural sector impacts for a range of tradable permit prices. Appendix Table A1.1 reports multipliers which can be used to calculate the economic impacts for any permit prices.

Examples of using the multipliers follows: from Table A1.1, Net Cash Returns for Crops and Livestock are projected to be $74,214.9 million in 2010. Using the multiplier, Net Cash Returns with a $50 permit price would be $73,450.9 million ($74,214.9 - ($50/$50)*$763.3 million). Assuming a $100 permit price, Net Cash Returns decline to $72,688.5 million ($74,214.9 - ($100/$50) * $763.3 million). Multipliers are presented for crop prices and production, crop domestic use and exports, income, total expenses, and welfare measures.

The impacts on the agricultural sector increase as carbon prices increase . However, even with significantly higher carbon prices, the impacts on the agricultural sector remain far below those predicted by Sparks (1999) and Francl (1997) because our analysis more accurately reflects the carbon content in farm production inputs and takes into consideration market adjustments.

Table A1.1. 2010 key variables under Kyoto Protocol and multipliers for alternate permit prices.

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-weight	12.87	12.98	0.23135
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-weight	206.4	204.4	-4.14855
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-weight	7.00	6.98	-0.0420
Soybeans	Bushel	152.17	152.12	-0.10410
Cotton	Bale	13.20	13.16	-0.1090
Silage	Ton	27.52	27.43	-0.2079
Hay	Ton	79.22	78.66	-0.59850

Item	Unit	2010 base level	$23/ton permit price	Change per $50 permit price change[1]
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-weight	85.40	83.65	-3.73210
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	100,665.00	276.93
Conservation Reserve Payments		933.10	933.10	0.00
Production Flexibility Payments		4,009.70	4,009.70	0.00
Total variable costs		55,037.70	55,486.10	940.42
Net cash returns		50,435.20	50,121.70	-663.49
Livestock				
Value of Production		117,329.30	117,644.00	657.34
Total variable costs		93,549.60	93,922.10	757.15
Net cash returns		23,779.70	23,721.90	-99.81
Crops and Livestock-				
Value of Production		217,859.40	218,309.00	934.28
Total variable costs		148,587.30	149,408.20	1,697.57
Net cash returns		74,214.90	73,843.50	-763.29
Welfare Measures				
Producer Surplus		1,096,957	1,096,540	-888.81
Net farm cash returns		74,215	73,844	-763.29000
Consumer surplus		822,239	821,865	-798.90
Consumer and producer surplus		1,919,196	1,918,405	-1690.10
Revenue transfers out of agriculture		0	724	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 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 energy use peaked in 1978, declining in response to the oil price shocks of the 1970s and early 1980s (Table A2.1). By 1993, fossil energy use declined by 25 percent, but electricity use increased by about 17 percent (ERS, 1997a).

Major factors affecting agricultural use of refined petroleum products and electricity are planted acreage and irrigated acreage (ERS, 1997a; and Uri and Gill, 1995). Irrigated land in farms increased from 46.4 to 53.3 million acres between 1987 and 1996 (Appendix Table A2.2). Planted acres over the period 1990 to 1996 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. Annual agricultural commodity cash receipts are about $203 billion (1996 through 1998[3])—about 53 percent from crops and 47 from livestock (Table A2.3). The crop proportion is slightly higher than the 51 percent share from 1989 through 1998. Energy related expenses are about $40 to 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, although there has been a slight increase since 1994. This increase has been 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 use with long-run shifts in relative prices and technology changes. 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 machinery, labor, and energy use. 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

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[3] Values for 1998 are USDA ERS forecasts.

costs of pumping and the returns to irrigation, and over time efficiency gains have occurred with irrigation (ERS, 1997a).

Crop enterprises. Expenditures by commodity for direct energy, chemicals, and other energy intensive inputs range between about 30 and 75 percent of total crop cash expenses (Appendix Table A2.4). As a share of total cash expenditures, this sum is quite stable across each crop's reporting regions. For corn, expenditures for direct energy, chemicals, and other energy intensive inputs range from 66 percent of total cash expenses in the Northeast to 70 percent in the Plains States. Similarly, for wheat, expenditures for direct energy, chemicals, and other energy intensive inputs range from 57 percent of total cash expenses in the Northern Plains to 66 percent in the North Central.

Although regional expenditures for direct energy, chemicals, and other energy are a fairly constant share of total expenses, there is considerable variation in direct energy and chemical expenditures and shares of total cash expenses. For example, in corn production direct energy expenses vary from 8.7 percent to 22 percent of total cash expenses. reflecting the differences in production techniques across the country. The data in Appendix Table A2.4 are regional averages—considerable variation would be expected within regions, driven by land quality, farm type, land tenure and other factors. The regional stability in the share of total cash expenses accounted for by direct, chemical, and other energy related expenses probably reflects competitive profit maximizing relationships among commodity and input prices and land productivity.

Livestock Enterprises. Energy related expenses as a share of total cash expenses range between about 6 and 33 percent for livestock (dairy, cow–calf, and hogs) and broilers (Appendix

Table A2.5). 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, which are among the crops highest in energy expenses.

Dairy, with power requirements for cooling and milking equipment, 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 are higher marketing and hauling expenditures. 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 cost increases (ERS, 1998c).

Appendix Table A2.1. Use of energy inputs in U.S. agriculture; 1978 and 1990-94.

Year	Gasoline	Diesel	LP gas	Electricity	Nitrogen	Phosphate	Potash	Pesticide
		billion gallons		billion kWh		million pounds		
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 Table A2.2. 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
							cents per Kwh.				
Electricity (Retail industrial rate) [4]	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 Table A2.3. 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													
Manufactured inputs													
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
Other expenses													
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
Total Energy Related Expenses		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 Table A2.4 . Cash expenses that include energy for U.S. field and horticultural crops, 1996

Commodity	Region	Direct Energy (1) $ per planted acre	Direct Energy (1) Percent of total	Chemicals (2) $ per planted acre	Chemicals (2) Percent of total	Other Inputs[2] (3) $ per planted acre	Other Inputs[2] (3) Percent of total	Sum (1)+(2)+(3) $ per planted acre	Sum (1)+(2)+(3) Percent of total	Total Cash Expenses[1] $ per planted acre	Revenue $ per planted acre	Expense/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	54.5
	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	58.3
Sugar Beets	United States	41.64	9.6	144.8	33.3	42.15	9.7	228.59	52.5	435.18	746.61	58.3
	Great Lakes	22.77	7.7	131.49	44.2	28.35	9.5	182.61	61.4	297.2	439.68	67.6
	Red River Valley	21.87	6.7	112.8	34.7	24.88	7.6	159.55	49.0	325.43	698.52	46.6
	Great Plains	53.53	11.1	167.75	34.8	38.86	8.1	260.14	54.0	481.49	692.29	69.6
	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	64.8
Sugarcane	United States	29.80	4.3	135.26	19.6	70.30	10.2	235.36	34.1	690.16	979.40	70.5
	Florida	23.79	3.1	119.15	15.7	104.81	13.8	247.74	32.6	760.95	1040.40	73.1
	Hawaii	93.51	3.7	450.15	17.8	62.57	2.5	606.23	24.0	2526.63	2645.37	95.5
	La/Texas	29.73	7.2	119.48	29.1	31.89	7.8	181.09	44.1	410.67	727.00	56.5
		$ mil.	percent	$ mil.	percent	$ mil.	percent		percent	$ mil.	$ mil.	percent
Horticultural	United States	2386	9.8	2275	9.4	2874	11.8	7535.31	31.0	24308	38497	63.1

[1] Total cash expenses for commodities include cash expenses as reported in ERS Cost of Production tables.

[2] 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.

[3] Expenses including energy as a proportion of cash expenses.

[4] 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 web page, http://www.econ.ag.gov/briefing/fbe/car/car.htm, and USDA-ERS-RED-FSP.

Appendix Table A3.5. Cash expenses that include energy for U.S. livestock enterprises (1996) and broiler farms (1995)

Enterprise and Region	Fuel, Lub., and Electricity.		Marketing and Hauling		Custom Services.and Sup.		Energy[2]	Animal Feed		Total Cash Expenses	Revenue
	Expense	Share of Total	Expense	Share of Total	Expense	Share of Total	Share of Total	Expense	Share of Total		
Dairy	$ per cwt. milk	percent	$ per cwt. milk	percent	$ per cwt. milk	percent	percent	$ per cwt. milk	percent	$ per cwt. milk	$ per cwt. milk
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
Cow-calf	$ per bred cow	percent	$ per bred cow	percent	$ per bred cow	percent	percent	$ per bred cow	percent	$ per bred cow	$ per bred cow
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
Hogs	$ per cwt. gain	percent	$ per cwt. gain	percent	$ per cwt. gain	percent	percent	$ per cwt. gain	percent	$ per cwt. gain	$ per cwt. gain
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
Broilers[3]	$ per farm[4]	percent	$ per farm[5]	percent	$ per farm	percent	percent	$ per farm[6]	percent	$ per farm	$ per farm
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

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[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 in "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 web page, 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 sector[4]. 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. 1987 and 1992). 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, 1980), USMP incorporates agricultural commodity supply, use, and policy measures (House, 1987), as well as natural resource and environmental impacts derived through biophysical models (Faeth, 1995).

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

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[4] 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.

analysis with a 2001 base year, USMP's base U.S. corn acreage planted equals the USDA baseline's 2001 projection (80.5 million acres), and corn acreage in each model region/cropping practice strata is determined by share information from the USDA National Resources Inventory (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, 1995) with U.S. aggregate commodity supply response calibrated to supply response elasticities from the FAPSIM econometric simulation model (Green and Price, 1987)[5]. 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

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[5] The 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.

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 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.*, 1990) For each "baseline" solution or alternative scenario, the USMP 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.*, 1985), trade agreements (Burfisher *et al.*, 1992), beef imports (Spinelli *et al.*, 1996), input taxes (Peters *et al.*,1997), irrigation policy (Horner *et al.*, 1990), ethanol production (House *et al.* 1993), wetlands policy (Heimlich *al.* 1997), 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 model 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. Environmental coefficients for each crop rotation and tillage system in USMP are calculated as the 60-year average results from calibrated EPIC simulations.