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PROJECTED ECONOMIC IMPACTS AND MITIGATION STRATEGIES FOR GLOBAL CLIMATE CHANGE IN MULTI-COUNTY REGIONS OF THE MIDWEST

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Summary

The nature and magnitude of regional economic-environmental-energy demand impacts and economic development effects of global climate change on rural have not been adequately explored. The purpose of this paper is to begin to address this problem by delineating these impacts for a four-county rural, recreation-based region.

The most appropriate methodology for detecting the potential regional economic impacts of climate change is an integrated model designed to capture the explicit interdependencies and dynamic feedbacks between climate and other environmental changes in multiple economic sectors. A simultaneous equation, econometric modeling approach fulfills these requirements. The authors are presently engaged in the development, testing, and application of a integrated economic-environmental-energy demand model which translates regional climate-change effects on natural resources into impacts on economic activity.

The Pere Marquette Watershed in Central Western Michigan was chosen as an initial testing ground for this model. The structure of the model, along with climate change forecast results. These results represent a significant expansion of the state-of-knowledge of regional economic-environmental-energy demand interactions associated with global climate change; a delineation of the specific impacts of global climate change in multi-county regions; and an impact analysis modeling structure which can be further developed, refined, and cost-effectively implemented in future research on other regions.

1. Introduction

The uncertainty within the scientific community regarding the existence of global warming is no secret. Regardless, the fact remains that the Earth's climate system does change regionally and globally. Whether the warming trend of the past 100 years is an indication of anthropogenically induced global climate change or the result of a natural cycle does not change the fundamental principles of how climate influences the availability of natural resources, the structure and function of ecosystems, and the development and modification of social and economic systems. Until recently, the latter has received the least attention with respect to identifying the potential impacts of global climate change.

It is evident from climatological studies that climate is regionally sensitive, i.e., global climate change, anthropogenically induced or not, will not be geographically uniform. Since regions of relatively uniform climate vary in ecosystem types, natural resources, human population, political structure and economic activity, not to mention many other facets, it appears that studies of climate change impact must have a regional focus. More importantly, the focus must go beyond studies of singular impacts (e.g., habitat loss or migration impacts). The linkage between the natural environment and regional economic activity requires considerable attention via multidisciplinary studies which cross the lines of natural and economic sciences (Committee on Earth and Environmental Sciences, 1991).

The purpose of this paper is to address these issues by delineating the potential environmental-economic impacts for the city of Ludington, set in a four-county rural, recreation-based region of Central-Western Michigan. This research advances the state-of-knowledge in this important research priority area by testing a framework and methodology for an integrated economic-environmental model developed by the authors. This model explicitly captures the interdependencies and dynamic feedbacks among climate change, environmental effects, and multiple-sector economic responses at the regional level.

The remainder of this paper is organized as follows: **Section 2** is a review of climate change literature, regional/urban economic impacts, and integrated environmental-economic modeling at the regional level. **Section 3** describes the integrated economic-environmental model framework, methodology, and data sources that will allow for empirical specification to other geographical locations. **Section 4** provides results from the preliminary research that serve to validate this approach, whereas **Section 5** presents the conclusions.

2. Background and Literature Review

2.1 Global Climate Change

The level of research conducted on the impacts of global climate change is tremendous. Evidence strongly suggests climate change impacts biological diversity (Peters, 1991; Peters and Lovejoy, 1992), wildlife and habitat fragmentation (Davis and Zabinski, 1990; Lester and Meyers, 1991), species extinction (Ehrlich and Ehrlich, 1981; Steadman, 1991), hydrology and water resources (Nemec and Schaake, 1982; Waggoner, 1990), agriculture and food resources (Bach *et al.*, 1981; Blasing and Solomon, 1983; Decker *et al.*, 1986), fishing and fisheries (Kawasaki, 1985; Meisner *et al.*, 1987), human health (Escudero, 1985; Kalkstein, 1991; Longstreth, 1989), transportation (Marchand *et al.*, 1988), energy demand (Solomon and Rubin, 1985; Linder *et al.*, 1989), and insurance costs (Aldred, 1990a; Gilbert, 1990). Research and development has also been accelerated in the area of forecasting climate trends. The use of General Circulation Models (GCM) based on numerical simulation methods has been the primary instrument for predicting global climate changes under simulated conditions of rising CO_2. Additionally, paleoclimatology has played a critical role in the reconstruction of past climates using a variety of techniques (Fritts, 1976; McGhee, 1981; Barnola *et al.*, 1987).

However, GCMs are difficult to build, maintain, and use (Robinson, 1985) and are limited by computer resources (Hengeveld, 1991). Despite these limitations, GCM output has played an important role in numerous studies and 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." (Robinson, 1985)

Of the many studies which have incorporated GCM results, several have been directed at analyzing the regional impacts of climate change. These include the potential effects of climate change on soil moisture (Kellog *et al.*, 1981; Gleick, 1987); regional GCM temperature and precipitation simulations (Gortch, 1988; Cushman *et al.*, 1989); the potential impacts of global warming on energy demand (Baxter and Calandri, 1992); and the potential effects of climate change on water resources of the Great Lakes basin (Cohen, 1986b; Cohen, 1987; Croley II, 1990). The most comprehensive study of climatic change impacts on regions of the U.S. was prepared by Smith and Tirpak for the Office of Research and Development of the U.S. Environmental Protection Agency (EPA) in 1990 (Smith and Tirpak, 1989). Their conclusions for the Great Lakes region 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" (Smith and Tirpak, 1989).

Concensus regarding the full nature and magnitude of economic effects of global climate change is not likely to be reached for a long time. Nordhaus (1991a, 1991b) predicts that 3% of U.S. national income is sensitive to climatic change, and that global warming will lead to a 0.25% decrease in GNP, or a loss of approximately $14 billion per year. Cline (1992b), 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. Hurricane Andrew, the eastern winter storms of 1993 and 1994, plus the summer 1993 floods of the Mississippi Valley are evidence of these severe events. This increased frequency of severe 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 (Kates *et al.*, 1985). With respect to the United States, the drought of 1988 alone cost the nation $39 billion (Changnon and Changnon, 1990); the heavy snow of 1982 accounted for $6 billion in direct losses (Hughes, 1983); the severe winter of 1976-77 cost $40 billion in production, transportation, retail sales, and energy consumption losses; and the 1980 heat wave/drought cost the U.S. another $15-20 billion. Such weather events affect not only GNP, but also impact migration patterns. The "dustbowl" drought of the 1930s is illustrative of how a weather event may cause massive changes in migration flows.

2.2 Economic Impacts of Global Climate Change

The review of numerous studies has lead the authors to conclude that the economic impacts of climate change will be most readily observed in nine economic sectors: farming; construction; manufacturing; services; finance, insurance and real estate; retail and wholesale trade; transportation and utilities (energy consumption); state and local government; and a residual sector (comprised mainly of forestry and federal government employment). In the urban environment, all of these sectors, with farming to a lesser extent, play a critical role in defining its economic structure and activity. Consequently, each of these sectors are given specific attention in the modeling to be described later.

Rural and urban areas feel the impact of climate variation via numerous pathways. Certainly, geographic location has a significant bearing on the character and magnitude of the impact. For instance, Ludington and Milwaukee are both situated on Lake Michigan and highly influenced by conditions of the lake itself and the economic activity which depends on the lake (e.g., shipping of products, commercial fishing, recreational activities, tourism, etc.). It is well understood that changes in the precipitation patterns and evaporation rates of the Great Lakes region will alter the hydrologic cycle impacting surface and groundwater systems. Under current consumption conditions, the Great Lakes region is expected to face a 20% decrease in basin water supplies in the early 21st century (Smit, 1992). Several studies predict that with increasing consumptive water use and a decreasing net basin supply, water rights conflicts will intensify (Bruce, 1984; Cohen, 1986a; Cohen, 1986b; Cohen, 1987).

Coupled with water consumption patterns are the impacts to the construction industry. With increasing water demand and consumption, rural and urban areas become susceptible to vertical movements in the foundation soil of buildings and other structures. Although global climate change may provide the benefit of 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 (Russo, 1966; Gilbert, 1990). A one degree celsius increase in temperature above the optimal can cause a 2-4% decrease in productivity (Kellog and Zhao, 1988). 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 (Smith and Tirpak, 1989).

Manufacturing and retail/wholesale trade will primarily be impacted by changes in energy use, transportation and other consumption patterns. The effects of weather on manufacturing industries have been studied extensively (most recently by Maunder, 1974; Kellog and Schware, 1981; Palutikof, 1983; Gabe, 1985). The expected impact of water resource consumption in other regions is likely to benefit urban areas around 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.

Although global climate change is expected to reduce the ice cover [thereby leaving the lakes free for navigation eleven months of the year (Ramirez, 1988)], low lake levels due to increasing consumptive water use; changing precipitation patterns, and evapotranspiration are expected to offset this benefit (International Joint Commission, 1981; International Joint Commission, 1985; Marchand *et al.*, 1988; Smith and Tirpak, 1989). 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 (Marchand *et al.*, 1988).

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 (Miller, 1990; Smith and Tirpak, 1989). Increased demand for public expenditures for disaster relief could occur due to severe weather events, with potentially undesirable increases in public sector employment.

2.3 Integrating Climate, Environmental, Economic, and Energy Impacts

There is substantial need for additional research to establish regional environmental-economic demand linkages. In a review of research over the past two decades, Bolton (1989) expressed the necessity of further integrated modeling framework development:

> "Integrating environmental variables into regional input-output and econometric models is a high priority...Yet regional modeling research has gone on relatively unconnected to other important work in environmental economics, cost-benefit analysis, and natural systems modeling, in spite of the fact that environmental changes can cause major changes in the nonpecuniary income of a region. From a theoretical point of view, then, regional models that ignore environmental changes are lacking in an important way." (Bolton, 1989)

The costs and benefits to any aggregation choice, in view of the location-specificity of projected impacts, support the need for climate change analysis which focuses at a regionally disaggregated level. An economic-ecological modeling framework is ideal for capturing these complex regional interdependencies and feedbacks (Hafkamp, 1984; Bolton, 1989). Jeffers (1987) identifies several approaches to identifying the linkages between ecologic and economic systems which have been developed. Most approaches utilized one or more of three major analysis methods - mathematical simulation models, input-output analysis, or econometric (stochastic) models (DeSouza, 1979; Miernyk, 1982; Hafkamp, 1984).

Efforts to identify ecologic and economic linkages at regional levels originally focused on input-output analysis to develop pollution coefficients for industrial activity. Typical of these efforts are Hite and Laurent (1972) and Rose (1974). However, the input-output approach lacked the ability to integrate economic and ecologic effects. Moreover, such models tended to be static in nature and required huge commitments of resources to construct the required interindustry transactions tables (Gordon and Ledent, 1981; McConnell *et al.*, 1982). In response, some researchers began utilizing econometric formulations to integrate ecologic and economic systems (Fishkind and Milliman, 1978; Lakshmanan, 1983; Solomon and Rubin, 1985).

Although little research has tried to integrate physical-environmental-economic linkages with respect to climate change, the report "Climate Change, The IPCC Scientific Assessment," which was prepared under the auspices of the World Meteorological Organization, United Nations Environment Program, summarizes several independent projects. The report details climatic, hydrologic, and ecologic impacts, but leaves many unanswered questions about economic impacts. An important effort to integrate environmental-economic impact assessment was a congressionally-mandated EPA (Smith and Tirpak, 1989) study entitled: "The Potential Effects of Global Climate Change on the United States".[1] The 55 studies by academic and government specialists contained in this project evaluated the impacts of global climate change on water resources, sea level rise, agriculture, forests, aquatic resources, air quality, health, infrastructure, variability, and policy. The EPA study provides preliminary information on the consequences of global climate change; however, the economic analysis is limited to agriculture, forestry, health, and infrastructure, with no detailed assessment of how global climate change will affect the mix and level of economic activity in other key economic sectors.

The MINK Study, sponsored by the U.S. Department of Energy, is another example of a regional evaluation of climate change impacts. This research was confined to four natural resource sectors -- forestry, agriculture, water, and energy consumption -- in the four-state region of Missouri, Iowa, Nebraska, and Kansas. Simulation models and the use of static, aggregate level input-output multipliers were the primary analytical tools. Rosenberg and Crosson (1991) stated the objectives of this study were to establish baseline information regarding the regional economies and analyze the potential impact of various climate scenarios on baseline resource productivity . Again, like the EPA study by Smith and Tirpak, the MINK study was conducted by several independent research teams and does not address

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There are, of course, a large number of qualitative assessments of the economic impact of global warming. See for example: "The Greenhouse Effect: Implications for Development" by Erik Arrhenius and Thomas W. Waltz, World Bank Discussion Paper # 78, Washington D.C.

detailed impacts on manufacturing, trade, services and other major economic sectors; nor does it allow for any analysis of the dynamics of such impacts over time.

3. The Modeling Framework and Methodology

An econometric model is simply defined as a set of linked statistical (regression) and deterministic equations. Linkages are established when the dependent variable of one equation also appears as an independent (i.e., predictor) variable in another equation of the model set. When the interdependencies are structured such that all equations must be solved at the same time, the system of equations is considered simultaneous. Unlike static forecasting techniques (e.g., shift-share analysis, economic base analysis, input-output studies, etc.), simultaneous equation models of this nature can capture the detailed dynamic aspect of economic changes which occur from one time period to the next. The two types of variables included in such models are 'exogenous' variables, which are determined outside of the model, and 'endogenous' variables, which are determined by the model.

The econometric modeling framework is flexible enough to allow the incorporation of both stochastic (statistical) and non-stochastic (deterministic) relationships, as well as linear and non-linear (e.g., exponential, logarithmic, etc.) relationships, in the same set of linked equations. Additionally, lagged impacts (i.e., an impact in the current time period caused by a change in a previous time period) can be incorporated in the same set of linked equations. Consequently, the parameters of each regression equation will be linear but each of the variables may be linear, non-linear, lagged, etc. By using the econometric structure as the overall integrating framework, the results of previous simulation or input-output research in this area can be readily incorporated into the impact analysis. Each regression equation of the model provides a specific test of a hypothesis concerning the interaction of economic and climate change variables, thus making it easier to understand what is potentially important.

The model can be disaggregated to the two-digit standard industrial classification level for most sectors, thus providing the level of detail required for most regional impact studies. A simultaneous equation structure for the model allows for dynamic linkages between economic and ecologic systems. Climate variables provide the primary external (exogenous) variables to drive the economic-ecologic equations of the model. The direct effects of climate change are represented in the models by temperature and precipitation. Regional economic variables, e.g., per capita income, employment, output, and gross regional product, are also included as both exogenous and endogenous components to represent causal relationships. The model must minimally address six primary areas of economic activity: employment and wages (each disaggregated by sector), personal income, labor force, population, and public sector revenues and expenditures. Given the level of disaggregation, such a modeling framework will contain over 75 stochastic equations. Annual data for the Ludington area is consistently available from 1969-1990, providing an estimation period in excess of 20 years.

Although long-term climate change of the type expected from global warming is not part of the historical record, variations in mean seasonal temperatures, rainfall, and lake levels have occurred in the Great Lakes region during the estimation period (Bruce, 1984; Cohen, 1988; Bishop, 1990; Hartmann, 1990). These variations include sufficient range to encompass the changes in predicted means that are associated with global warming trends that are expected for the region. These variations have had substantial impacts on multiple aspects of the regional economy and will enable the econometric model to capture many economic-climate change relationships.

Where global climate variations might change structural relationships between these systems, historic data will not depict the newly emerging relationships. This circumstance would call for deterministic simulation equations to be inserted into the model. As Lovell and Smith (1985) point out, the need to add such structures to incorporate the linkage between climate and the regional economy is a characteristic of all economic impact assessment approaches.

In addition to these endogenous variables, the model predicts labor force participation rate, unemployment, public sector revenues and expenditures, local prices, and gross regional product. Population growth is predicted utilizing a cohort survival method to reflect natural increase and a stochastic equation for migration.

Long-range forecasts of climate change impacts can be carried out in two ways. In order to determine the overall dynamics of economic impacts over the period for which global climate change is predicted to reach an equilibrium atmospheric concentration of doubled CO_2 concentration (30-60 years), a series of long-term forecasts can be made for this time horizon. However, this extended forecasting horizon proves too lengthy for reasonable projections of exogenous variables. An alternative forecasting approach begins with the artificial assumption that the doubling of CO_2 occurs much sooner, for example, within the next ten years. Forecasts generated via this short-term approach provide the regional economic impacts of global climate change given current economic conditions and relationships. Although such a short-term impact analysis approach does not reflect general economic trends occurring over the 30-60 year forecasting horizon, it does eliminate likely forecasting errors that result from long-run forecasts, while still giving useful information about economic impacts in today's terms. This procedure may, in fact, overstate some impacts, such as effects on agriculture production leading to long-term crop or import substitution.

The model simulations can utilize sensitivity analyses over a broad confidence interval, in view of the uncertainties associated with global change forecasts. These analyses will reflect alternative assumptions or specifications concerning the deterministic relationships utilized in the model. Different climate scenarios derived from global or regional models can be used to generate alternative forecasts, thus allowing for research to explore the potential impacts of different climate change predictions arising from various GCMs or regional climate models. The results would also reflect the possibility of any structural economic changes.

4. Modeling Results

The authors have been developing an integrated economic-environmental model of the kind described above for application at a regional watershed level since early 1992. The modeling effort is being applied to a four-county region of Central-Western Michigan and the six-county Milwaukee MSA. Although many of the equations for the Milwaukee model have been estimated, this model is not yet complete. Thus, the focus of this discussion is on the results obtained for the Michigan model.

The four-county area in Michigan is predominantly rural and the structure of the economy is recreationally based. The city of Ludington is the largest urban area in the region with a population of 8,937 in 1992. The Pere Marquette River is a federally-protected scenic river and is nationally known for its excellent fly fishing. Camping, canoeing, and other outdoor activities draw a large number of tourists throughout the summer months. Winter sports include cross-country skiing and snowmobiling. The population in 1990 was 95,100, and in that year, the region had a labor force of 37,674, total employment of 34,020, an unemployment rate of 9.7%, and per capita income of $13,871. The primary economic sectors are services (21.6%), retail and wholesale trade (19.1%), and manufacturing (17.3%). The first two of these sectors are highly dependent on tourism and recreation. Agriculture is also significant in the region (8.5%), providing the raw material for over one-third of the region's manufacturing sector, which is largely food processing and packaging.

Table 1 presents the model structure and the regression estimation results for the primary stochastic equations of the model. All independent variables included in these equations are statistically significant at the .05 level or better. Table 2 provides the variable definitions for each of these equations. Nine employment sectors have been empirically modeled with employment and wage equations: farming; construction; manufacturing; services; finance, insurance and real estate; retail and wholesale trade; transportation and utilities; state and local government; and a residual sector (comprised mainly of forestry and federal government employment). The specification of these equations commonly follows the generalized formulation of employment equations in previous research, with the major non-climate explanatory variables being regional wages in the respective sector, national demand as represented via GNP, and local demand as represented by population, total employment, or employment in related sectors.

The climate variables in these equations include daily mean annual precipitation, winter precipitation, spring precipitation, and summer precipitation, mean daily annual and winter temperature, and various soil stress indices. These climate variables appear in the equations for construction employment and wages, farming employment, financial sector employment, manufacturing employment and wages, services employment and wages, trade sector wages, transportation and utilities employment and wages, regional unemployment rate, park attendance, regional energy demand and net migration.

Table 3 presents some summary results for the model's current simulation capabilities. The *mean absolute percent error* (MAPE) provided in Table 3 indicates the average error for the forecasts for some of the major endogenous variables over the sample period. Most of these are less than five percent. In fact, 19 of the 34 endogenous variables of the model have MAPEs less than five percent, and another 13 are less than ten percent. This is very good to excellent performance for a regional econometric model, and especially for one targeted at a region with a small population base.

Analysis of the model's tracking behavior also indicates that the model captures the turning points of the economy quite well. In most cases, the large majority of directional changes in the growth of the endogenous variables are captured by the simulation. This ability to capture econometric turning points and the relatively low values for the MAPE statistics indicate that the model works well over the simulation period.

Table 4 provides the results of a baseline forecast, a climate change-scenario forecast, and the resulting climate change impacts for the period from 1995 to 2010. In order to derive the baseline forecast, it was assumed that the model's non-climate exogenous variables would continue to change based on past trends. In order to project these trends through 2010, an autoregressive time-series forecast approach provided by the SAS software FORECAST Procedure was utilized. The values of the climate variables were projected as remaining relatively constant over the forecast period. To derive the climate-change scenario, the climate variables were assumed to have an exponential growth rate consistent with doubling the concentration of carbon dioxide in the atmosphere within ten years, and then continuing to grow at an accelerating rate for the remaining years thereafter. This climate-change scenario is intended to illustrate what would occur *if the global warming likely during the next 50 to 75 years took place over the next 20 years.* As previously discussed, this 20 year forecast allows the effects of global climate change to be explored in terms relevant to current economic conditions.

Table 4 indicates that the climate change scenario has the effect of increasing the Peré Marquette region's employment while concomitantly yielding a slight decrease in per capita incomes. These two trends are consistent throughout the 20 year forecast period. By 2010, when average daily temperature in the climate change scenario increases to 61 degrees F, over 2600 new jobs are projected.. One other large impact forecast by the model is a decrease in population size over that which would occur in the absence of global climate change. By 2010, the difference between the baseline and climate change scenario forecasts represents a population loss of 2508, which in percentage terms is a decline of 2.5 percent.

5. Conclusions

This paper has presented an integrated economic-environmental impact analysis framework and methodology specifically tailored for a multicounty region. The methodology is based on an econometric modeling strategy which explicitly models the interdependencies and dynamic feedbacks among climate, environmental changes, and responses in multiple economic sectors. The modeling framework allows for research hypotheses concerning the interaction of climate-induced environmental and economic effects to be tested. This framework serves to translate regional climate-change effects on temperature and precipitation into economic and demographic impacts. Thus, it will allow for the evaluation of alternative global warming scenarios by generating associated regional economic impact scenarios. These economic impact scenarios will reveal the effects of global warming on jobs, income, production, unemployment levels, population levels, and government expenditures and revenues.

The preliminary results obtained from applying this modeling framework to the four county region surrounding Ludington, Michigan provide initial verification of the ability of this prototypic methodology to capture climate change effects. These results, in the form of the parameter estimates on the climate change variables and sample period simulation performance, illustrate the utility of this approach in analyzing the regional economic impacts of climate change.

Much of the policy debate surrounding global climate change hinges on assessing tradeoffs between preventing global climate change by reducing the emission of greenhouse gases versus mitigating the effects of a changing climate. Various prevention approaches have been evaluated using highly aggregated models. However, the economic impacts of prevention strategies have considerable spatial variation, implying that a disaggregated regional model of the kind developed in our research is needed for a more accurate assessment. While such a model is preferable for evaluating prevention strategies, it is essential for evaluating mitigation strategies. Only by assessing the combined ecologic, economic, and human effects of global climate change in a disaggregated model that incorporates the economic system's ability to adapt, can various prevention and mitigation alternatives be examined and compared effectively. The modeling framework and methodology described in this paper provides such a mechanism for evaluating and comparing the alternative public policies which can be implemented to deal with the anticipated effects of global climate change.

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Table 1. Primary Econometric Equations

```
RECON = -1521.467 + 0.048274 RWCON + 0.099458 RPCI +  28.081876 SUMPDSI
         (-3.684)     (11.952)          (2.580)          (4.281)
         + 11.069596 CPISHEL - 24.303249 LTINST + 0.050809 NETMIG
           (10.903)            (-2.293)            (2.954)
            R-SQUARE = .9584               DW =  1.735       N = 20

RWCON = 170.417 + 2.917305 RWSER - 2562.845468 SPRDPCP - 70.020935 CPISHEL
         (0.067)    (3.188)          (-3.529)              (-2.230)
                R-SQUARE = .8570           DW = 1.758        N = 20

REFRM = 1676.038 - 0.01034 RWFRM + 0.0327 SEFRM - 27.1399 AVGDTMP  - 15.5072 SPRZNDX
         (4.306)     (-3.098)        (23.470)       (-3.572)            (-2.125)
            R-SQUARE = .9692               DW = 1.453        N = 21

RWFRM = 34490 - 7.374798 REFRM + 3.384348 REMFG - 3.713465 RETRD + 0.384639 SWFRM
        (3.459)  (-4.322)          (3.550)          (-4.560)         (2.441)
            R-SQUARE = .8819               DW = 2.209        N = 21

REFIR = -1688.984 - 0.046972 RWFIR + 0.0260214 RPCI + 7.6784585E-8 PROPVAL
          (-5.195)    (-4.006)         (12.271)           (5.803)
        - 33.070299 AVGPHDI + 30.161451 FALDPCP
           (-3.925)            (2.420)
            R-SQUARE = .9829               DW = 2.267        N = 19

RWFIR = -17275 - 6.79536 REFIR + 1.42698 NWFIR + 553.64623 LTINTST + 0.07408 RPCI(-1)
          (-5.410) (-16.915)       (11.314)        (5.515)              (3.281)
            R-SQUARE = .9821               DW = 1.438        N = 19

REMFG = 341.5724 + 0.000119 NWMFG  - 0.36754 RWMFG + 0.37580 RETOT + 0.01864 RPOP
         (0.422)     (5.112)           (-8.687)        (29.034)        (2.751)
        - 24.55137 CPIALL + 50.52903 SPRDPCP - 115.68508 WINDPCP
           (-13.159)        (2.990)             (-4.201)
            R-SQUARE = .9856               DW = 2.623        N = 20

RWMFG = -16594 + 28.2817 CPIALL - 0.1474 RWFRM + 0.49675 RWTOT + 44.7320 SUMZNDX
          (-2.941) (7.629)          (-5.667)        (4.659)          (2.121)
         + 0.30764 SPOP + 1.54312 RETPU
            (4.831)       (3.213)
            R-SQUARE = .9316               DW = 2.363        N = 20

RERES = -1258.5211 + 7.18289E-10 NTPI + 0.07521* NETMIG
          (-5.533)     (11.823)          (3.064)
            R-SQUARE = .8909               DW = 1.987        N = 20

RWRES = -20669 + 1.07292 SWRES + 0.000000297 PROPVAL + 40894389 RLESER
          (-4.055) (13.722)        (3.367)               (2.359)
            R-SQUARE = .9252               DW = 2.247        N = 20

RESER = -2466.628 + 0.00016 NESER + 0.2598 REMFG + 33.770 FALDTMP + 18.058 WINDTMP
          (-3.148)    (43.533)        (4.543)        (2.751)           (2.201)
            R-SQUARE = .9917               DW = 1.575        N = 21

RWSER = -3198.420 - 1.56151 RESER + 1.42201 NWSER + 73.52697 SUMZNDX
          (-2.253)    (-21.288)       (13.701)        (2.404)
            R-SQUARE = .9580               DW = 1.765        N = 21

RESTL = -887.56572 + 0.00604 SESTL + 3783171 RLESER + 0.05026 RETOT
         (-1.415)      (7.163)         (2.158)          (5.433)
            R-SQUARE = .9497               DW = 1.828        N = 20

RWSTL = -12791 + 0.09803 RPOP + 0.69931 SWSTL + 0.00118 PKTTND + 0.30717 RWSTL(-1)
          (-4.386) (4.081)        (5.763)         (2.783)          (2.579)
            R-SQUARE = .9338               DW = 1.989        N = 20
```

Table 1. Primary Econometric Equations (cont.)

```
RETRD = -10286 + 0.02101 RPOP + 0.08663 RETOT + 0.14083 RWMFG - 1.15396 RETPU
        (-4.670) (3.762)        (6.535)        (2.564)          (-5.064)
       + 0.10656 SPOP
         (4.066)
         R-SQUARE = .9862               DW = 2.697        N = 20

RWTRD = -771.2449 - 0.3744 RETRD + 1.2834 NWTRD + 0.1851 NETMIG - 91.7250 SUMDTMP
        (-0.292)    (-2.891)       (16.491)       (2.576)         (-2.972)
         R-SQUARE = .9844               DW = 1.097        N = 20

RETPU = 3924.505 + 0.2161 DJINDUS - 1.0772 PCTPAY - 6465577 RLESER  - 0.0685 RWTOT
       (7.813)     (8.896)          (-12.695)       (-4.372)          (-5.656)
       + 13.0207 SUMDTMP + 8.2576 ANNDPCP
         (2.932)                    (5.445)
         R-SQUARE = .9295               DW = 2.315        N = 20

RWTPU = 5871.739 - 4.3939 RETPU + 55.5618 DJPUTIL + 1.9185 SWTRD - 559.6623 AVGDTMP
       (0.551)     (-2.669)       (14.775)          (10.625)       (-4.422)
       + 12.6287 SUMCLDD + 0.1696 RPOP
         (2.696)           (2.621)
         R-SQUARE = .9438               DW = 2.528        N = 20

RUNEMPR = 45.9026 + 0.7193 NUNEMP - 0.00157 RPCI - 0.0014 RWTOT - 0.0059 ANNCLDD
          (5.732)   (3.045)         (-3.816)       (-6.707)       (-3.250)
          - 0.5640 SPRDPCP
            (-2.571)
         R-SQUARE = .9441               DW = 2.465        N = 20

TPAY = -15385187 + 1071701 RUNEMPR + 0.000446 NTPAY
       (-6.060)    (5.989)           (81.388)
         R-SQUARE = .9972               DW = 1.543        N = 22

RDIVID = -8357780 + 78504 GNP82 + 2485311 LTINTR(-1) - 5261.5580 RETOT
         (-0.379)   (9.111)       (4.301)              (-3.255)
         R-SQUARE = .9894               DW = 1.809        N = 21

RTPI = -771214601 + 32501 RWTOT + 7865.4849 RPOP+ 150226 GNP82
       (-11.944)    (16.689)      (12.115)          (27.801)
         R-SQUARE = .9954               DW = 1.547        N = 20

TOTEREV = -92565048 + 0.000117 BASE + 9166.8229 RPCI
          (-6.758)    (12.479)        (6.021)
         R-SQUARE = .9504               DW = 1.252        N = 20

TOTEEXP = -150502841 + 33780 REDUC + 1201.07 RPOP+ 2834.12 NETMIG + 2333.58 RETOT
          (-9.296)     (6.451)       (5.100)       (2.583)          (4.634)
         R-SQUARE = .9758               DW = 2.387        N = 20

PKATTND = 2196449 + 0.3855 RHOTEL - 91.9512 NETMIG - 172.9870 RWTOT
          (2.541)   (7.406)         (-3.728)         (-7.281)
          + 32303 SUMDTMP - 29277 WINDTMP
            (2.310)         (-3.584)
         R-SQUARE = .8668               DW = 2.233        N = 20

RKWH = -181715060 + 8215.3678 RPOP - 126405 REFRM + 15691 REMFG + 3539269 SUMDTMP
       (-0.943)     (13.332)         (-7.656)       (2.303)       (2.201)
         R-SQUARE = .9779               DW = 1.994        N = 20

NETMIG = 14160 - 1.2296 LIPOP60 - 235.9796 NUNEMP + 31372 RLFPR - 168.7645 SUMDPCP
         (7.071) (-11.111)        (-4.286)          (7.401)       (-2.770)
         - 98.8480 FALDTMP + 207.3560 AVGPHDI
           (-2.674)          (4.477)
         R-SQUARE = .9089               DW = 2.177        N = 20
```

Table 2. Econometric Equation Variable Definitions

Employment Variables:

NEMFG	=	National Employment for Manufacturing
NESER	=	National Employment for Services
NETPU	=	National Employment for Transportation and Utilities
RECON	=	Regional Employment for Construction
REFIR	=	Regional Employment for Finance, Insurance, and Real Estate
REFRM	=	Regional Employment for Farming
REMFG	=	Regional Employment for Manufacturing
RERES	=	Regional Employment for Residuals
RESER	=	Regional Employment for Services
RESTL	=	Regional Employment for State and Local Government
RETOT	=	Regional Total Employment
RETPU	=	Regional Employment for Transportation and Utilities
RETRD	=	Regional Employment for Trade (Retail + Wholesale)
RLESER	=	Relative Regional-National Wage Rate for Services
RLABOR	=	Regional Labor Force
RUNEMPR	=	Regional Unemployment Rate
SECON	=	State Employment for Construction
SEFRM	=	State Employment for Farming
SESTL	=	State Employment for State and Local Government
SETRD	=	State Employment for Trade (Retail + Wholesale)
SUNEMP	=	State Unemployment Rate

Wage Variables:

NWFRM	=	National Wage Rate for Farming
NWFIR	=	National Wage Rate for Finance, Insurance, and Real Estate
NWMFG	=	National Wage Rate for Manufacturing
NWRES	=	National Wage Rate for Residuals
NWSER	=	National Wage Rate for Services
NWSTL	=	National Wage Rate for State and Local Government
NWTRD	=	National Wage Rate for Trade (Retail + Wholesale)
RHOTEL	=	Regional Wage Bill for Hotels
RWCON	=	Regional Wage Rate for Construction
RWFIR	=	Regional Wage Rate for Finance, Insurance, and Real Estate
RWFRM	=	Regional Wage Rate for Farming
RWMFG	=	Regional Wage Rate for Manufacturing
RWRES	=	National Wage Rate for Residuals
RWSER	=	Regional Wage Rate for Services
RWSTL	=	Regional Wage Rate for State and Local Government
RWTOT	=	Regional Total Wage Rate
RWTPU	=	Regional Wage Rate for Transportation and Utilities
RWTRD	=	Regional Wage Rate for Trade (Retail + Wholesale)
SWCON	=	State Wage Rate for Construction
SWFRM	=	State Wage Rate for Farming
SWRES	=	State Wage Rate for Residuals
SWSTL	=	State Wage Rate for State and Local Government
SWTRD	=	State Wage for Trade
SWTPU	=	State Wage Rate for Transportation and Utilities

Table 2. Econometric Equation Variable Definitions (cont.)

Income Variables:		
NTPAY	=	National Transfer Payments
NTPI	=	National Total Personal Income
RDIVID	=	Regional Dividend/Interest Income
RPCI	=	Regional Per Capita Income
RTPI	=	Regional Total Personal Income
TPAY	=	Regional Transfer Payments
Other Variables:		
BASE	=	State Equalized Value - Education
CPIALL	=	National Consumer Price Index for All Items
CPIFOOD	=	National Consumer Price Index for Food
CPISHEL	=	National Consumer Price Index for Shelter
CPICHG	=	Percent Change in National Consumer Price Index for All Items
DJINDUS	=	Dow Jones Industrial Average (1982 Dollars)
DJPUTIIL	=	Dow Jones Utilities Average (1982 Dollars)
DOWADJ	=	Dow Jones Average (1982 Dollars)
GNP82	=	Gross National Product (1982 Dollars)
LOCRPUP	=	Regional Revenue for Education Per Pupil
LTINTST	=	Long Term Interest Rate
NETMIG	=	Regional Net Migration
NSSLKATT	=	National Seashore and Lakeshore Attendance
PKATTND	=	State Park Attendance
RPOP	=	Regional Population
PROPVAL	=	State Equalized Property Value
SPOP	=	State Population
Climate Variables:		
SPRDPCP	=	Mean (Monthly) Spring /Precipitation
SUMDPCP	=	Mean (Monthly) Summer Precipitation
WINDPCP	=	Mean (Monthly) Winter Precipitation
ANNDPCP	=	Annual Precipitation
WINDTMP	=	Mean (Monthly) Winter Temperature
AVGDTMP	=	Mean (Monthly) Annual Temperature
SUMPDSI	=	Summer Palmer Drought Severity Index
SPRZNDX	=	Spring Z Index
SUMZNDX	=	Summer Z Index
AVGPHDI	=	Average Palmer Hydrologic Drought Index

Table 3. Mean Absolute Percent Errors for Selected Simulation Variables

Variable	Mean Absolute Percent Error	Variable	Mean Absolute Percent Error
Farm Employment	0.97	Trade Employ	2.39
Farm Wage Rate	12.55	Trade Wage Rate	1.64
Manufacturing Employment	5.86	Per Capita Income	3.75
Manufacturing Wage Rate	1.9	Unemployment Rate	4.66
Service Employment	2.74	Population	2.51
Service Wage Rate	2.08	Net Migration	16.47
State and Local Government Employment	1.58	Total Employment	2.07
State and Local Government Wage Rate	3.28	Total Wage Rate	6.46
		Kilowatt Hours	5.08

Table 4. Comparison of Regional Economic Forecasts under a Status Quo and Climate Change Scenario

	1995			2000			2005			2010		
Variable	Baseline Forecast	Climate Scenario	Climate Change Impact	Baseline Forecast	Climate Scenario	Climate Change Impact	Baseline Forecast	Climate Scenario	Climate Change Impact	Baseline Forecast	Climate Scenario	Climate Change Impact
Manufacturing Employment	5249	5628	379	5462	6191	729	5534	6710	1176	5435	7153	1718
Service Employment	7595	7857	262	8405	8913	508	9220	10045	825	10003	11216	1213
Total Employment	33973	34531	558	36168	37272	1104	38102	39907	1805	39675	42339	2664
Average Annual Wages	11668	11570	-98	10671	10342	-329	9691	9131	-560	8733	7887	-846
Total Population	97085	96538	-547	99678	98631	-1047	101580	99882	-1698	103114	100606	-2508
Per Capita Income	10776	10739	-37	10990	10915	-75	11233	11109	-124	11489	11306	-183
Winter Temperature	25.15	29.20	4.05	25.61	33.54	7.93	26.06	39.02	12.96	26.52	45.64	19.12
Summer Temperature	67.46	70.74	3.28	67.59	74.10	6.51	67.73	78.42	10.69	67.86	83.71	15.85
Average Daily Temperature	46.39	49.32	2.93	46.53	52.32	5.79	46.67	56.18	9.51	46.67	60.89	14.22
Spring Precipitation	3.02	2.74	-0.28	2.51	2.58	0.07	2.87	2.35	-0.52	2.79	2.05	-0.74
Winter Precipitation	1.69	1.66	-0.03	1.56	1.54	-0.02	1.43	1.44	0.01	1.31	1.35	0.04
Annual Precipitation	37.19	34.27	-2.92	37.98	32.79	-5.19	38.77	30.75	-8.02	39.56	28.17	-11.39