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Economic Impacts of Global Climate Change on the Great Lakes Region

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Abstract

Global climate change has been widely discussed in the academic literature and the popular press. Yet beyond sweeping generalizations or lists of possible effects, this discussion has not addressed what global climate change will mean for individuals in specific terms of job losses or gains, wage and income effects, unemployment impacts, or population change. A report prepared by the Committee on Earth and Environmental Sciences as a supplement to the President's Fiscal Year 1992 budget highlights this problem by stating that current global climate analyses "...have been hampered by a lack of fundamental economic research on resource-economy-environmental interactions"

The lack of research identifying such economic impacts is compounded by the geographic level of most analyses. Climate change research has been conducted primarily at the global level. However, neither the impacts of climate change nor climate change itself will be geographically uniform -- both will be region-specific -- implying that economic impacts must be addressed from a regional perspective.

This regional approach is even more critical to identifying and evaluating various strategies for prevention or mitigation of the effects of climate change. Given the spatial dimensions of climatological effects and ecological systems, prevention and adaptation strategies will have considerable regional variation, so that a regional perspective is necessary to provide an accurate assessment of the economic consequences of specific strategies. Only by assessing the combined ecologic, economic, and human effects of global climate change in a framework that incorporates the ability of ecological and economic systems to adapt, can various prevention and mitigation alternatives be examined and compared effectively.

In the Great Lakes region, global climate change would primarily impact nine economic sectors. These are agriculture and forestry, energy, construction, shipping, fisheries, recreation, manufacturing, retail/commercial trade, and the public sector. Determining the impacts of global climate change on these sectors in terms of income, employment, and wage effects, and developing prevention/mitigation strategies for the Great Lakes, demands an interdisciplinary research effort to address interactions between environmental effects and their resulting economic impacts. While some interdisciplinary research of this type has been undertaken, much more is required to identify these interactions. The need for additional research to establish regional environmental-economic linkages is severe.

The most promising approach to delineating the full spectrum of economic impacts of global climate change on the Great Lakes Basin is a multi-equation, econometric economic-environmental model focused primarily on the seven-state U.S. region and the Canadian province of Ontario. Such a model could translate climate-change effects on temperature, precipitation, lake level, biological productivity, and ecosystem health into economic impacts. Research hypotheses concerning the interaction of climate-induced environmental and economic effects could be tested as part of the modeling framework. Moreover, the validity of the econometric modeling methodology in this context has clearly been demonstrated by the utilization of a similar modelling framework by the author to identify the economic impacts of global climate change for the Pere Marquette Basin in west central Michigan.

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Introduction

Global climate change has been widely discussed in the academic literature and the popular press. Yet beyond sweeping generalizations or lists of possible effects, this discussion has not addressed what global climate change will mean for individuals in specific terms of job losses or gains, wage and income effects, unemployment impacts, or population change. A report prepared by the Committee on Earth and Environmental Sciences as a supplement to the President's Fiscal Year 1992 budget highlights this problem by stating that current global climate analyses "...have been hampered by a lack of fundamental economic research on resource-economy-environmental interactions" (17). The report identifies the following critical research priorities:

- to document economic system and sector trends that determine economic inputs and sensitivities to global change;
- to focus studies on economic issues surrounding inputs, consequences, and responses to global change, and;
- to develop interdisciplinary linkages to address issues that cross-cut the natural and economic sciences.

The lack of research identifying such economic impacts is compounded by the geographic level of most analyses. Climate change research has been conducted primarily at the global level. However, neither the impacts of climate change nor climate change itself will be geographically uniform -- both will be region-specific -- implying that economic impacts must be addressed from a regional perspective.

This regional approach is even more critical to identifying and evaluating various strategies for prevention or mitigation of the effects of climate change. Given the spatial dimensions of climatological effects and ecological systems, prevention and adaptation strategies will have considerable regional variation, so that a regional perspective is necessary to provide an accurate assessment of the economic consequences of specific strategies. Only by assessing the combined ecologic, economic, and human effects of global climate change in a framework that incorporates the ability of ecological and economic systems to adapt, can various prevention and mitigation alternatives be examined and compared effectively.

Global Climate Change

In 1827, the French mathematician Baron Jean-Baptiste-Joseph Fourier first predicted a probable increase of 4 to 6 °C in the Earth's temperature subsequent to a doubling of carbon dioxide released from burning fossil fuels (22). In 1896, the Swedish chemist, Svante Arrhenius, made the first forecast of global warming based upon increasing concentrations of atmospheric carbon dioxide (1).

The greenhouse effect is now one of the most well-established theories in atmospheric science. Yet the threat of the greenhouse effect and global warming received little attention until 1957, when it was reported that the oceans were not absorbing carbon dioxide at a previously assumed rate (43).

Since then, an astounding level of research has been conducted on the climatic effects of the accelerated generation of greenhouse gases. As a result, it is believed that climate changes impact biological diversity, wildlife and habitat fragmentation, species extinction, hydrology and water resources, agriculture and food resources, fishing and fisheries, human health, transportation, energy consumption and demand, and insurance costs. The concern over global climate change has stimulated and accelerated research and development efforts aimed at forecasting climate trends. Predicting global climate change has been largely rooted in the use of general circulation models (GCM) based on numerical simulation methods, as well as various reconstructions of past climates (5, 11, 36).

GCMs, however, were not designed for climatic analysis; are relatively young so that their predictions are difficult to place within confidence limits; are difficult to build, maintain, and use (44); and are limited by computer resources (26). Despite these limitations, Robinson suggests that GCM results can be used to "establish background scenarios for economic, demographic, and resource trends that are to be anticipated concurrently with possible climatic change over the next 2-12 decades." (44)

There has been some regional research utilizing GCMs. Comparisons of the different models' projections for specific resource regions include the potential effects of climate change on soil moisture (24, 32); regional GCM temperature and precipitation simulations (21, 47); and the potential effects of climate change on water resources of the Great Lakes basin (13,14,15, 18). One of the most comprehensive studies utilizing GCMs for regional analysis was prepared by Smith and Tirpak for the Office of Research and Development of the U.S. Environmental Protection Agency (EPA) in 1990, and focused on the Great Lakes (49). The results of this study are described in the next section.

Economic Impacts of Climate Change and the Great Lakes Economy

No agreement exists about the full nature and magnitude of the economic effects of global warming. Nordhaus (38, 39) predicts that 3% of U.S. national income is sensitive to climate change, and that global warming will lead to a 0.25% decrease in GNP, or a loss of approximately $14 billion per year. Cline (12), however, predicts a $61.6 billion per year decrease in national income for a 2.5 degree Celsius rise in temperature, and a decrease of $335.7 billion per year if temperature rises 10 degrees Celsius. Although the major impacts of global climate change are not predicted to occur until well into the next century, rare "weather events," such as blizzards and severe droughts, are becoming more common. This increased frequency of weather events is believed to be correlated with temperature increases which may be a result of global warming. The average global cost of these events is estimated at $40 billion per year (30). The drought of 1988 alone cost the United States an estimated $39 billion (10); the heavy snow of 1982 accounted for $6 billion in direct losses (27); the severe winter of 1976-77 cost the U.S. $40 billion in production, transportation, retail sales, and energy consumption losses; and the 1980 heat wave/drought cost another $15-20 billion. Such weather events affect not only GNP, but also impact migration patterns, the mix of business activity in a region, and the adaptation of new technology. The "dustbowl" drought of the 1930s illustrates how a weather event may cause large changes in each of these areas.

The U.S. portion of the Great Lakes region encompasses one tenth the U.S. land area, one fifth the population, and leads the country in key economic sectors, including agriculture and manufacturing. The region has fertile soils, abundant northern forests, moderate temperatures, plentiful rainfall, and inexpensive transportation. On the Canadian side, Ontario borders four of the five Great Lakes and is Canada's most populous and second largest province. However, the rich water resources in the Great Lakes (containing 18% of the world's and 95% of the U.S.'s fresh water), which are vital to the economic livelihood of the region, are severely threatened by global climate change and the potential redistribution of water resources.

The most recent and comprehensive study of the impacts of climate change on the Great Lakes region was prepared by Smith and Tirpak for the Office of Research and Development of the U.S. Environmental Protection Agency (EPA) in 1990 (49). Their conclusions were that "global climate change could affect the Great Lakes, by lowering lake levels, reducing the ice cover, degrading water quality in rivers and shallow areas of the lakes...expand agriculture in the north, change forest composition, decrease regional forest productivity in some areas, increase open water fish productivity, and alter energy demand and supply." In addition to Smith and Tirpak's work, empirical climate change research efforts in the Great Lakes region have been directed at lake levels (7, 9, 19, 25, 42), limnology (8, 35), ice cover (2,3), fishing and fisheries (33, 37), and economic issues.

In the Great Lakes region, global climate change would primarily impact nine economic sectors. These are agriculture and forestry, energy, construction, shipping, fisheries, recreation, manufacturing, retail/commercial trade, and the public sector. Great Lakes agricultural production is valued at almost $10 billion per year. Although no projections of the overall impact of global warming on the Great Lakes states yet exist, Cline (12) estimates annual U.S. agriculture losses at $5.9 billion, given a 2.5 degree Celsius rise in mean temperature. This problem is exacerbated by the uniformity of crop gene pools, which make them more vulnerable to weather shifts (45, 46). Global climate change will also change the composition, abundance, and values of forest biomasses. Although an increase in high latitude forest biomass is expected, especially in Canada, potential dry sites in central Michigan will decrease biomass by as much as 77-99% within 30-60 years (29). Van Kooten (50) and Singth and Higinbotham (48) predict other impacts, including more frequent and intense forest fires and increased insect activity. The results of tree species migration will also impact forest related industries and forestry management (30, 41, 50).

The benefit of global climate change to the construction industry in the Great Lakes region is a prolonged building season. The costs, due to temperature rise and increasing severe storms, are lost work days, damaged materials, and a 30-40% increase in the costs of building coastal or lakeshore homes (23). A one degree Celsius increase in temperature above the optimal can cause a 2-4% decrease in productivity (31). Lower lake levels in the Great Lakes could mean hundreds of millions of dollars in reconstruction costs for marinas, port facilities, water supply and outfall sources, and beaches (49).

Although global climate change is expected to reduce the ice cover [thereby leaving the lakes free for navigation eleven months of the year (42)], low lake levels due to increasing consumptive water use, changing precipitation patterns, and evapotranspiration are expected to offset this benefit (28, 29, 34, 49). Mean annual costs to shipping are expected to rise 30%, with the low lake levels of the 1960s occurring as often as 77% of the time (34). Several studies predict that with increasing consumptive water use and a decreasing net basin supply, water rights conflicts will intensify (9, 13, 14, 15).

The Great Lakes fishing industry accounts for a total indirect and direct regional income estimated at $2.3-4.3 billion (52). Bakun (4) predicts that an increase in the production of fisheries will occur in areas of warm upwelling. However, analysis of historical patterns suggests that increased levels and types of invading species to the Great Lakes will continue to alter fish communities (33). Warmer lake temperatures, for example, will be more conducive to some fish species such as bass, but less supportive of species such as trout. Lower water levels or warmer water in the streams and rivers feeding the Great Lakes could reduce suitable spawning habitat of several Great Lakes species. Changes in either the quantity of fish or the mix of species would likely have important impacts on both commercial and sport fishing. A reduced flow of water into the Great Lakes could also increase water pollution levels, even with no increase in pollution discharge. Increased water pollution could, through bioaccumulation, increase pollution concentrations in Great Lakes fish, eventually diminishing their suitability for human consumption even if fish populations did not increase. In addition, such increased pollutant concentrations will reduce water quality, thereby reducing fish production (49).

These are critical climate-related issues for the Great Lakes Basin and the U.S. Agricultural and manufacturing industries have the potential for adaptation/mitigation via migration to more hospitable locations. In the case of the Great Lakes fisheries, however, there is far less migration potential. While lakes in other locations may become suitable for some Great Lakes species, the Great Lakes' scale offers a unique habitat for many fish species. Thus, in the Great Lakes Basin, the emphasis must be on adaptation of a specific and unique resource.

A warmer climate is likely to provide a net increase to Great Lakes vacation and recreation activities. Camping, canoeing, boating, golf, hunting, and sports fishing will increase, and downhill skiing, cross-country skiing, and snowmobiling will decrease (20, 51). Tourism to the 67 state and 3 national parks along the Great Lakes' U.S. shores is expected to rise, so much so that overuse may become a problem (49). Canada would likely have similar impacts. The primary direct impacts of global climate change on manufacturing and retail/wholesale trade will be through changes in energy use and other consumption patterns. The effects of weather on manufacturing industries have been studied extensively (3, 31, 40). Water resource consumption in other regions is likely to benefit the Great Lakes as high-technology companies are drawn to large sources of clean water. These companies will be competing with traditionally inefficient water use and polluting industries, such as pulp and paper and waste disposal. An effect of climate change on the public sector may be a reduction in tax base as lakeshore land values drop due to lower lake levels and increased pollutants, although these may be partly offset by in-migration from coastal regions (49). Increased demand for public expenditures for disaster relief could occur due to severe weather events, with potential increases in public sector employment.

Identifying Specific Employment, Income, and Unemployment Effects

Although the description of the potential economic impacts of global climate change contained above is illustrative of the effects that are likely to occur within the Great Lakes Basin, this discussion does not detail the specific impacts on jobs, wages, income, unemployment, etc. To determine the impacts of global climate change on such traditional indicators of economic health, and to develop prevention/mitigation strategies for the Great Lakes, demands an interdisciplinary research effort to address interactions between environmental effects and their resulting economic impacts. While some interdisciplinary research of this type has been undertaken, much more is required to identify these interactions. Moreover, the interdisciplinary research that does exist is limited in scope to some specific sectors. The need for additional research to establish regional environmental-economic linkages is severe.

The most promising approach to delineating the full spectrum of economic impacts of global climate change on the Great Lakes Basin is a multi-equation, econometric economic-environmental model focused primarily on the seven-state U.S. region and the Canadian province of Ontario. The inclusion of Ontario in such an analysis is critical, for this province contains much of the watershed that drains into four of the five Great Lakes, and adaptation to climate change in Ontario could have an important impact throughout the Great Lakes system.

Such a model could translate climate-change effects on temperature, precipitation, lake level, biological productivity, and ecosystem health into economic impacts. Research hypotheses concerning the interaction of climate-induced environmental and economic effects could be tested as part of the modeling framework. Moreover, the validity of the econometric modeling methodology in this context has clearly been demonstrated by the utilization of a similar modelling framework by the author to identify the economic impacts of global climate change for the Pere Marquette Basin in west central Michigan. The employment component of this model, together with an assessment of the initial employment impacts, is provided in Tables 1 through 4.

The results of the estimation process for the nine employment equations of the Pere Marquette model reveal a definite relationship between climate variation and regional employment. These linkages between climate and regional economic activity are summarized in Table 3, which identifies the seven climate variables which are statistically significant in the equations; presents the relevant coefficients for each equation in which these variables appear; and provides the net change in the region's total employment that would result from a one unit change in each climate variable.

The regression coefficients presented in Table 3 can be further utilized to derive employment impacts under various global climate change scenarios. A forecast of a 3.94 degree C increase in surface air temperature and a 10.1 % increase in precipitation as a result of global climate change has been derived for the Great Lakes region by Karl, *et al.* (53). This climate change scenario assumes a doubling of CO_2 in the atmosphere, and was generated by averaging the projections of five General Circulation Models. For the Pere Marquette region, the average ratio between mean temperature and precipitation levels in the study area and peak and mean summer and winter levels were used to derive projections of these latter variables. Table 4 displays the potential employment impacts of this climate change scenario for the four-county study area.

At first glance, the employment impact estimates in Table 4 would seem to indicate that the consequences of climate change on the region would be minimal -- a net loss of 94 jobs. But a more detailed examination of Table 4 reveals that the net employment change obscures substantial sectoral impacts. The analysis projects a loss of 818 jobs in manufacturing and 169 jobs in transportation/public utilities, and a gain of 1,049 jobs in the services sector. Such a substitution of low-paying services employment for the higher-paying jobs in manufacturing and transportation/utilities exacerbates existing trends in this direction. The sensitivity of each sector to the specific elements of climate change -- variation in mean temperature, peak temperature, precipitation level, etc. -- can also be evaluated.

It is precisely this type of modeling framework which is required to determine the specific economic impacts of global climate change on the Great Lakes region. Not only can these impacts be estimated, but such a modeling structure can be used to help derive public policy that can mitigate the negative effects which will surely arise.

Table 1. Employment Equations for the Pere Marquette Global Climate Change Impact Model

1. Farming

$$\text{RE\_FARM} = \underset{(6.891)}{4413.151} - \underset{(-7.130)}{44.427}\ \text{RWFARM} - \underset{(-2.065)}{1.325}\ \text{NI\_FOOD} + \underset{(1.902)}{0.228}\ \text{L\_EFARM} - \underset{(-3.443)}{28.780}\ \text{AVG\_DTMP}$$

R-SQUARE = 0.9603 DW = 2.578 N = 21

2. Construction

$$\text{RE\_CONST} = -\underset{(-11.820)}{1499.426} + \underset{(4.341)}{0.0462}\ \text{RE\_TOTAL} + \underset{(23.765)}{2471696}\ \text{RLWGCON} + \underset{(6.765)}{0.470}\ \text{GNP82} - \underset{(-6.288)}{31.641}\ \text{RWCON}$$

R-SQUARE = 0.9851 DW = 2.350 N = 22

3. Manufacturing

$$\text{RE\_MFG} = \underset{(2.852)}{38212.160} - \underset{(-8.253)}{146.627}\ \text{RWMFG} + \underset{(7.908)}{1.945}\ \text{GNP82} + \underset{(6.720)}{12943255}\ \text{RLWGMFG} - \underset{(-2.309)}{29.833}\ \text{WIN\_DTMP} - \underset{(-3.479)}{71.703}\ \text{SUM\_DTMP}$$

R-SQUARE = 0.9410 DW = 1.919 N = 22

4. Finance, Insurance and Real Estate

$$\text{RE\_FIRE} = -\underset{(-1.721)}{681.516} + \underset{(2.593)}{0.368}\ \text{RE\_TR\_UT} + \underset{(19.333)}{0.116}\ \text{R\_PCI} + \underset{(2.594)}{0.010}\ \text{R\_POP}$$

R-SQUARE = 0.9881 DW = 1.366 N = 22

5. Services

$$\text{RE\_SERV} = -\underset{(-2.558)}{2909.958} + \underset{(3.753)}{0.229}\ \text{RE\_MFG} + \underset{(3.251)}{0.417}\ \text{RE\_CONST} + \underset{(36.109)}{0.294}\ \text{R\_PCI} + \underset{(3.679)}{77.746}\ \text{AVG\_DTMP} + \underset{(2.701)}{141.274}\ \text{WIN\_DPCP}$$

R-SQUARE = 0.9909 DW = 2.002 N = 22

6. Wholesale and Retail Trade

$$\text{RE\_TRADE} = -\underset{(-0.058)}{20.227} + \underset{(2.539)}{0.00037}\ \text{PK\_ATTND} + \underset{(3.941)}{0.418}\ \text{L\_RETRD} + \underset{(5.872)}{0.125}\ \text{RE\_TOTAL} - \underset{(-3.031)}{21.268}\ \text{MPW\_DTMP}$$

R-SQUARE = 0.9802 DW = 1.867 N = 21

7. State and Local Government

$$\text{RE\_STLOC} = -\underset{(-0.336)}{239.357} + \underset{(5.211)}{0.655}\ \text{L\_RESGV} + \underset{(3.270)}{0.114}\ \text{RE\_SERV} + \underset{(2.158)}{0.0636}\ \text{NUM\_PUP}$$

R-SQUARE = 0.8860 DW = 1.661 N= 21

Table 1. Employment Equations (continued...)

8. **Transportation and Utilities**

```
RE_TR_UT = - 1335.085 + 4129241 RLWGTPU + 0.195 GNP82 - 49.688 WIN_DPCP
             (-3.188)    (10.140)          (4.439)       (-3.077)

           + 0.000081 PROD_VAL + 0.275 RE_FARM
            (4.357)             (3.766)

           R-SQUARE = 0.9078    DW = 2.006    N = 22
```

9. **Residual**

```
RE_RESID = - 2898.601 + 0.00021 NE_FGOVT + 0.090 RE_TOTAL + 57.078 WIN_DPCP
             (-7.373)    (3.475)            (15.469)         (1.827)

           R-SQUARE = 0.9235    DW = 2.333    N = 22
```

Table 2. Employment Equation Variable Definitions for the Pere Marquette Global Climate Change Impact Model

Employment Variables:

RE_TOTAL =	Regional Total
RE_CONST =	Regional Construction
RE_FARM =	Regional Farming
L_EFARM =	Lagged (1 year) Regional Farming
RE_FIRE =	Regional Finance, Insurance, and Real Estate
RE_MFG =	Regional Manufacturing
RE_SERV =	Regional Services
RE_STLOC =	State and Local Government
L_RESGV =	Lagged (1 year) State and Local Government
RE_TRADE =	Regional Trade (Retail + Wholesale)
L_RETRD =	Lagged (1 year) Regional Trade (Retail + Wholesale)
RE_TR_UT =	Regional Transportation and Utilities

Wage Variables:

RWFARM =	Regional Wage Rate for Farming
RWMFG =	Regional Wage Rate for Manufacturing
RLWGCON =	Relative Wages for Construction
RLWGMFG =	Relative Wages for Manufacturing
RLWGTPU =	Relative Wages for Transportation and Utilities

Other Variables:

GNP82 =	Gross National Product (1982 Dollars)
NI_FOOD =	National Consumer Price Index for Food
R_PCI =	National Per Capita Income
R_POP =	Regional Population
PK_ATTND =	State Park Attendance
NUM_PUP =	Number of Pupils in Public Schools
PROD_VAL =	Value of Farming Production

Climate Variables:

SUM_DTMP =	Mean (Monthly) Summer Temperature
WIN_DTMP =	Mean (Monthly) Winter Temperature
AVG_DTMP =	Mean (Monthly) Annual Temperature
MPW_DTMP =	Mean (Monthly) Winter Peak Temperature
WIN_DPCP =	Total Winter Precipitation

Table 3. Climate Dependent Coefficients for Pere Marquette Watershed Region

Employment Sector / Climate Variable	Mean Summer Temp.	Mean Winter Temp.	Mean Peak Winter Temp.	Mean Annual Temp.	Mean Winter Precip.	Net Impact
Farming				-28.78		**-28.78**
Manufacturing	-71.70	-29.83				**-101.53**
Services				77.75	141.27	**219.02**
Trade			-21.27			**-21.27**
Transportation and Public Utilities					-49.69	**-49.69**
Residual					57.08	**57.08**
Net Change	**-71.70**	**-29.83**	**-21.27**	**48.97**	**148.66**	**74.83**

Table 4. Pere Marquette Watershed Region Employment Impacts Under Doubled CO_2 Scenario

Employment Sector / Climate Variable	Mean Summer Temp.	Mean Winter Temp.	Mean Peak Winter Temp.	Mean Annual Temp.	Mean Winter Precip.	Net Impact
Farming				-204.11		**-204.11**
Manufacturing	-676.30	-141.74				**-818.04**
Services				551.40	497.85	**1,049.25**
Trade			-146.32			**-146.32**
Transportation and Public Utilities					-168.68	**-168.68**
Residual					193.89	**193.89**
Net Change	**-676.30**	**-141.74**	**-146.32**	**347.29**	**523.06**	**-94.01**

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