Economic Impacts of Projected Climate Change in Pennsylvania
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1.0 Executive Summary

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) concludes that "Warming of the climate system is unequivocal…" and that "Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases." The report also finds that "A global assessment of data since 1970 has shown it is likely that anthropogenic warming has had a discernible influence on many physical and biological systems." As with other regions of the world, Pennsylvania's climate is very likely to change over the course of the next century and beyond. Pennsylvania's climate future, and the projected impact of climate change on climate-sensitive human and natural systems in Pennsylvania, are examined in the 2009 *Pennsylvania Climate Impacts Assessment* (PACIA) produced for the Department of Environmental Protection (DEP) by Penn State University. This companion report, also sponsored by DEP, and building on the findings of that assessment, examines the impacts of projected global climate change on Pennsylvania's economy at mid-century (2050).

Economic model

The economic impacts presented in this report are derived from a 32 sector, multi-year computer model of the Pennsylvania, US, and world economies. By including the national and global economies, and linking them to that of Pennsylvania, the model captures essential economic relationships that influence the economic impacts of climate change to Pennsylvania.

The 32 sectors included in the economic model encompass economic sectors addressed in the PACIA. The criteria that guided the choice of sectors in the PACIA, and the depth with which they were examined, were: (1) the importance of the sector to the state's economy, human wellbeing, and ecosystems; (2) the expected sensitivity of the sector to climate variability and change; and (3) the data and scientific results available to perform a credible assessment. Because this study examines the economy-wide impacts of climate change, the economic model includes additional sectors to capture *general equilibrium* and *multiplier effects* of individual sectoral responses to climate change.

Assessment Period

The PACIA presented climate projections for three 20-year periods in the 21st century (2011-2030, 2046-2065, and 2080-2099) referenced to the recent 20-year period (1980-1999). The use of multi-year averages is the norm for global climate projections since natural climate variability requires that sufficiently long averages are taken to assess a climate signal. The three time frames were selected in the PACIA to characterize climate in the early, middle, and late 21st Century. In this study, the impacts of climate change on the economy are considered only to mid-century (2050). The reason for this truncated assessment period is that the evolution of regional economic systems is much more uncertain than is the evolution of climate systems. Forecast errors in economic modeling increase rapidly with forecast length and are likely to be far larger beyond mid-century than errors in climate projections. It is simply not possible to make projections with any confidence of what the Pennsylvania economy will look like beyond 2050.

Climate Scenarios

A key determinant of future human-induced climate change is the path of greenhouse gas (GHG) emissions resulting from burning of fossil fuels and other economic activities. The PACIA used two plausible emission scenarios to display a range of possible climate impacts depending on the path of greenhouse gas emissions. The scenarios were taken from the IPCC Special Report on Emissions Scenarios (SRES), which describes global GHG emissions in response to alternative world development pathways and covers a wide range of demographic, economic and technological driving forces. The SRES emissions scenarios are widely used in assessments of future climate change and its impacts. One of the two scenarios considered in the PACIA assumes continued growth in global emissions throughout the 21st Century. This "high" emissions scenario is the IPCC A2 Scenario. The second, lower emissions scenario, assumes that emissions growth is moderated to the middle of the 21st century, and declines thereafter to about 50 percent of current rates by the end of the century (global emissions in 2007 from fossil fuel burning, cement manufacturing, and deforestation were about 10 Gt C). This scenario is the IPCC B1 scenario in the AR4.

The main findings of the PACIA for the projected climate of the Commonwealth are:

- It is very likely that Pennsylvania will warm throughout the 21st century; not a single GCM simulates cooling under the high (A2) or low (B1) emissions scenarios.
- It is likely that annual precipitation will increase in Pennsylvania and very likely that winter precipitation will increase in both emissions scenarios.
- Projected climate change for the Commonwealth over the next 20 years does not differ between the high and low emissions scenarios. Pennsylvania's projected climate by the end of the century differs significantly between the two scenarios.
- By the end of the century, the median projected warming according to the A2 scenario is almost 4 degrees C (7 degrees F), which is nearly twice that of the B1scenario.
- By late century, the median B1 and A2 annual precipitation projections increase by 6 and 10 percent, respectively. Corresponding winter projections are 8 and 15 percent.
- Warming will lead to a longer growing season, with median B1 and A2 projections of nearly 3 and 5 weeks lengthening, respectively, by late century. Corresponding Frost days decreases are nearly 4 and 6 weeks.
- It is likely that precipitation events in Pennsylvania will become more extreme in the future, with longer dry periods and greater intensity of precipitation when it occurs.
- There is substantial uncertainty in projections of future tropical and extratropical cyclones for Pennsylvania. Current research suggests fewer storms but with increases in intensity.

These and other findings from the PACIA inform the economic analyses conducted in this study. It is important to emphasize the insensitivity of Pennsylvania's projected climate to the choice of emissions scenarios to mid-century found in the PACIA. This insensitivity reflects the slow response of the climate system to changes in GHG concentrations, and implies that Pennsylvania is highly likely to experience climate change to mid-Century regardless of the evolution of economic and policy processes affecting GHG emissions. Given that the period of this study is limited to economic impacts to mid-century, this insensitivity also implies little variation in the climate impacts between the A2 and B1 emissions scenarios over the period of the assessment. For this reason, the economic projections presented in this study do not distinguish between emissions scenarios. *This study is essentially addressed to the economic impacts of the "committed climate change" in Pennsylvania to mid-century*.

Economic Scenarios and Simulations

Economic impacts are calculated as the difference between the value of economic indicators (e.g. prices, output, income) "with" climate change versus the values of these indicators "without" climate change; the "without" climate change values of economic indicators are referred to as the "baseline" values. Economic indicators without climate change are derived by simulating the economic model forward in time given projections of key exogenous economic variables (population, working age population, saving rates, depreciation rates, government taxes, rates of productivity growth, and rates of improvement in capital and labor quality). Economic indicators with climate change are derived by simulating the model forward in time with changes in selected parameters (e.g. sector productivity growth rates) to reflect the impacts of climate change on underlying economic conditions. The adjustments to the economic model to represent the effects of climate change on underlying economic conditions in the model are based on the results of the PACIA supplemented by additional economic research.

Two types of economic simulations are conducted. One type estimates the impacts of climate change on individual sectors assuming that climate change does not directly affect other sectors. This exercise allows us to abstract from the economic effects of climate change in any one sector, such as energy, on others, such as agriculture, so as to better understand the direct effects of climate change on the sector. In the second type we estimate the economic impacts when climate change affects all climate sensitive and energy intensive sectors to fully capture indirect and induced effects of our changing climate on the economy as a whole.

Forestry

Climate change is projected to impact forests in both positive and negative ways. On the positive side, longer growing seasons, increased temperatures, increased rainfall, reduced cloud cover, and the CO_2 fertilization effect are expected to increase forest productivity. On the negative side, mortality due to stress and forest disturbances, including fire, insects and disease, and damaging storms is likely to increase. Range shifts of tree and other forest-related species could also have both positive and negative effects. On the southern and lower-elevation parts of their ranges, species are likely to experience increasing stress. On the other hand, in Pennsylvania in particular, the species that are found to the south of the state tend to be more productive than species currently found in the state. Climate change induced tree mortality, also referred to as dieback, while generally negative for forest ecosystems, can have positive economic effects. Dying trees can often be salvaged, and if dieback creates opportunities to replace relatively slow-growing, natural stands of northern species with fast-growing plantations of southern species, forest growth rates could be increased substantially.

Because of the difficulty of projecting whether and when a major forest dieback event will occur in a particular state, such as Pennsylvania, as a result of climate change, two scenarios are considered: an optimistic scenario and a pessimistic scenario. Under the optimistic scenario, forest productivity/output is assumed to increase faster than it would without climate change in Pennsylvania, the rest of the US, and the rest of the world. This scenario assumes that dieback resulting from climate change will occur, but that productivity increases in some areas within each region outpace losses due to dieback. Over the time horizon from 2007 to 2050, the total relative increase in productivity in the Forestry sector in Pennsylvania is assumed to be 20 percent, in the rest of the US it is assumed to be 15 percent, and in the rest of the world it is assumed to be 20 percent.

The pessimistic scenario is intended to illustrate what could happen if a sudden major dieback event were to occur in the state. Under this scenario, it is assumed that productivity in Pennsylvania's Forestry sector increases initially at the same rate as under the optimistic scenario until 2020, at which time a fairly sudden major dieback episode is assumed to occur. This is assumed to lead to a rapid increase (10 percent per year) in the harvest for three years as the dying trees are salvaged, followed by a rapid decline (10 percent per year) for the next seven years due to the diminished inventory of mature timber. Following this dieback episode, the scenario assumes that state rebuilds its Forestry sector, planting new species that are better adapted to the new climate. Assumptions for the rest of the US and the world are the same for both the pessimistic and the optimistic scenarios.

Key results for the optimistic case are:

- Pennsylvania's Forestry sector output in 2050 increases by nearly 33 percent, while the price falls by 22 percent. Employment in the Forestry sector increases by 15 percent.
- In the rest of the US, Forestry sector output increases by 20 percent and employment increases by 5 percent. Nationally, Forestry sector prices fall by 20 percent.
- Output in Pennsylvania's Wood Products sector increases correspondingly by 5 percent, with a 2.4 percent increase in employment in that sector. Wood Products prices also fall by 4 percent in the state.
- Output in Pennsylvania's Pulp and Paper sector declines by 1.6 percent. This is most likely due to increasing production in this sector in the rest of the US and the world; Pulp and Paper output in the rest of the US increases by 1.6 percent.

Key results for the pessimistic case are:

- Pennsylvania's Forestry sector output falls by about 28 percent by the year 2050, while Forestry sector prices fall by 12 percent and employment in the sector falls by nearly 30 percent.
- Forestry sector output in the rest of the US increases by 17 percent, resulting in a decline of Forestry sector prices in the rest of the US of 17 percent.
- Output in Pennsylvania's Wood Products sector increases by less than half a percent.
- Pennsylvania's Pulp and Paper sector output falls by 2.4 percent.

The overall impact of the projected shifts in the Forestry sector on the state's economy is minimal.

Agriculture

The PACIA finds that climate change between now and 2050 is likely to have mixed effects on Pennsylvania agriculture. Changes in patterns of temperature and precipitation are likely to raise productivity for some agricultural products, reduce productivity for others, and in some cases have minimal impacts on productivity.

The economic model results indicate that climate change will increase production of grains and oilseeds in Pennsylvania in 2050 due to climate change-induced productivity gains. Production in the rest of the US also increases because of such productivity gains there, and grain and oilseed prices fall as a result of these increases in output. For Pennsylvania farmers, these changes in prices and output essentially offset each other, with the result that there is very little change in grain and oilseed revenues. This same pattern of higher production but lower prices is also evident for fruits, vegetables and nuts. However, for Pennsylvania growers the increase in production is significantly greater than the decline in price, with the result that fruit, vegetable and nut revenues increase.

All of the Pennsylvania livestock sectors in the model—beef, dairy, poultry and eggs, and other animal products (primarily hogs and pigs)—show either no gains in productivity in 2050 as a result of climate change or declines in productivity. Nonetheless, all of these sectors gain as a result of climate change because of even steeper declines in productivity in other states. Some production of livestock products shifts to Pennsylvania from other states, and Pennsylvania's net shipments of these products to other states increase.

Agricultural products are inputs into food processing, and changes in the economic model in agricultural prices and production lead to changes in prices and production in the model's food processing sector. The model results indicate that Pennsylvania food processing output in 2050 will increase as a result of climate change, and that prices received by Pennsylvania food producers will also increase. These gains in production occur mostly because of increases in net shipments of food products to other states. The model results indicate that production of food products in the rest of the US in 2050 falls as a result of climate change.

The economic model results indicate that Pennsylvania production in all of the agricultural sectors in the model increases in 2050 as a result of climate change. As production increases, resources—labor, capital, and intermediate inputs—are drawn away from some other sectors of the economy and into agriculture through general equilibrium impacts. These general equilibrium impacts are mostly small in percentage terms.

Energy

The PACIA highlights the impact of climate change on the demand for electricity. It concludes that climate change will lead to slightly higher demand for air conditioning and lower demand for heating by 2050 in Pennsylvania and the US. The resulting net increase in residential electricity demand in Pennsylvania and in the US from the “no climate change” case is expected to rise over time, reaching 2 percent in 2050. This net increase in electricity demand from climate change has little impact on the Pennsylvania economy--gross state product (GSP) in 2050 is only 0.05 percent less than GSP in the case without climate impacts while consumption and investment are only 0.06 percent and 0.05 percent less, respectively. The sectors most negatively impacted in this scenario are the electricity-intensive sectors while the electricity sector and sectors supplying to the electricity sector experience higher output and prices.

Human Health

The PACIA examined the impact that climate change would have on human health. It identified several mechanisms through which climate change could affect human health. In most cases, these mechanisms are speculative, but three impacts on human health were identified where the direction of the impact could be established with high confidence; climate change will result in an increase in heat-related deaths during summer, a decrease in cold-related deaths during winter, and an increase in respiratory disease due to higher ozone concentrations during summer. Different studies that have estimated the impact that warming will have on temperature-related mortality have arrived at different conclusions about whether the decrease in cold-related deaths will be larger or smaller than the increase in heat-related deaths. To capture this uncertainty, two sets of projections are generated based on different source studies. One set projects that temperature-related mortality will decrease in Pennsylvania by about 7,700 deaths per year. The other set projects that temperature-related mortality will increase by about 550 deaths per year. Almost all of the change in temperature-related mortality will be among residents aged 65 and older. For working-age adults, the change in temperature-related mortality is very small, relative to baseline mortality rates, so the impact on labor supply and wage income will be small. Further, the medical costs associated with these excess deaths are very small relative to the total amount spent on health care in Pennsylvania. For these reasons, any change in temperature-related mortality due to warming in Pennsylvania is expected to have a negligibly small impact on the economy of Pennsylvania.

Higher summer temperatures are projected to increase ozone concentrations by 5ppb in Philadelphia and Pittsburgh and by 2.5ppb in the rest of the state. Using published concentration-response functions, the number of hospital admissions for respiratory disease is projected to increase by between 248 and 641 per year by 2050 as a consequence of climate change, with an estimated medical cost of $2.5-$5.8 million. Again, this impact is very small relative to total spending on health care, and its impact on the Pennsylvania economy is expected to be negligible.

Property Impacts and Insurance

The PACIA concludes that Pennsylvania’s precipitation climate will become more extreme in the future, with longer dry periods and greater intensity of precipitation when it occurs. However, there is substantial uncertainty in projections of future tropical and extratropical cyclones for Pennsylvania. Current research suggests fewer storms but with increases in intensity. Summer floods and general stream flow variability are projected to increase. A reduced snowpack might cause a reduction in rain-on-snow events, a process which historically caused major flooding events in Pennsylvania, though this conclusion remains speculative before more detailed studies have been performed. The frequency of short and medium length soil moisture droughts is projected to increase.

These conclusions do not provide a definitive case for a net increase or decrease in the frequency and severity of weather related property losses in Pennsylvania due to climate change. Additional research is needed to fully assess risks and consequences before an aggregate economic analysis can be conducted with any degree of confidence.

Outdoor Recreation and Tourism

The PACIA found that climate change would have impacts on outdoor recreation and tourism that vary by activity. Some outdoor recreation activities would be harmed by climate change, including snow- and ice-based outdoor recreation and trout fishing. Other activities would see an increase in participation, including warm-water fishing, boating, swimming, golf and bicycling. It is unclear what impact climate change might have on forest-based activities such as hunting, camping and hiking. Climate change could extend the summer season, resulting in an increase in visits to Pennsylvania by out-of-state tourists, but could also cause more Pennsylvania residents to travel out of state for recreation. Whether climate change will cause an increase or a decrease in outdoor recreation activity and related spending cannot be determined with confidence.

Overall Impacts

The projected impacts of climate change on Pennsylvania's (GSP) during the assessment period are small. When agriculture, forestry and energy impacts are considered together, GSP in 2050 decreases by 0.09 percent in the pessimistic case and increases by 0.02 percent in the optimistic case. By comparison, Pennsylvania's real (inflation-adjusted) GSP grew by an average of 2.1 percent per year during 1997-2008, and is projected by the economic model to grow by 2.7 percent per year between now and 2050 in the model's baseline scenario.

In both the optimistic and pessimistic forestry cases, climate change increases average prices paid by Pennsylvania households and businesses—the GDP price index rises by about 0.2 percent in each case. This increase in prices reduces consumption expenditures by households in both cases. However, in the optimistic forestry case there is a significantly greater increase in Pennsylvania exports to other states and countries (1.6 percent) than in the pessimistic forestry case (0.7 percent). The additional exports are enough to raise GSP in the optimistic case.

Leaving aside the primary climate sensitive and primary energy intensive sectors, impacts of climate change on prices and production in the model's sectors are generally small. The exceptions are food processing and wood products, two of the secondary climate sensitive sectors. The other secondary climate sensitive sectors and secondary energy intensive sectors show only small changes in prices and production.

2.0 Introduction

The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate Change (IPCC) concludes that "Warming of the climate system is unequivocal…" and that "Observational evidence from all continents and most oceans shows that many natural systems are being affected by regional climate changes, particularly temperature increases." The report also finds that "A global assessment of data since 1970 has shown it is likely that anthropogenic warming has had a discernible influence on many physical and biological systems." As with other regions of the nation and world, Pennsylvania's climate is very likely to change over the course of the next century and beyond as the globe experiences climate change driven by increased atmospheric concentrations of carbon dioxide and other greenhouse gases. Pennsylvania's climate future, and the projected impact of climate change on climate-sensitive human and natural systems in Pennsylvania, are presented in the 2009 *Pennsylvania Climate Impacts Assessment* (PACIA), produced for the Department of Environmental Protection (DEP) by Penn State University. This report, building on the findings of that assessment, examines the impacts of projected global climate change on Pennsylvania's economy at mid-century (2050).

The report begins with an overview of the methods used to identify and quantify economic impacts. The economic impacts of projected climate change are then reported for specific sectors of the economy and for the economy as a whole. Additional technical detail on the economic model used for the study is presented in the Appendix.

3.0 Methodology Overview

Steps in this assessment of climate change impacts on the Pennsylvania economy include (1) assessing how the Commonwealth's climate might change over the next century, (2) identifying pathways through which projected climate change would affect the Pennsylvania economy, (3) developing a multi-year, multi-sector economic model for impact analysis, (4) selecting and modeling climate change impacts in climate-sensitive sectors, and (5) estimating climate change impacts on the overall economy. This section summarizes key elements of the procedures.

3.1 Projected Climate Change

An essential first task in regional climate impact assessment is defining the future regional climate. This study uses the climate projections presented in the 2009 PACIA. A summary of the procedures and findings of that assessment is presented below, but details can be found in the earlier report and are therefore not repeated in this study.

The projections of Pennsylvania's future climate were derived from a suite of General Circulation Models (GCMs). GCMs are complex mathematical models that are solved on supercomputers to simulate the earth's climate. The GCM results used in the PACIA are the same as those used in support of the Fourth Annual Assessment (AR4) of the Intergovernmental Panel on Climate Change (IPCC) as they provide the best scientific information available for projecting 21st century climate at this time. An average of the projections from a suite of GCMs was used because model-average backcasts are found to more closely replicate the historical climate record in Pennsylvania in the 20th Century than the backcasts for any individual model, thus indicating greater reliability for the model average than for individual models or subsets. GCM projections of future climate require assumptions about the future course of global GHG emissions. The PACIA used two plausible emission scenarios to display a range of possible climate impacts depending on what global society does to mitigate greenhouse gas emissions (See Figure 3.1).

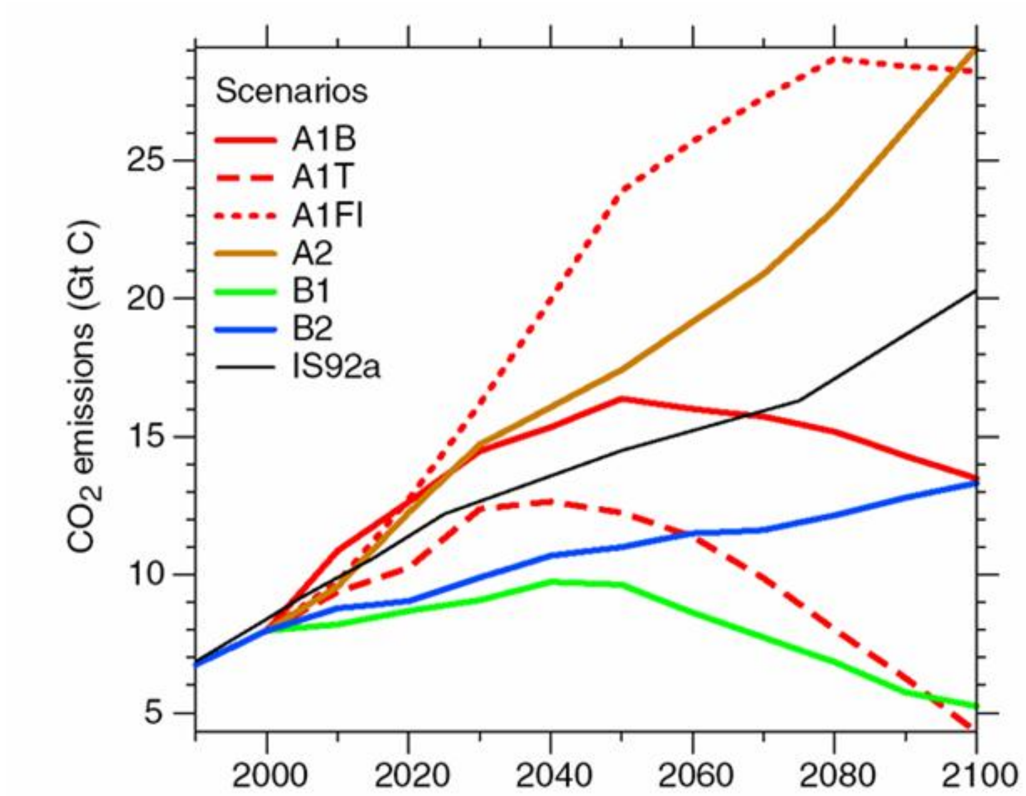

Figure 3.1. Annual CO_2 emissions for the 21st century in gigatons of carbon (Gt C) for a range of possible world development path ways. Source: IPCC 2007a

The scenarios are taken from the IPCC Special Report on Emissions Scenarios (SRES), which describes global GHG emissions in response to alternative world development pathways and covers a wide range of demographic, economic and technological driving forces. The SRES emissions scenarios are widely used in assessments of future climate change and its impacts.

One of the two scenarios considered in the PACIA assumes continued growth in global emissions throughout the 21st Century. This "high" emissions scenario is the IPCC A2 Scenario. The second, lower emissions scenario, assumes that emissions growth is moderated to the middle of the 21st century, and declines thereafter to about 50 percent of current rates by the end of the century (global emissions in 2007 from fossil fuel burning, cement manufacturing, and deforestation were about 10 Gt C). This scenario is the IPCC B1 scenario in the AR4.

The path of future emissions is highly uncertain because the course of world development and global collective actions to mitigate climate change over the next century are highly uncertain. SRES emissions scenarios with more rapid emissions growth than the A2 scenario are available. For example, the Union of Concerned Scientists' recent study of climate change impacts in Pennsylvania used the IPCC A1FI scenario (Frumhoff et al. 2007; Union of Concerned Scientists 2008). Similarly, scenarios with lower emissions than the B1 scenario are available. The PACIA emissions scenario selection was based on the availability of archived GCM output for model averaging, and the frequent use of the A2 and B1 scenarios in recent scientific research on climate change impacts.

The PACIA presented climate projections for three 20-year periods in the 21st century (2011-2030, 2046-2065, and 2080-2099), referenced to the recent 20-year period (1980-1999). The use of multi-year averages follows the norms for global climate projections and is done because natural climate variability requires that sufficiently long averages are taken to assess a climate signal. The three time frames essentially describe climate in the early, middle, and end of the 21st Century. *In this study of economic impacts, we consider only climate change to mid-century (2050). The reason for this is that the evolution of regional economic systems is much more uncertain than is the evolution of climate systems. Forecast errors in economic modeling increase rapidly with forecast length, and are likely to be far larger beyond mid-century than errors in climate projections*. *It is simply not possible to make projections with any confidence of what the Pennsylvania economy will look like beyond 2050*.

The PACIA projections are for the state as a whole but not for particular places or sub-regions of the Commonwealth. However, spatial variations across the Commonwealth that exist today are likely to remain in the future because they are due primarily to geographic factors that will remain unchanged in the future. These factors include elevation and distance from the coast. For example, climate in high elevations should remain cooler than the climate in the Piedmont Plain of Southeastern Pennsylvania even though temperatures may rise in each.

The main findings of the PACIA for the projected climate of the Commonwealth are:

- It is very likely that Pennsylvania will warm throughout the 21st century; not a single GCM simulates cooling under the high (A2) or low (B1) emissions scenarios.
- It is likely that annual precipitation will increase in Pennsylvania and very likely that winter precipitation will increase in both emissions scenarios.
- Projected climate change for the Commonwealth over the next 20 years does not differ between the high and low emissions scenarios. Pennsylvania’s projected climate by the end of the century differs significantly between the two scenarios.
- By the end of the century, the median projected warming according to the A2 scenario is almost 4 degrees C (7 degrees F), which is nearly twice that of the B1scenario.
- By late century, the median B1 and A2 annual precipitation projections increase by 6 and 10 percent, respectively. Corresponding winter projections are 8 and 15 percent.
- Warming will lead to a longer growing season, with median B1 and A2 projections of nearly 3 and 5 weeks lengthening, respectively, by late century. Corresponding frost day decreases are nearly 4 and 6 weeks.
- It is likely that precipitation events in Pennsylvania will become more extreme in the future, with longer dry periods and greater intensity of precipitation when it occurs.
- There is substantial uncertainty in projections of future tropical and extratropical cyclones for Pennsylvania. Current research suggests fewer storms but with increases in intensity.

These and other relevant findings from the PACIA inform the economic analyses conducted in this study. It is important to emphasize the insensitivity of Pennsylvania's projected climate to the choice of emissions scenarios to mid-century. This insensitivity reflects the slow response of the climate system to changes in GHG concentrations, and implies that Pennsylvania is highly likely to experience climate change to mid-century regardless of the evolution of economic and policy processes affecting GHG emissions. *Given that this study is limited to economic impacts to mid-century, this insensitivity also implies little variation in the climate impacts between the A2 and B1 emissions scenarios over the period of the assessment. For this reason, our economic projections do not distinguish between emissions scenarios. The study is essentially addressed to the economic impacts of "committed climate change" in Pennsylvania. Economic impacts beyond this period will depend to a much greater degree on the paths of GHG emissions and the resulting climate change.*

3.2 Global Climate Change, Regional Climate Change, and the Pennsylvania Economy

Global climate change will affect climate-sensitive human and natural systems within Pennsylvania because it affects Pennsylvania's regional climate. The regional climate change will affect Pennsylvania's economy through several channels.

Impacts on the productivity and costs in sectors that are climate sensitive in supply such as agriculture, forests, and snow-based recreation. Most crop and livestock production in Pennsylvania occurs, for example, partly or entirely in the open air, exposed to the elements and dependent on the weather for success. Even production that occurs under controlled climatic conditions, such as a mushroom house, is affected by climate through heating and cooling costs.

Impacts of climate change on the demand for goods produced in sectors that are climate sensitive in demand. The leading example is electricity, where demand is strongly affected by residential, commercial, and industrial heating and cooling demands. Climate change affecting human health in ways that leads to changes in the demand for health care services is another example.

Impacts of climate change on labor supply and productivity. Climate change affecting human health may also affect production in the economy by affecting the time that workers spend on the job or their productivity on the job.

Impacts of climate change on property. Sudden losses of property due to extreme events such as floods and hurricanes represent a loss of physical capital for production of market goods and services. Any capital good that is exposed to the elements may be subject to this type of damage, but those in agriculture, forestry, fisheries, construction, transport, electric power generation, and water supply would be especially vulnerable. Commercial, residential and government buildings might also be vulnerable.

General Equilibrium Impacts. Some economic sectors are largely insulated from climate change in terms of their own production processes and yet affected indirectly by other, climate-sensitive economic sectors within the region. For example, prices of capital, labor, materials, or other production inputs facing producers in one economic sector might change as a result of climate change impacts on other sectors within the region. Similarly, output prices received by producers in one sector might change as a result of climate change impacts on other sectors. For both outputs and inputs, price changes stimulate substitution away from higher-priced goods and toward lower-priced goods. These phenomena acting through markets and prices are commonly referred to as general equilibrium effects.

Multiplier Impacts. In addition, changes in prices of inputs can lead to changes in personal income, because ultimately, individuals are the owners and suppliers of inputs such as labor, capital, and many natural resources. Impacts such as these are not limited to direct impacts, because the direct first-round effects can generate a chain reaction of additional, although increasingly smaller, rounds of indirect effects. The total impact, taking into account all rounds of effects on all economic sectors, is some multiple of the direct impacts, and hence, the often-used term ''multiplier'' effects.

The impacts described above are impacts that influence the economy through the supply and demand for goods traded in markets. These represent the *market impacts of climate change*. This category of impacts is examined in this study using a multi-year, multi-sectoral economic model of the Pennsylvania economy. The model is a dynamic, Computable General Equilibrium (CGE) model that by design captures general equilibrium and multiplier effects. The sector specification of the model is selected to capture major upstream and downstream effects of climate change impacts on climate sensitive sectors. The model is described in detail in the Appendix. The sectoral specification and the modeling of climate change within sectors are described below.

Regional climate change can also have economic impacts through affects on the supply and demand for economically valuable *ecosystem services* that are not traded in markets. *Nonmarket impacts* such as impacts on non-game wildlife, impacts on quality of life, and pain and suffering associated with health impacts are excluded from this study. This exclusion reflects the objective of this study to estimate the conventional sectoral and macroeconomic impacts of climate change in Pennsylvania. The multi-year, multi-sector economic models best used for this purpose are not generally capable of nonmarket impacts analysis. The excluded nonmarket costs of climate change may well be of greater overall economic significance than the market costs (reference 3.)

3.3 Other Global Climate Change Impacts on the Pennsylvania Economy

Global climate change can also affect Pennsylvania through other economic, demographic, and ecological pathways (Abler et al. 2000a, Najjar et al., 2000) (See Figure 3.2)

Through exports, imports, inflows and outflows of capital, and in-migration and out-migration of labor, Pennsylvania' economy is highly interconnected with the economies of surrounding states, the nation, and the world. In consequence, climate change impacts on regional, national, and global markets for goods and services produced in the state can have implications for Pennsylvania's economy separate from the direct impacts of climate change on the economy. Differences in climate impacts between Pennsylvania and regions with which the state trades and competes must be taken into consideration when examining global climate change impacts on Pennsylvania. For example, global climate change will affect agricultural production across the

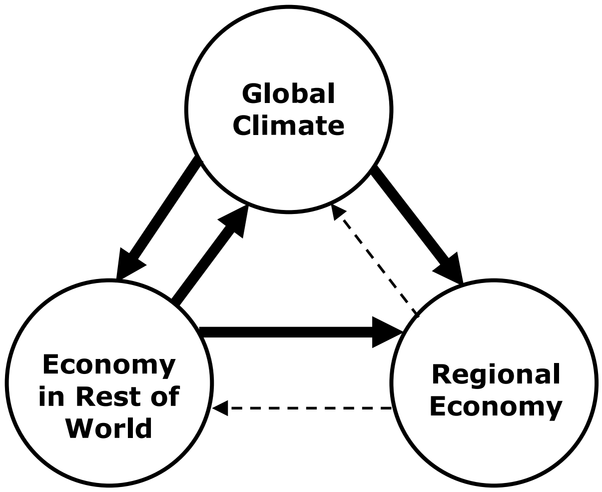

Figure 3.2. Schematic diagram illustrating the interaction of a regional economy with the global economy and the global climate. Solid arrows represent stronger influences than dashed arrows.

nation and the planet, affecting global agricultural markets. As a result, Pennsylvania farmers will be affected not only by changes in climatic conditions affecting agricultural productivity within the state, but also by changes in prices and agricultural technology induced by global climate change. Indirect impacts are important because they can amplify or counteract direct impacts on a sector, and because they can in some cases have greater impacts for a region than the direct impacts (e.g., Abler et al 2000b, 2002).

Referring to Fig. 3.2, effects on market goods and services within the state are represented by the arrow running directly from global climate to the state economy. Effects operating indirectly through other regions are represented by the two arrows running first from global climate to the rest-of-world economy and then from the rest-of-world economy to the state's economy. To capture these linkages between Pennsylvania and the national and world economies, the Economic model developed for this study includes modules that capture these interactions.

3.4 Sector Specification

The economic impacts presented in this report are derived from a 32 sector, multi-year computer model of the Pennsylvania, US, and world economies. By including the national and global economies, and linking them to that of Pennsylvania, the model captures essential economic relationships that influence the economic impacts of climate change to Pennsylvania. The 32 sectors included in the economic model encompass economic sectors addressed in the PACIA. The criteria that guided the choice of sectors in the PACIA, and the depth with which they were examined, were: (1) the importance of the sector to the state's economy, human wellbeing, and ecosystems; (2) the expected sensitivity of the sector to climate variability and change; and (3) the data and scientific results available to perform a credible assessment. Because this study examines the economy-wide impacts of climate change, the economic model includes additional sectors to capture general equilibrium and multiplier effects of individual sectoral responses to climate change.

The North American Industry Classification System (NAICS) that is the US standard for defining sectors for the measurement of economic activity is used as the basis for defining economic sectors in this study. To facilitate the economic analysis, the sectors included in the economic model are divided into climate sensitive sectors (in supply), energy intensive sectors, and other sectors. See Table 3.1. The types are not mutually exclusive and are classified by the dominant characteristic. In order to best capture and represent the general equilibrium effects of climate change in these sectors, the climate sensitive and energy intensive sectors were further broken down into primary and secondary production. Primary production refers to those sectors that produce the primary commodities that are used as inputs into secondary production. To illustrate this concept, consider the forestry sector. Commercial logging is a primary producer of timber. Climate change will directly impact the ability of commercial loggers to harvest timber from Pennsylvania’s forests by altering the species mix and growth rates of forests, and forest inventories. The wood products sector is an example of a secondary producer. While the production of wood products, lumber, engineered wood, veneer, etc. will not be directly affected by the changing climate, alterations in the type and quantity of the supply of timber produced by the logging industry will certainly have price effects on the wood products industry as well as changing the nature of their final product.

Table 3.1. Sector Aggregation Scheme

Climate Sensitive	Energy Intensive	Other
Primary	**Primary**	Other Manufacturing Services Insurance
Grains and Oilseeds Fruits, Vegetables and Nuts Greenhouse Products Other Crops Beef Dairy Poultry and Eggs Other Animal Production Forestry Pulp and Paper Other Agriculture	Coal Electricity Natural Gas Distribution Oil and Gas Extraction Petroleum and Petroleum Products	
Secondary	**Secondary**	
Food Processing Wood Products Manufacturing Water and Sewage Heating and Air Conditioning Equipment	Chemicals Rubber and Plastics Mining Nonmetallic Mineral Products Primary Metals and Metal Products Furniture Manufacturing Transportation Construction	

Sectors that are defined as those in which primary production takes place in the ambient environment. Their output will be directly affected by the changing climate. Primary climate sensitive sectors include the production of agricultural and forestry products. These are the sectors that produce crops, livestock and timber commodities for input into downstream processing into value-added products. Secondary climate sensitive sectors rely on the primary production of agricultural and forestry products as inputs into their production process. Examples of secondary climate sensitive sectors include food processing and wood products manufacturing. Energy intensive sectors are those that rely heavily on energy commodities, either as an output or input into the production process. Primary energy intensive sectors consist of the industries that produce primary energy products, i.e. electricity and fossil fuel production. Secondary energy intensive producers rely heavily on the output of the primary sector and include mining (other than coal), primary metals production, transportation, and construction, among others. Whereas agricultural production is affected by changes in output on the production side, energy intensive sectors are affected by price effects of changes in heating and cooling demands.

Not all sectors needed to represent the Pennsylvania economy, and that may be indirectly impacted by climate change, fit into this taxonomy. These sectors are primarily service sectors, the production of non-durable goods, and the insurance industry. These sectors fall into the "Other" column in Table 3.1.

The sector specification explicitly includes the agricultural, energy, forest, and insurance sectors that were addressed in the PACIA. The PACIA also considered impacts of climate change on aquatic ecosystems, human health, outdoor recreation and related tourism, and water resources. Climate change impacts on aquatic ecosystems, human health, and water resources will have market and nonmarket impacts. As noted previously, this study is limited to market impacts. Discernable market impacts of climate change impacts on aquatic ecosystems will most likely occur through impacts on recreational fishing. Commercial fishing and aquaculture are very small components of the Pennsylvania economy and are included within "other agriculture" in the sector specification scheme. Market impacts of climate change impacts on human health can show up in labor markets and in various sectors that provide health services and are addressed accordingly. The NAICS sector scheme defines the water supply and sewage sector as establishments primarily engaged in operating water treatment plants and/or operating water supply systems. The water supply system may include pumping stations, aqueducts, and/or distribution mains. The water may be used for drinking, irrigation, or other uses. Market impacts of climate change impacts on water resources would occur in these sectors, but also in other sectors, such as agriculture. Outdoor recreation and related tourism affect multiple sectors. The economic implications of climate change impacts on these activities are addressed accordingly.

3.5 Baseline economic scenarios

Economic impact analysis involves comparing "with" and "without" states of the economy. In this case, "with" means the economy with climate change and "without" means the economy without climate change. The economy without climate change is the reference economy for defining impacts and is referred to as the baseline economy. Because climate change is a long-term phenomenon, generating baseline economic scenarios requires consideration of potential economic conditions far into the future. The exogenous variables in the model influencing the evolution of the economy with or without climate change include total population, working age population, saving rates, depreciation rates, government taxes, rates of productivity growth, and rates of improvement in capital and labor quality. We assume the household savings rate is constant over time, set at the observed rate in the 2007 benchmark data set. Labor supply is the product of population and labor quality improvements. Population projections for the state of Pennsylvania were obtained from the State Data Center of the Pennsylvania State University at Harrisburg. Population projections for the rest of the US were obtained from the US Census. Given the expectation of higher educational attainment in the future, we assume that labor quality grows at 2.5 percent per year initially, falling to a growth rate of 0.5 percent per year by the end of the modeling period. An adjustment for improvements in future capital quality is also made in the model. This quality change refers to the shift in the composition of capital towards assets with shorter life. As with labor, we assume that capital quality rises by 2.5 percent per year initially, falling to a growth rate of 0.5 percent by the end of the modeling period.

In addition to growth in capital stocks and population and improvements in labor and capital quality over time, economic growth in the model is driven by improvements in total factor productivity (TFP). An improvement in TFP implies that fewer inputs are required to produce a unit of output. For Pennsylvania and the rest of the US, sectoral TFP improvements in the model were chosen to generate projections of growth in output and employment that replicate published state-level projections by industry from sources such as the Bureau of Economic Analysis (BEA). The model also assumes improvements in autonomous energy efficiency of 2 percent per year over the modeling period, consistent with published forecasts.

3.6 Climate Change Scenarios

The Pennsylvania economy with climate change is modeled by changing parameters of the baseline economic model to reflect the effects of regional climate change on demand or supply conditions in particular sectors, and to reflect the effects of global climate change on the national and world economies. *Because there is little difference in Pennsylvania's climate under the A2 or B1 scenarios to 2050, the "with climate change" scenarios are essentially intended to reflect the impact of committed climate change to mid-Century*. Details of modeling the impact of climate change on supply and demand by sector are described in subsequent sections.

4.0 Model Overview

The economic projections presented in this study are developed using a recursive dynamic inter-regional computable general equilibrium (CGE) model of the Pennsylvania economy.[1] The model is based on the modeling framework of Rausch and Rutherford (2008)—which calibrates the model to the IMPLAN state-level accounts—and the static regional modeling applications of Sue Wing (2007) and Sue Wing and Kolodziej (2008). In this analysis, we employ a model that extends these previous models to allow for the simulation of climate change impacts on factor productivity and demand for goods and services. The Economic modeling approach used in this analysis provides a flexible and theoretically rigorous platform for modeling climate change impacts at the sector level, and aggregates sectoral responses to the economy as a whole while capturing general equilibrium and multiplier effects (Bohringer et al., 2003, Bergman, 1991, Shoven and Whalley, 1992).

In the model, all interactions of the four economic agents—consumers, producers, government, and the trade sector—are captured. Consumers are endowed with a supply of labor and capital, which are employed by firms as factors of production. Firms purchase these factors at a price determined by the supply and demand (i.e. market) for those factors. Firms transform these factors of production into commodities that are either purchased by other firms as factors of production or by households as final consumption goods. A competitive equilibrium exists when prices equate supply and demand in all markets, producers earn no excess profit, and consumers exhaust all income. These are the three principles that govern general equilibrium theory. By specifying functional forms and elasticities of substitution between inputs and goods, these three principles guide all interaction within the simulated economy.

The production sector comprises a total of 32 producing sectors consisting of 10 agricultural sectors, 5 energy sectors, 11 nonenergy manufacturing sectors, construction, transportation, and four service sectors. The inter-industry structure of the model allows both direct and indirect effects of climate change to be captured. The production technology is assumed to exhibit constant returns to scale and firms are assumed to maximize profits.

Consumer demand for each of the 32 commodities is determined by utility maximization, where household income is derived from labor income, capital income and transfers. As in the Solow growth model, the household savings rate is set exogenously. The government sector collects taxes and uses the revenue to purchase goods and services. The trade sector is modeled using the standard one-country Armington approach which assumes domestic and imported goods are imperfect substitutes. There are three regions represented in the model: Pennsylvania, the rest of the US, and the rest of the world. Both intra-national and international trade are represented in the model, with trade flows influenced by differences in relative prices for goods and services across regions.

The primary sources of data for the construction of model parameters are state-level social accounting matrices (SAM) for 2007 from the Minnesota IMPLAN group (MIG).[2] These state-level SAMs are constructed using data from sources such as the Bureau of Economic Analysis

[1] Details on the model used in this analysis are provided in the Appendix.
[2] Further information on the IMPLAN data set can be found at www.implan.com.

(BEA), the Bureau of Labor Statistics (BLS), and the US Census. These social accounting matrices trace the flow of commodities and payments across all sectors of the regional economy in a given benchmark year. From this we derive the labor and capital incomes, the tax revenue by type of tax, and the expenditures on specific commodities by the household, government and foreign sectors.

5.0 Forestry

5.1 Climate Impacts on Pennsylvania's Forests

As discussed in the PACIA, climate change is projected to impact forests in both positive and negative ways. On the positive side, longer growing seasons, increased temperatures, increased rainfall, reduced cloud cover, and the CO_2 fertilization effect are expected to increase forest productivity. On the negative side, mortality due to stress and forest disturbances, including fire, insects and disease, and damaging storms, is likely to increase. Tree and other forest-related species are also projected to shift their ranges to the north and to higher elevations. These range shifts could have both positive and negative effects. On the southern and lower-elevation parts of their ranges, species are likely to experience increasing stress as the climate becomes less suitable. This may cause increased rates of mortality and would make these species more susceptible to insect and disease problems. On the other hand, in Pennsylvania in particular, the species that are found to the south of the state tend to be more productive than species currently found in the state.

Assessing forestry impacts is further complicated by the fact that what may be bad for forest ecosystems may not be bad for the forest products industry. Tree mortality, also referred to as dieback in the climate change literature, can lead to salvage opportunities that can increase timber supplies in the short run. However, if dieback occurs very rapidly, it may not be possible to harvest all the dying timber before it becomes unusable, and valuable timber inventories (and carbon stores) may be lost. Furthermore, if dieback creates opportunities to replace relatively slow-growing, natural stands of northern species with fast-growing plantations of southern species, forest growth rates could be increased substantially within a few decades.

Because of the difficulty of predicting when, where and how forest disturbances will occur, most assessments of the potential economic impact of climate change on the forest products industry (e.g., Joyce et al. (1995), Perez-Garcia et al. (1997) and McCarl et al. (2000), Kirilenko and Sedjo (2007)) have focused mainly on the potential for increased productivity. In the literature reviewed for this report, only Sohngen and Mendelsohn (1998) and Sohngen et al. (2001) explicitly modeled the impacts of a potential dieback. In general, dieback events are more likely to be local or regional than at a scale like the US. Typically, they would be caused by a species or group of species becoming stressed and then becoming susceptible to an insect or disease pathogen or caused by a regional drought resulting in high mortality or fires. Another possibility at approximately the scale of a state could be a major blow-down due to a hurricane.

Most forest products markets are global, so it is likely that indirect impacts due to climate change impacts in other regions will affect Pennsylvania's forest products sector. At scales such as the US and the world, most likely some areas will experience diebacks while other areas experience increased growth rates; in fact, there is considerable evidence that this is already happening (c.f., Nemani et al. 2003 and Westerling et al. 2006). Most studies (e.g., Kirilenko and Sedjo (2007)) assume that at a national scale for the US and at a global scale forest productivity increases will outweigh local dieback events, resulting in a net increase in overall supplies. Thus, we assume in our scenarios that forest productivity will increase in the rest of the US and the world.

Because it is difficult to project whether, when and how a major forest dieback event due to climate change will occur in a particular state such as Pennsylvania, two scenarios are proposed: an optimistic scenario and a pessimistic scenario. Under the optimistic scenario, in Pennsylvania, the rest of the US, and the rest of the world forest productivity/output is assumed to increase faster than it would without climate change. This scenario assumes that dieback resulting from climate change will occur, but that productivity increases in some areas within each region outpace losses due to dieback in other areas. Under this scenario, over the time horizon from 2007 to 2050, the total relative increase in productivity in the Forestry sector in Pennsylvania is assumed to be 20 percent (for the modeled 43-year time period, this corresponds to an annual increase of approximately 0.425 percent). This represents a relatively optimistic scenario for the state where dieback is assumed to be minimal – or at least at a slow enough rate that most of the dying trees can be salvaged – and that the relatively slow-growing natural stands of northern species in the state are replaced over time by faster-growing plantations of more southern species. The total relative increase for the rest of the US is assumed to be 15 percent (or an annual rate of approx. 0.326 percent). This is lower than for Pennsylvania because a larger proportion of the US is assumed to suffer dieback, and in some regions, particularly the southeast, there is less opportunity to replace natural stands with plantations. This projected increase is similar to the increased growth rates assumed by Joyce et al. (1995) and Sohngen et al. (2001), but more optimistic than the rates assumed in Perez-Garcia et al. (1997), Sohngen and Mendelsohn (1998) and Irland et al. (2001). The total relative increase in the Forestry sector for the rest of the world is assumed to be 20 percent. This higher rate is assumed because globally there are many opportunities to replace natural forests with fast-growing plantations. Our assumed growth rate is slightly more conservative than the 23 percent improvement assumed by Kirilenko and Sedjo (2007).

The pessimistic scenario is not intended to be a prediction of what is likely to happen. It is intended to illustrate what could happen if a sudden wide-spread dieback event were to occur in the state. From Pennsylvania's perspective, the "worst case" scenario assumes that net productivity increases occur in other regions, but that Pennsylvania experiences a major dieback event. This would result in a situation where a lot of salvaged wood would be put on the market at a time when prices are low due to increased supplies in the rest of the US and the world. Thus, assumptions for the rest of the US and the world are the same for both the pessimistic and the optimistic scenarios. For Pennsylvania, we assume that productivity increases initially at the same rate as under the optimistic scenario until 2020, at which time a fairly sudden major dieback episode is assumed to occur. This is assumed to lead to a rapid increase (10 percent per year) in the harvest for 3 years as the dying trees are salvaged, followed by a rapid decline (10 percent per year) for the next 7 years due to the diminished inventory of mature timber. Following this dieback episode, the scenario assumes that state rebuilds its Forestry sector, planting new species that are better adapted to the new climate. These species are assumed to be more productive and managed on shorter rotations, leading to a relatively rapid expansion of the sector (1.71 percent per year) for the remainder of the simulation period (Figure 5.1).

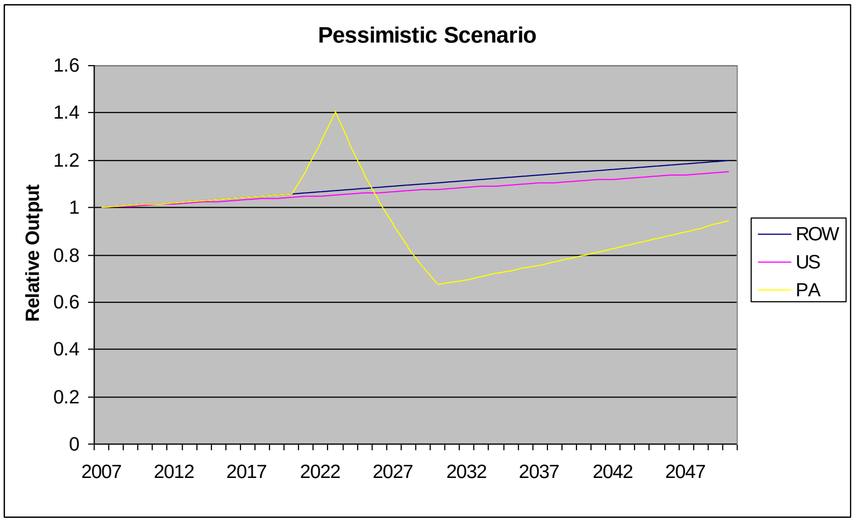

Figure 5.1. Relative output (compared to 2007) in the forestry sector for three regions under the pessimistic scenario.

5.2 Economic model Results (Forest Sector Impacts Only)

This section focuses primarily on the "Forestry Sector Impacts Only" results. In the optimistic case, Pennsylvania Forestry sector output in 2050 increases by nearly 33 percent, while the price falls by 22 percent (Tables 5.1a and 5.1.b). Employment in the Forestry sector increases by 15 percent. Output increases by more than the assumed increase in productivity as capital and labor are drawn to the sector due to its increased profitability. Output in the closely related Wood Products sector increases correspondingly by 5 percent, with a 2.4 percent increase in employment in that sector. Wood Products prices also fall by 4 percent in the state. In the rest of the US, Forestry sector output increases by 20 percent – again, more than the assumed increase in productivity – and Forestry employment increases by 5 percent. Nationally, Forestry sector prices fall by 20 percent.

Somewhat surprisingly, output in Pennsylvania's Pulp and Paper sector declines by 1.6 percent in this scenario. This is most likely due to increasing production in this sector in the rest of the US and the world; Pulp and Paper output in the rest of the US increases by 1.6 percent. This reflects the fact that Pennsylvania's forestry and Wood Products sectors are currently structured to produce solid wood products such as lumber, rather than pulp and paper, as such uses are more appropriate for the species that currently grow in the state. This could change, however, if the state's forests are converted to fast-growing softwood plantations, as wood from such plantations is generally more suitable for use in the Pulp and Paper sector. This may be an area where the Economic model does not capture certain types of economic adjustments that might occur. Another possibility that is difficult to capture in a model such as this is that much of the wood that is produced in 2050 may be used in entirely new industries, such as biomass refineries, that are not included in the model because its structure is based on an input-output matrix that represents the current economy.

The only other sector that is notably affected in this scenario is the Other Agriculture sector, whose output is projected to increase by 1.3 percent. This likely represents increased production from tree nurseries. If, indeed, a substantial portion of the state's forests were converted from natural to planted forests, the actual impact on this sector could be many times greater than this.

Table 5.1a. Sectoral impacts (percent difference from base case with no climate change in 2050) of the optimistic Forestry sector scenario for Pennsylvania.

Pennsylvania			
Sector	Prices	Output	Employment
Grains_and_oilseeds	0.10%	0.03%	-0.14%
Fruits_vegetables_nuts	0.03%	-0.01%	-0.05%
Greenhouse_products	0.09%	-0.02%	-0.05%
Other_crops	0.11%	0.07%	0.05%
Beef	0.08%	0.09%	0.05%
Dairy	0.06%	0.13%	0.06%
Poultry_and_eggs	0.06%	0.09%	0.04%
Other_animal_production	0.09%	0.09%	0.03%
Forestry	-21.73%	32.58%	15.03%
Other_agric	0.24%	1.27%	0.67%
Oil_gas	0.03%	-0.05%	-0.10%
Coal	0.09%	-0.04%	-0.10%
Other_mining	0.07%	-0.01%	-0.03%
Electricity	0.07%	0.01%	-0.02%
Nat_gas_distr	0.05%	-0.01%	-0.05%
Water_and_sewage	0.06%	0.05%	0.01%
Construction	-0.07%	0.12%	0.00%
Food_tobacco	-0.06%	0.17%	0.07%
Wood_products	-4.17%	4.92%	2.43%
Pulp_paper	-1.26%	-1.58%	-2.22%
Petro_products	0.07%	0.01%	-0.09%
Chemicals	0.05%	-0.04%	-0.09%
Rubber_plastics	-0.08%	-0.01%	-0.11%
Nonmetallic_metals	0.03%	0.09%	0.02%
Primary_metals	0.05%	-0.05%	-0.08%
Other_mfg	0.02%	-0.02%	-0.08%
Transportation	0.06%	-0.01%	-0.05%
Furniture	-0.12%	0.42%	0.18%
Services	0.09%	0.02%	0.00%
Insurance	0.09%	0.00%	-0.02%
Healthcare	0.10%	0.04%	0.03%
Tourism_related	0.07%	0.06%	0.02%

Table 5.1b. Sectoral impacts (percent difference from base case with no climate change in 2050) of the optimistic Forestry sector scenario for the rest of the US.

Rest of US			
Sector	Prices	Output	Employment
Grains_and_oilseeds	0.10%	-0.01%	-0.20%
Fruits_vegetables_nuts	0.04%	0.04%	-0.06%
Greenhouse_products	0.09%	0.00%	-0.06%
Other_crops	0.11%	0.03%	-0.08%
Beef	0.09%	0.04%	-0.01%
Dairy	0.05%	0.07%	0.00%
Poultry_and_eggs	0.05%	0.07%	0.00%
Other_animal_production	0.08%	0.06%	-0.02%
Forestry	-20.18%	19.55%	5.28%
Other_agric	0.13%	0.20%	0.13%
Oil_gas	0.03%	-0.04%	-0.11%
Coal	0.10%	0.02%	-0.11%
Other_mining	0.07%	0.00%	-0.09%
Electricity	0.09%	0.05%	0.00%
Nat_gas_distr	0.07%	0.06%	0.00%
Water_and_sewage	0.07%	0.05%	0.00%
Construction	-0.06%	0.14%	0.01%
Food_tobacco	-0.05%	0.12%	0.01%
Wood_products	-4.11%	5.40%	2.82%
Pulp_paper	-1.27%	1.63%	1.09%
Petro_products	0.07%	0.02%	-0.10%
Chemicals	0.06%	0.02%	-0.08%
Rubber_plastics	-0.12%	0.26%	0.12%
Nonmetallic_metals	0.03%	0.08%	0.00%
Primary_metals	0.05%	-0.05%	-0.11%
Other_mfg	0.03%	-0.04%	-0.12%
Transportation	0.06%	-0.01%	-0.08%
Furniture	-0.21%	0.69%	0.41%
Services	0.10%	0.03%	-0.01%
Insurance	0.09%	-0.02%	-0.05%
Healthcare	0.12%	0.04%	0.02%
Tourism_related	0.08%	0.06%	0.01%

While substantial increases are projected under this optimistic scenario for the forestry and Wood Products sectors, the overall impact on the state's economy, and the economy of the rest of the US, is minimal: GSP increases by less than 0.1 percent in the year 2050 (Table 5.2a and 5.2b).

Table 5.2a. Forestry Impacts Only (optimistic) Changes in Macroeconomic Indicators, Pennsylvania.

Forestry Impacts (optimistic) case vs. Baseline case - % difference						
Year	Pennsylvania					
	GDP	Consumption	Investment	Government	Net exports*	GDP price index
2010	0.00%	0.00%	0.00%	0.00%	-0.03%	0.00%
2020	0.02%	0.01%	0.02%	-0.01%	-5.09%	0.02%
2030	0.04%	0.02%	0.05%	-0.02%	0.76%	0.03%
2040	0.06%	0.04%	0.08%	-0.03%	0.68%	0.04%
2050	0.08%	0.05%	0.11%	-0.05%	0.71%	0.05%
Difference in average annual growth rate, 2007-2050	0.002%	0.001%	0.003%	-0.001%	-0.017%	0.001%

* Includes both intra- and international trade

Table 5.2b. Forestry Impacts Only (optimistic) Changes in Macroeconomic Indicators, Rest of US.

Forestry Impacts (optimistic) case vs. Baseline case - % difference						
Year	Rest of US					
	GDP	Consumption	Investment	Government	Net exports*	GDP price index
2010	0.00%	0.00%	0.00%	0.00%	-0.02%	0.00%
2020	0.02%	0.01%	0.02%	-0.02%	4.12%	0.02%
2030	0.04%	0.03%	0.05%	-0.03%	0.37%	0.03%
2040	0.06%	0.04%	0.08%	-0.04%	0.35%	0.05%
2050	0.09%	0.06%	0.11%	-0.06%	0.39%	0.07%
Difference in average annual growth rate, 2007-2050	0.002%	0.001%	0.003%	-0.001%	-0.009%	0.002%

* Includes both intra- and international trade

In the pessimistic case, where Pennsylvania is assumed to experience a major dieback event starting in 2020, Pennsylvania's Forestry sector output falls by about 28 percent by the year 2050, while Forestry prices fall by 12 percent and employment in the sector falls by nearly 30 percent (Tables 5.3a and 5.3b). Even though the productivity of the state's Forestry sector is assumed to rebound again after the dieback event, by 2050 it is still below the initial 2007 baseline.

Table 5.3a. Sectoral impacts (percent difference from base case with no climate change in 2050) of the pessimistic Forestry sector scenario for Pennsylvania.

Pennsylvania			
Sector	Prices	Output	Employment
Grains_and_oilseeds	0.08%	0.15%	0.06%
Fruits_vegetables_nuts	0.03%	0.17%	0.11%
Greenhouse_products	0.05%	0.07%	0.06%
Other_crops	0.08%	0.17%	0.14%
Beef	0.06%	0.19%	0.15%
Dairy	-0.01%	0.18%	0.17%
Poultry_and_eggs	0.03%	0.14%	0.10%
Other_animal_production	0.06%	0.08%	0.05%
Forestry	-11.90%	-28.20%	-29.69%
Other_agric	-0.23%	-2.34%	-1.02%
Oil_gas	0.00%	0.05%	0.05%
Coal	0.06%	0.08%	0.06%
Other_mining	0.06%	0.10%	0.10%
Electricity	0.02%	0.02%	-0.01%
Nat_gas_distr	0.02%	0.01%	0.00%
Water_and_sewage	0.01%	0.00%	-0.02%
Construction	-0.08%	0.04%	-0.02%
Food_tobacco	-0.06%	0.16%	0.12%
Wood_products	-2.72%	0.41%	-1.51%
Pulp_paper	-1.06%	-2.37%	-2.89%
Petro_products	0.03%	0.03%	-0.01%
Chemicals	0.03%	0.00%	0.00%
Rubber_plastics	-0.08%	-0.02%	-0.07%
Nonmetallic_metals	0.02%	0.12%	0.12%
Primary_metals	0.04%	0.09%	0.08%
Other_mfg	0.01%	0.03%	0.04%
Transportation	0.02%	0.02%	0.03%
Furniture	-0.10%	0.25%	0.10%
Services	0.03%	0.03%	0.04%
Insurance	0.05%	0.07%	0.08%
Healthcare	0.02%	0.01%	0.04%
Tourism_related	0.02%	0.04%	0.02%

Table 5.3b. Sectoral impacts (percent difference from base case with no climate change in 2050) of the pessimistic Forestry sector scenario for the rest of the US.

Rest of US			
Sector	Prices	Output	Employment
Grains_and_oilseeds	0.08%	-0.01%	-0.17%
Fruits_vegetables_nuts	0.03%	0.03%	-0.05%
Greenhouse_products	0.07%	0.00%	-0.05%
Other_crops	0.09%	0.03%	-0.07%
Beef	0.07%	0.03%	-0.01%
Dairy	0.04%	0.06%	-0.01%
Poultry_and_eggs	0.04%	0.06%	0.00%
Other_animal_production	0.07%	0.05%	-0.02%
Forestry	-17.39%	17.20%	4.92%
Other_agric	0.11%	0.18%	0.10%
Oil_gas	0.03%	-0.04%	-0.09%
Coal	0.08%	0.00%	-0.11%
Other_mining	0.06%	0.00%	-0.08%
Electricity	0.07%	0.04%	0.00%
Nat_gas_distr	0.06%	0.05%	0.00%
Water_and_sewage	0.06%	0.05%	0.00%
Construction	-0.05%	0.12%	0.01%
Food_tobacco	-0.04%	0.10%	0.01%
Wood_products	-3.48%	4.68%	2.51%
Pulp_paper	-1.08%	1.41%	0.96%
Petro_products	0.06%	0.02%	-0.09%
Chemicals	0.05%	0.02%	-0.06%
Rubber_plastics	-0.10%	0.22%	0.10%
Nonmetallic_metals	0.03%	0.07%	0.00%
Primary_metals	0.04%	-0.04%	-0.10%
Other_mfg	0.02%	-0.04%	-0.10%
Transportation	0.05%	-0.01%	-0.07%
Furniture	-0.18%	0.58%	0.35%
Services	0.08%	0.02%	-0.01%
Insurance	0.08%	-0.02%	-0.04%
Healthcare	0.10%	0.03%	0.01%
Tourism_related	0.06%	0.05%	0.01%

Since Forestry sector productivity in the rest of the US is assumed to have steadily increased during this time, Forestry sector output in the rest of the US has increased by 17 percent, resulting in a decline of Forestry sector prices in the rest of the US of 17 percent. With lower overall prices and relatively lower productivity compared with the rest of the US and the world, output and employment in Pennsylvania's Forestry sector is projected to have contracted by nearly a third. Somewhat surprisingly, however, output in Pennsylvania's Wood Products sector increases, albeit by less than half a percent. A possible explanation is that the state's Wood Products sector has taken advantage of the increased supplies and lower prices of forest products from the rest of the US and the world and is importing more of its raw materials. No such shift occurs in the state's Pulp and Paper sector. The state's Pulp and Paper sector output falls in this scenario by 2.4 percent.

As in the optimistic scenario, the Other Agriculture sector is linked to the Forestry sector, and since output in the Forestry sector declines in this scenario, there is a corresponding decline in the Other Agriculture sector. Again, this most likely reflects the linkage between the Forestry sector and tree nurseries. If, however, a major forest dieback event occurred, this sector would likely benefit substantially due to the increased demand for seedlings for reforestation, so the results here likely underestimate the potential benefits to the Other Agriculture sector. Also, as in the optimistic scenario, the overall impact of the shifts in the forestry sector on the state's economy, and the economy of the rest of the US, is minimal (Tables 5.4a and 5.4b).

Table 5.4a. Forestry Impacts Only (pessimistic) Changes in Macroeconomic Indicators, Pennsylvania.

Forestry Impacts (pessimistic) case vs. Baseline case - % difference						
Year	**Pennsylvania**					
	GDP	**Consumption**	**Investment**	**Government**	**Net exports***	**GDP price index**
2010	0.00%	0.00%	0.00%	0.00%	-0.03%	0.00%
2020	0.01%	0.01%	0.02%	-0.01%	-4.54%	0.01%
2030	-0.04%	-0.03%	-0.04%	0.02%	-0.98%	-0.02%
2040	-0.05%	-0.04%	-0.03%	0.01%	-0.60%	-0.01%
2050	-0.02%	-0.02%	0.00%	-0.01%	-0.20%	0.01%
Difference in average annual growth rate, 2007-2050	-0.001%	0.000%	0.000%	0.000%	0.005%	0.000%

* Includes both intra- and international trade

Table 5.4b. Forestry Impacts Only (pessimistic) Changes in Macroeconomic Indicators, Rest of US.

Forestry Impacts (pessimistic) case vs. Baseline case - % difference						
Year	Rest of US					
	GDP	Consumption	Investment	Government	Net exports*	GDP price index
2010	0.00%	0.00%	0.00%	0.00%	-0.02%	0.00%
2020	0.02%	0.01%	0.02%	-0.01%	3.74%	0.02%
2030	0.03%	0.03%	0.04%	-0.03%	0.33%	0.03%
2040	0.06%	0.04%	0.07%	-0.04%	0.31%	0.04%
2050	0.08%	0.05%	0.09%	-0.05%	0.34%	0.06%
Difference in average annual growth rate, 2007-2050	0.002%	0.001%	0.002%	-0.001%	-0.008%	0.001%

* Includes both intra- and international trade

6.0 Agriculture

In this and subsequent sections we present our projections of the economic impacts of climate change by sectors that are expected to be directly impacted by climate change in supply or demand. The selection of sectors follows the PACIA. The sections review climate change impacts on each sector based on the PACIA, interpret that information to construct sectoral climate impact scenarios used to model economic impacts, and present the estimated impacts. We first present projections of the impacts of climate change on individual sectors assuming that climate change does not affect other sectors. This exercise allows us to abstract from the economic effects of climate change in any one sector, such as energy, on others, such as agriculture, so as to better understand the direct effects of climate change on the directly affected sector, and how affects on the sector spill over into other sectors. We then present projections of the economic impacts when climate change simultaneously affects each of the sectors.

6.1 Climate Impacts on Agriculture

The PACIA finds that climate change between now and 2050 is likely to have mixed effects on Pennsylvania agriculture. Changes in patterns of temperature and precipitation are likely to raise productivity for some agricultural products, reduce productivity for others, and in some cases have minimal impacts on productivity.

The PACIA concludes that carbon dioxide fertilization effects and climate change are likely to raise Pennsylvania yields of grains and oilseeds between now and 2050. Elevated levels of CO_2 may lead to an increase in photosynthesis and thus crop yields, a phenomenon often called the CO_2 fertilization or enrichment effect. Comparisons of present-day grain and oilseed yields in Pennsylvania with yields in states to the south of Pennsylvania indicate that moderate warming of 1-3 degrees C is likely to raise yields. Based on the evidence discussed in the PACIA, we project that climate change will raise productivity in Pennsylvania grain and oilseed production by 5 percent in 2050.

The PACIA finds that the same forces working to raise Pennsylvania grain and oilseed yields are also likely to be at work elsewhere in the US and in other countries. Grain and oilseed production in Midwest states with similar or more northerly latitudes than Pennsylvania is also likely to benefit from warmer temperatures, although yields in southern states may fall. The same may be said for grain and oilseed producing regions in many other countries. Based on the studies and statistics reviewed when preparing the PACIA, we project that climate change will also raise productivity in grain and oilseed production in the rest of the US by 5 percent in 2050.

The PACIA projects that climate change between now and 2050 will likely increase Pennsylvania yields of warm-weather fruits and vegetables such as sweet corn while reducing yields of cool-weather products such as apples. The result is likely to be a shift in fruit and vegetable acreage in Pennsylvania toward more warm-weather crops and crop varieties, some of which are higher value products than the cool-weather ones they would replace. Based on these considerations, we project that climate change will raise productivity in Pennsylvania fruit, vegetable, and tree nut production by 10 percent in 2050. Similar forces are likely to be at work in other states with similar or more northerly latitudes than Pennsylvania, although fruit and vegetable production in southern and southwestern states could be hurt by changes in temperature and precipitation in those areas. For the rest of the US, we project that climate change will increase productivity in fruit, vegetable, and tree nut production by 5 percent in 2050.

Greenhouse products, by definition, are produced under controlled climatic conditions. With climate change, there will on average be less heating required during the winter months but additional cooling during the summer months. The net effects on annual energy use and annual production costs are unclear, and the PACIA concludes that we cannot say with confidence whether they will increase or decrease. Given this, we assume here that climate change will have no effect on productivity in greenhouse production in Pennsylvania or the US in 2050.

The “other crops” sector in the Economic model is a diverse collection of products, and the mix of products in this sector might change over time if climate change makes some less profitable and others more profitable. This makes it difficult to quantify the effects of climate change on production. For lack of evidence one way or the other, we assume that climate change will have no effect on productivity in other crop production in Pennsylvania or the US in 2050. Similarly, for the “other agriculture” sector in the model, we assume that climate change will have no effect on productivity in other crop production in Pennsylvania or the US in 2050.

In Pennsylvania dairy and beef cattle production, livestock are outdoors much of the time. The PACIA notes that dairy cows and beef cattle prefer cool temperatures, with the optimum temperature range for milk production being 4.5-23.8 degrees C (40-75 degrees F). Increases in temperatures between now and 2050 are likely to lead to some heat-stress losses in milk and meat production in Pennsylvania. The heat-stress losses are likely to be greater in more southern states, where climate change will push average temperatures even further outside of the optimum temperature range. Producers in those states could compensate by keeping livestock indoors more of the time, but that would entail additional housing and cooling costs. Based on the studies and statistics reviewed when preparing the PACIA, we project that climate change will reduce productivity in Pennsylvania dairy and beef cattle production by 5 percent in 2050. In the rest of the US, we project that productivity in these two sectors will decline by 10 percent in 2050.

Poultry and eggs in Pennsylvania and other states are mostly produced in large-scale indoor facilities where the birds are kept in close quarters. Climate change will reduce heating costs during the winter while increasing cooling costs during the summer. The PACIA concludes that the net effects on poultry and egg production are unclear. However, in southern states where a large portion of US poultry production is currently concentrated, the additional cooling costs during the summer are likely to outweigh the additional heating costs during the winter. The PACIA finds that climate change could lead to a shift in poultry production from southern states to more northerly ones such as Pennsylvania. Given this, we project that productivity in the poultry and egg sector will not change in Pennsylvania by 2050, but in the rest of the US it will decline by 5 percent in 2050.

In the Economic model, hogs and pigs are included in the “other animal” sector and they are the most important products in this sector. Hogs and pigs in Pennsylvania are typically housed inside of growing facilities, with ventilation and fans used to keep hogs cool during the summer.

During very high summer temperatures, producers will sometimes spray water on their hogs to keep them cool. The PACIA notes that adult hogs prefer cooler temperatures, with the optimum temperature range for adult hog growth being 13-21 degrees C (55-70 degrees F). Baby pigs must be kept warmer, with optimum temperatures between 29-32 degrees C (85-90 degrees F). Climate change will increase summer cooling costs but reduce winter heating costs. Like poultry and eggs, the PACIA finds that climate change could lead to a shift in hog and pig production from southern states to more northerly ones such as Pennsylvania. Given this, we project that productivity in the other animal sector will not change in Pennsylvania by 2050, but in the rest of the US it will decline by 5 percent in 2050.

6.2 Economic model Results (Agricultural Impacts Only)

This section focuses primarily on the "Agricultural Impacts Only" results because the results for agriculture when changes in forestry and energy costs are also considered are very similar. Changes in forest productivity and energy costs have general equilibrium and multiplier impacts on agriculture, and changes in energy costs also have direct impacts on costs of production in the agricultural sectors. However, the Economic model results indicate that these indirect impacts are small. Nearly all of the changes in prices, output, and employment in the agricultural sectors are due to the impacts of climate change on agricultural productivity in Pennsylvania and the rest of the United States.

The Economic model results (see tables 6.1a and 6.1b) indicate that climate change will increase production of grains and oilseeds in Pennsylvania in 2050 by about 7 percent while the number of grain and oilseed farmers (employment) will increase by approximately 8 percent. Production in the rest of the US also increases by about 7 percent because of productivity gains there, and grain and oilseed prices fall as a result of these increases in output. The results indicate that grain and oilseed prices received by Pennsylvania farmers will fall by about 6 percent. These changes in prices and output essentially offset each other, with the result that there is very little change in grain and oilseed revenues.

This same pattern of higher production but lower prices is also evident for fruits, vegetables and nuts. The Economic model results indicate that climate change will increase fruit, vegetable and nut production in Pennsylvania in 2050 by about 21 percent while the number of growers (employment) will increase by about 10 percent. Production in the rest of the US increases by about 6 percent, which is less than Pennsylvania because the rise in productivity in this sector is smaller for the rest of the US than Pennsylvania. These increases in output cause fruit, vegetable and nut prices received by Pennsylvania growers to decline by about 4 percent. For Pennsylvania growers the increase in production is significantly greater than the decline in price, with the result that fruit, vegetable and nut revenues increase.

For greenhouse products and other crops, as mentioned earlier, we did not project any changes in productivity in Pennsylvania or other states. These sectors are still affected by climate change to a small extent because of general equilibrium and multiplier impacts. There are small increases in prices, production and employment in these sectors.

For beef and dairy, we project declines in productivity in Pennsylvania. However, both sectors gain as a result of climate change because of even steeper declines in productivity in other states. Some production of beef and dairy products shifts to Pennsylvania from other states, and Pennsylvania's net shipments of these products to other states increase. For beef, the Economic model results indicate that climate change will increase Pennsylvania production in 2050 by about 6 percent, while employment will increase by about 11 percent. For dairy, the results indicate that climate change will increase Pennsylvania production by about 2 percent and employment by nearly 13 percent. Production in the rest of the US falls by 10 percent for beef and 7 percent for dairy. These declines in production in the rest of the US lead to increases in prices received by producers. Prices received by Pennsylvania producers rise by about 11 percent for beef and 4 percent for dairy.

For poultry and eggs, we project no change in productivity in Pennsylvania but a decline in productivity in other states. Like beef and dairy, this gives Pennsylvania a competitive advantage relative to other states, as declines in production in other states cause an increase in prices received by Pennsylvania producers. The Economic model results indicate that climate change will increase Pennsylvania poultry and egg production and employment in 2050 by about 8 percent, and that prices received by producers will increase by approximately 3 percent.

For other animal products, which are primarily hogs and pigs, the pattern of results is similar to poultry and eggs, beef, and dairy. We project no change in productivity in Pennsylvania but a decline in productivity in other states. The Economic model results indicate that climate change will increase Pennsylvania production and employment of other animal products in 2050 by about 5 percent, and that prices received by producers will increase by nearly 7 percent.

Agricultural products are inputs into food processing, and changes in the Economic model in agricultural prices and production lead to changes in prices and production in the model's food processing sector. The model results indicate that Pennsylvania food processing output will increase in 2050 by about 2 percent as a result of climate change, and that employment in this sector will rise by about 3 percent. Prices received by Pennsylvania food producers will increase by 1 percent. These gains in production occur mostly because of increases in net shipments of food products to other states. The model results indicate that production of food products in the rest of the US in 2050 falls by about 1 percent.

The Economic model results indicate that Pennsylvania production in all of the agricultural sectors in the model increases in 2050 as a result of climate change. As production increases, resources—labor, capital, and intermediate inputs—are drawn away from some other sectors of the economy and into agriculture through general equilibrium impacts. These general equilibrium impacts are mostly small in percentage terms.

Table 6.1a. Sectoral impacts (percent difference from base case with no climate change in 2050) of the Agriculture sector scenario for Pennsylvania.

Pennsylvania			
Sector	Prices	Output	Employment
Grains_and_oilseeds	-5.95%	6.57%	7.94%
Fruits_vegetables_nuts	-4.35%	20.63%	10.36%
Greenhouse_products	0.29%	0.24%	0.23%
Other_crops	0.48%	3.02%	2.78%
Beef	11.20%	6.06%	10.95%
Dairy	3.80%	1.68%	12.68%
Poultry_and_eggs	2.63%	7.50%	7.75%
Other_animal_production	4.96%	6.73%	6.33%
Forestry	0.15%	-0.09%	-0.11%
Other_agric	0.69%	1.62%	1.78%
Oil_gas	0.10%	-0.17%	-0.19%
Coal	0.12%	-0.13%	-0.22%
Other_mining	0.15%	-0.01%	0.05%
Electricity	0.15%	0.03%	0.04%
Nat_gas_distr	0.12%	0.02%	0.01%
Water_and_sewage	0.12%	-0.01%	-0.01%
Construction	0.12%	0.00%	0.00%
Food_tobacco	1.00%	2.40%	2.80%
Wood_products	0.11%	-0.06%	-0.07%
Pulp_paper	0.12%	0.02%	-0.14%
Petro_products	0.18%	0.01%	-0.13%
Chemicals	0.20%	0.08%	0.02%
Rubber_plastics	0.13%	0.08%	0.07%
Nonmetallic_metals	0.11%	-0.03%	-0.06%
Primary_metals	0.07%	-0.19%	-0.22%
Other_mfg	0.05%	-0.20%	-0.24%
Transportation	0.10%	-0.04%	-0.08%
Furniture	0.04%	-0.14%	-0.12%
Services	0.13%	0.00%	0.00%
Insurance	0.10%	-0.05%	-0.05%
Healthcare	0.11%	-0.06%	-0.05%
Tourism_related	0.21%	-0.04%	0.02%

Table 6.1b. Sectoral impacts (percent difference from base case with no climate change in 2050) of the Agriculture sector scenario for the rest of the US.

Rest of US			
Sector	Prices	Output	Employment
Grains_and_oilseeds	-6.05%	7.48%	11.70%
Fruits_vegetables_nuts	-4.44%	5.67%	4.02%
Greenhouse_products	0.29%	0.12%	0.13%
Other_crops	0.29%	0.54%	0.36%
Beef	13.87%	-9.97%	0.43%
Dairy	10.99%	-7.05%	2.00%
Poultry_and_eggs	5.92%	-3.84%	0.84%
Other_animal_production	5.99%	-4.21%	-0.92%
Forestry	0.14%	-0.24%	-0.19%
Other_agric	0.88%	2.42%	2.14%
Oil_gas	0.09%	-0.16%	-0.13%
Coal	0.12%	-0.12%	-0.19%
Other_mining	0.16%	-0.01%	-0.06%
Electricity	0.15%	-0.03%	0.01%
Nat_gas_distr	0.12%	-0.03%	0.00%
Water_and_sewage	0.17%	0.12%	0.13%
Construction	0.13%	0.01%	0.03%
Food_tobacco	1.41%	-1.03%	-0.54%
Wood_products	0.11%	-0.09%	-0.08%
Pulp_paper	0.12%	-0.25%	-0.22%
Petro_products	0.19%	0.04%	-0.11%
Chemicals	0.23%	0.16%	0.03%
Rubber_plastics	0.13%	-0.21%	-0.19%
Nonmetallic_metals	0.11%	-0.11%	-0.10%
Primary_metals	0.07%	-0.24%	-0.22%
Other_mfg	0.05%	-0.22%	-0.25%
Transportation	0.09%	-0.11%	-0.14%
Furniture	0.07%	-0.13%	-0.13%
Services	0.14%	-0.02%	0.00%
Insurance	0.11%	-0.07%	-0.05%
Healthcare	0.12%	-0.05%	-0.03%
Tourism_related	0.24%	-0.07%	0.01%

As prices of agricultural products and products from other sectors change, and as incomes received by farmers and workers in others sectors change, there are slight changes in consumption and government spending (see Tables 6.2a and 6.2b). The economic model results indicate that consumption in 2050 falls by 0.06 percent while government spending falls by 0.13 percent. Net exports, which include shipments to both other states and other countries, rise by 0.73 percent. The combined impact on Pennsylvania's gross state product (GSP) in 2050 is small but slightly negative (-0.02 percent).

In the rest of the US, the economic model results indicate that consumption in 2050 falls by slightly less (0.05 percent) than in Pennsylvania (0.06 percent). This is because the sectors of the economy experiencing the largest price increases are those that account for a greater percentage of total consumption in Pennsylvania than in other states. In contrast to Pennsylvania, the model results indicate that gross domestic product (GDP) in the rest of the US in 2050 rises slightly (0.02 percent). This is due primarily to consumption, which declines by less in the rest of the US (0.05 percent) than in Pennsylvania (0.06 percent). Consumption also accounts for a smaller share of GDP in the rest of the US (71 percent) than in Pennsylvania (76 percent).

When changes in forest productivity and energy costs are considered, the results for the agricultural sectors, and the food processing sector, are virtually identical to the results discussed above. The only significant differences occur in the "other agriculture" sector, which includes forest nurseries. In the pessimistic case for forestry, Pennsylvania production in the other agriculture sector in 2050 declines by about 1 percent versus an increase of about 2 percent in the Agricultural Impacts Only results. In the optimistic case for forestry, Pennsylvania production in the other agriculture sector increases by about 3 percent.

Table 6.2a. Agricultural Impacts Only: changes in Macroeconomic Indicators, Pennsylvania

Agriculture Impacts case vs. Baseline case - % difference						
Year	Pennsylvania					
	GDP	Consumption	Investment	Government	Net exports*	GDP price index
2010	0.00%	0.00%	0.00%	0.00%	-0.02%	0.00%
2020	0.00%	-0.01%	0.00%	-0.02%	-4.23%	0.02%
2030	-0.01%	-0.02%	0.00%	-0.04%	0.70%	0.05%
2040	-0.01%	-0.04%	0.01%	-0.08%	0.67%	0.09%
2050	-0.02%	-0.06%	0.02%	-0.13%	0.73%	0.15%
Difference in average annual growth rate, 2007-2050	0.000%	-0.002%	0.000%	-0.003%	-0.017%	0.003%

* Includes both intra- and international trade

Table 6.2b. Agricultural Impacts Only: changes in Macroeconomic Indicators, Rest of US

Agriculture Impacts case vs. Baseline case - % difference						
Year	**Rest of US**					
	GDP	**Consumption**	**Investment**	**Government**	**Net exports***	**GDP price index**
2010	0.00%	0.00%	0.00%	0.00%	-0.01%	0.00%
2020	-0.01%	-0.02%	-0.01%	-0.01%	3.06%	0.02%
2030	-0.01%	-0.03%	0.00%	-0.04%	0.40%	0.05%
2040	0.00%	-0.04%	0.01%	-0.08%	0.49%	0.10%
2050	0.02%	-0.05%	0.03%	-0.14%	0.66%	0.17%
Difference in average annual growth rate, 2007-2050	0.000%	-0.001%	0.001%	-0.003%	-0.016%	0.004%

* Includes both intra- and international trade

7.0 Energy

The implications of climate change for Pennsylvania's energy sector have been studied in detail in the PACIA. As discussed in that report, increased temperatures in the summer will lead to greater demand for air conditioning which is partially offset by lower demand for heating in the winter months. Results from a modeling exercise that assesses the impact on annual electricity demand in the PJM system under six climate scenarios show that annual electricity demand will be approximately 2 percent higher under a "high" emissions scenario than if no climate impacts occurred. It is assumed that this percentage impact will affect the three broad sectors of the economy (industrial, commercial, and residential) equally.

The US Climate Change Science Program Synthesis and Assessment Product 4.5 (CCSP, 2007) provides a review of the literature on the impacts of climate change on energy use in the residential and commercial sectors in the US. Out of the list of studies highlighted in the CCSP report, Mansur et al. (2008) is one of the few studies that captures increases in the adoption of air conditioning units in households previously without air conditioning. Mansur et al. (2008) projects a net increase in residential demand for electricity of 2 percent in 2050 from a 1 degree C increase in annual temperature and a 0 percent net increase in electricity demand in the commercial sector. The CCSP report projects a negligible impact on electricity demand in the US industrial sector since this sector is not believed to be sensitive to temperature changes as a result of climate change.

Informed by these previous studies, our energy use scenario assumes that Pennsylvania will experience a gradual increase in electricity demand over time across all sectors compared to the baseline case, reaching 2 percent in 2050. For the rest of the US, we assume that the residential sector experiences a gradual increase in electricity demand compared to the baseline case over time, reaching 2 percent in 2050. We assume no impact on the commercial and industrial sectors.

7.2 Economic model Results (Energy Sector Impacts Only)

Assuming a 2 percent increase in electricity demand in all sectors of the Pennsylvania economy does little to impact the overall economy of the state. As shown in Table 7.1a, the fall in gross state product and the components of GSP is minimal—GSP in 2050 is only 0.05 percent less than GSP in the baseline case while consumption and investment are only 0.06 percent and 0.05 percent less, respectively. There is no negligible change in overall prices and net exports are slightly higher—0.14 percent. The impacts are even less in the rest of the US, as shown in Table 7.b, since only the residential sector experiences an increase in electricity demand.

Table 7.1a. Energy Impacts Only: Changes in Macroeconomic Indicators, Pennsylvania

Energy Impacts case vs. Baseline case - % difference						
Year	Pennsylvania					
	GDP	Consumption	Investment	Government	Net exports*	GDP price index
2010	0.00%	0.00%	0.00%	0.00%	-0.01%	0.00%
2020	-0.02%	-0.02%	-0.02%	0.00%	-1.47%	0.00%
2030	-0.03%	-0.04%	-0.03%	0.01%	0.21%	0.00%
2040	-0.04%	-0.05%	-0.04%	0.01%	0.16%	0.00%
2050	-0.05%	-0.06%	-0.05%	0.01%	0.14%	0.00%
Difference in average annual growth rate, 2007-2050	-0.001%	-0.001%	-0.001%	0.000%	-0.003%	0.000%

* Includes both intra- and international trade

Table 7.1b. Energy Impacts Only: Changes in Macroeconomic Indicators, Rest of US

Energy Impacts case vs. Baseline case - % difference						
Year	Rest of US					
	GDP	Consumption	Investment	Government	Net exports*	GDP price index
2010	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
2020	-0.01%	-0.01%	-0.01%	0.00%	0.65%	0.00%
2030	-0.01%	-0.01%	-0.01%	0.00%	0.05%	0.00%
2040	-0.01%	-0.02%	-0.01%	0.01%	0.04%	0.00%
2050	-0.01%	-0.02%	-0.02%	0.01%	0.04%	0.00%
Difference in average annual growth rate, 2007-2050	0.000%	-0.001%	0.000%	0.000%	-0.001%	0.000%

* Includes both intra- and international trade

Examining the sectoral impacts in Tables 7.2a and 7.2b, we again see minimal impacts. The electricity sector in both PA and the rest of the US experience an increase in output and prices as a result of higher electricity demand. The increase in Pennsylvania is higher than the rest of the US because the impact on electricity demand is assumed to be higher—i.e., a 2 percent increase in the commercial and industrial sectors in 2050 in PA versus a 0 percent increase in these sectors in the rest of the US. In both tables we see an increase in output and prices in the sectors that supply to the electricity sector (e.g., coal, refined oil, natural gas). Sectors that are more electricity-intensive (e.g., metals) experience lower output and higher prices due to the increase in electricity prices. Sectors that are less electricity-intensive (e.g., agricultural sectors, services, healthcare) experience a decline in output and prices due to lower demand as a result of consumption being diverted to electricity purchases and lower incomes.

Table 7.2a. Sectoral impacts (percent difference from base case with no climate change in 2050) of the Energy sector scenario for Pennsylvania.

Pennsylvania			
Sector	Prices	Output	Employment
Grains_and_oilseeds	-0.01%	-0.07%	0.00%
Fruits_vegetables_nuts	0.00%	-0.08%	-0.05%
Greenhouse_products	-0.01%	-0.04%	0.00%
Other_crops	-0.01%	-0.11%	-0.07%
Beef	0.00%	-0.21%	-0.14%
Dairy	0.05%	-0.20%	-0.17%
Poultry_and_eggs	-0.01%	-0.12%	-0.07%
Other_animal_production	-0.01%	-0.10%	-0.05%
Forestry	-0.01%	-0.06%	0.00%
Other_agric	-0.01%	0.00%	0.05%
Oil_gas	0.03%	0.00%	0.01%
Coal	0.16%	0.35%	0.21%
Other_mining	0.01%	-0.10%	-0.06%
Electricity	0.95%	1.91%	2.08%
Nat_gas_distr	0.07%	-0.10%	-0.06%
Water_and_sewage	-0.02%	-0.05%	-0.02%
Construction	-0.02%	-0.04%	-0.01%
Food_tobacco	0.00%	-0.14%	-0.09%
Wood_products	0.00%	-0.06%	-0.03%
Pulp_paper	0.00%	-0.22%	-0.19%
Petro_products	0.03%	0.02%	0.03%
Chemicals	0.00%	-0.06%	-0.02%
Rubber_plastics	0.00%	-0.05%	-0.02%
Nonmetallic_metals	0.00%	-0.14%	-0.12%
Primary_metals	0.00%	-0.14%	-0.10%
Other_mfg	-0.01%	-0.02%	0.02%
Transportation	-0.01%	-0.01%	0.02%
Furniture	-0.01%	0.00%	0.02%
Services	-0.02%	-0.03%	0.00%
Insurance	-0.02%	0.00%	0.04%
Healthcare	-0.04%	-0.05%	-0.02%
Tourism_related	-0.01%	-0.06%	-0.04%

Table 7.2b. Sectoral impacts (percent difference from base case with no climate change in 2050) of the Energy sector scenario for the rest of the US.

Rest of US			
Sector	Prices	Output	Employment
Grains_and_oilseeds	0.00%	-0.02%	0.00%
Fruits_vegetables_nuts	0.00%	-0.02%	-0.01%
Greenhouse_products	-0.01%	-0.02%	-0.01%
Other_crops	0.00%	-0.02%	0.00%
Beef	0.00%	-0.02%	-0.01%
Dairy	0.00%	-0.02%	0.00%
Poultry_and_eggs	-0.01%	-0.02%	-0.01%
Other_animal_production	0.00%	-0.02%	-0.01%
Forestry	0.00%	-0.01%	0.00%
Other_agric	-0.01%	0.00%	0.00%
Oil_gas	0.01%	0.02%	0.03%
Coal	0.16%	0.43%	0.28%
Other_mining	0.01%	-0.01%	0.00%
Electricity	0.42%	0.81%	0.87%
Nat_gas_distr	0.01%	0.02%	0.04%
Water_and_sewage	-0.01%	-0.02%	-0.01%
Construction	-0.01%	-0.01%	0.00%
Food_tobacco	-0.01%	-0.02%	-0.01%
Wood_products	0.00%	-0.01%	0.00%
Pulp_paper	0.00%	-0.01%	0.00%
Petro_products	0.02%	0.03%	0.03%
Chemicals	0.00%	-0.02%	0.00%
Rubber_plastics	0.00%	-0.01%	0.00%
Nonmetallic_metals	0.00%	-0.01%	0.00%
Primary_metals	0.00%	0.00%	0.01%
Other_mfg	0.00%	0.00%	0.01%
Transportation	-0.01%	0.00%	0.01%
Furniture	-0.01%	-0.01%	0.00%
Services	-0.01%	-0.01%	0.00%
Insurance	-0.01%	-0.01%	-0.01%
Healthcare	-0.02%	-0.02%	-0.02%
Tourism_related	-0.01%	-0.02%	-0.01%

Lastly, net exports are higher in both Pennsylvania and the rest of the US when electricity demand is higher. This is due to a fall in prices of goods that are heavily traded intranationally (e.g., other manufacturing and services). The percentage difference in net exports is higher in Pennsylvania than the rest of the US because prices of these goods are falling more in the Commonwealth than in the rest of the US.

8.0 Human Health

The PACIA identified several potential impacts that climate change could have on human health in Pennsylvania. These are summarized in Table 8.1.

Table 8.1. Summary of potential impacts of climate change on human health in Pennsylvania

Health Impact	Mechanism of Impact	Direction of Impact	Level of Confidence in Direction of impact
Mortality	Higher summer temperatures cause an in increase in heat-related deaths	↑	High
Mortality	Higher winter temperatures cause a decrease in cold-related deaths	↓	High
Respiratory disease	Higher summer temperatures cause in increased in ozone formation	↑	High
Respiratory disease	Higher temperatures increase formation of airborne particulates	↑	Low
Respiratory disease	Higher temperatures, higher CO2 levels and longer summer season increase prevalence of pollen and mold	↑	Low
Accidents	Increases in flood and sever rainstorms. Decreases in snow and ice storms	?	Low
Infectious Disease	Higher temperatures affect range and abundance of disease-carrying vectors	?	Low
Infectious Disease	Higher temperatures and runoff lead to increased concentration of water-borne pathogens in surface waters	↑	Medium
Infectious Disease	Higher winter temperatures affect incidence of pneumonia and seasonal influenza	↓	Low

The analysis in the PACIA found that most potential impacts of climate change on human health are speculative. For only three impacts could the direction be established with high confidence; climate change will cause an increase in heat-related deaths, a decrease in cold-related deaths, and an increase in respiratory disease caused by ground-level ozone. These three are examined in more detail below.

8.1 Temperature-Related Mortality

To evaluate the economic impact of a change in health from climate change, it is first necessary to project the change in the number of health outcomes that would occur per year. For temperature-related mortality, several studies have estimated the relationship between ambient temperature and mortality.

Martens (1998) estimates the excess mortality due to climate change for several countries, based on existing temperature-mortality relationships. For the US, he calculates changes in death rates for those under 65 and those 65 and older. These are given in Table 8.2. While these estimates are for the entire US, they are based on the baseline climate for two representative cities. A specific state in the US would differ from these average numbers because of acclimatization. However, Pennsylvania is pretty close to average for the US in terms of temperature. Also, the relationship between mortality and baseline temperature is not dramatic. Therefore, these numbers can be used to project excess mortality in Pennsylvania.

Table 8.2. Excess Deaths per 100,000 due to a 1C increase in temperature for the US. From Martens (1998)

Cold-Related	
Under 65	-3.3
Over 65	-153.3
Heat-Related	
Under 65	0.8
Over 65	26.7

The changes in mortality frequency in Table 8.2 were applied to the projected population of Pennsylvania. Projections of US total population and population by age for 2050 are from the Census. The proportion of US population located in Pennsylvania is extrapolated from projections generated by the Pennsylvania State Data Center. The resulting projected change in the number of excess temperature-related deaths from a 2 C increase in annual mean temperature are given in Table 8.3. The estimates in Table 8.3 include changes due to cardiovascular mortality only. Changes due to respiratory mortality are much more speculative, and projections of those changes are not robust.

Table 8.3. Change in Pennsylvania temperature-related excess deaths from a 2 degrees C increase in mean annual temperature. Based on Martens (1998).

	Change in Temperature-Related Mortality
Cold-Related	
Under 65	-717
Over 65	-8689
Heat-Related	
Under 65	174
Over 65	1513
Total	
Under 65	-543
Over 65	-7181

In a separate study, Curriero et al. (2002) estimated the percentage change in excess mortality associated with heat and cold specifically for Philadelphia. Their study did not differentiate between deaths for residents over 65 versus under 65, but the impact on total mortality estimated from their study can be compared to the impacts presented in Table 8.3. Using their estimated relationships between mortality and temperature above and below the minimum mortality temperature, and adjusting for the number of days that temperature exceeds or falls below the minimum mortality temperature, we find that a 2 degrees C increase in temperature would result in a decrease in excess deaths of 13,400 per year, a little over twice as large as the estimate based on the Martens study. This estimate is less useful for modeling economic impacts, because it does not distinguish between excess deaths among working age adults versus adults of retired age.

Not all studies project that the decrease in cold-related deaths will be larger than the increase in heat-related deaths. Whereas most studies examine the relationship between temperature and mortality, Kalkstein and Greene (1997) investigated the impact of different types of air masses on mortality, and projected the impact of climate change on frequency of those air masses. They find that excess mortality tends to be highest during times when tropical humid air masses are present. They measure the relative risk of different air masses with and without climate change, and calculate how often different air masses will occur in the future, based on three GCM model runs. In both Pittsburgh and Philadelphia, they find that the increase in heat-related deaths is larger than any decrease in cold-related deaths.

Kalkstein and Greene did not differentiate their estimates by age. In the Martens (1998) study, temperature-related excess mortality rates for persons under 65 years of age are about 2.5 percent of those for persons 65 and older. Using this ratio, and applying the average impact for Pittsburgh and Philadelphia to other areas of the states, estimates of the impact of climate change on temperature related mortality can be generated. These presented in Table 8.4.

Table 8.4. Change in Pennsylvania temperature-related excess deaths. Based on Kalkstein and Greene (1997).

	Change in Temperature-Related Mortality
Cold-Related	
Under 65	-8
Over 65	-82
Heat-Related	
Under 65	56
Over 65	589
Total	
Under 65	49
Over 65	507

The two studies, by Martens and by Kalkstein and Greene, both find that climate change would increase heat-related deaths and decrease cold-related deaths. They differ, however, in their conclusions about which effect would dominate. The projections in Table 8.3 and 8.4 can serve as upper and lower bounds on the impact that climate change could have on temperature-related mortality.

A change in temperature-related mortality would affect the economy of Pennsylvania in two ways. First, it would affect the supply of labor. Here, the change in mortality for working-age Pennsylvania residents is very small, regardless of which set of projections are used. Each year, the baseline mortality for Pennsylvania residents under the age of 65 years is about 0.27 percent. Under the optimistic projection based on the Martens study, this would decrease to 0.26 percent. Under the pessimistic projection based on the Kalkstein and Greene study, this mortality rate would increase to 0.272 percent. In neither case would the impact be large enough to materially impact labor supply, or the Pennsylvania economy through the labor supply.

The second way in which a change in temperature-related mortality could affect the Pennsylvania economy is through the expenditures on health care and other services associated with early deaths. Here, there are no specific estimates of the expenditures that are incurred when someone dies from excess heat or cold. It is more common to calculate the health care expenditures associated with attempting to avoid a death. However, there are some estimates of the expenditures associated with some other types of deaths. For example, the US Suicide Prevention Resource Center estimates that the average medical cost per suicide is $3983. The US Centers for Disease Control estimate that the average medical cost per homicide is $4906. These are fairly low, likely because many of these deaths occur before medical care can be given. Deaths from excess heat or cold would likely entail different costs, because they are most often due to cardiovascular events, rather than trauma. Molinari et al (2007) estimate an average cost of treatment per case of influenza that results in death of $42,000 for persons over 65 years old. Influenza deaths likely involve more medical treatment than deaths due to excess heat or cold.

Even using the estimated cost per death of $42,000, the medical costs associated with changes in temperature-related mortality are very small, ranging from an increase in annual medical expenditures of $23 million per year (using the projections based on the Kalkstein and Greene study) to a decrease in medical expenditures of $324 million per year (using the projections based on the Martens study). In contrast, the healthcare sector of the economic model of Pennsylvania used in this study has annual value of $65 billion. The impacts of climate change considered here are all less than 0.5 percent of the health care sector total, and less than 0.1 percent of total spending in Pennsylvania.

8.2 Morbidity From Increased Ozone Creation

The PACIA found that summer ozone concentrations in Pennsylvania would increase as a consequence of climate change, due to higher summer temperatures. By 2050, peak 8-hour summer ozone concentrations are expected to increase by 5ppb in Philadelphia and Pittsburgh, and about 2.5ppb for the rest of the state.

Medina-Ramon et al (2006) found that a 5 ppb increase in 8-hour ozone levels results in a 0.27 percent increase in COPD hospital admissions and a 0.41 percent increase in pneumonia admissions. Ponce de Leon (1996), found that a 29ppb increase in ozone concentration was associated with a 4.83 percent increase in the rate of hospital admissions for all ages. Rescaling this for a 5ppb change in concentrations generated an estimated summer increase in hospital admissions for all respiratory disease of 0.8 percent, which is over double that estimated in the Medina-Ramon et al. study.

These relative risk estimates were used to calculate the increase in hospital admissions in metro Philadelphia, metro Pittsburgh, and the rest of the state. Increased summer ozone concentrations from higher summer temperatures are projected to cause an increase in hospital admissions statewide of between 281 and 648 per year, depending on which source study is used.

Kaplan et al (2002) report an average cost per hospital admission for pneumonia for patients over 65 of $6,949. In the EPA's (1999) prospective cost-benefit analysis of the Clean Air Act, the average cost of respiratory and cardiovascular hospital admissions was $8,968. Using this latter estimate, the projected increase in medical costs from increased hospital admissions due to higher ozone concentrations from climate change is calculated to be $2.5-5.8 million. As with the costs associated with temperature-related mortality changes, these estimates are very small relative to the size of the health care sector in Pennsylvania.

Increased ozone concentrations have also been associated with higher frequency of emergency room visits for asthma (EPA 1999). However, the number of extra cases and cost per case are even smaller than those for hospital admissions.

Because the impacts of climate change on labor supply and health care expenditures are very small, the general equilibrium economic impacts associated with health effects of climate change would also be very small, and were not modeled for this report.

9.0 Property Impacts and Insurance

The PACIA concludes that Pennsylvania's precipitation climate will become more extreme in the future, with longer dry periods and greater intensity of precipitation when it occurs. However, there is substantial uncertainty in projections of future tropical and extratropical cyclones for Pennsylvania. Current research suggests fewer storms but with increases in intensity. Summer floods and general stream flow variability are projected to increase. A reduced snowpack might cause a reduction in rain-on-snow events, a process which historically caused major flooding events in Pennsylvania, though this conclusion remains speculative before more detailed studies have been performed. The frequency of short and medium length soil moisture droughts is projected to increase.

These conclusions, which indicate both positive and negative impacts, do not provide a definitive case for a net increase or decrease in the frequency and severity of weather related property losses in Pennsylvania due to climate change during the assessment period. Additional research on the vulnerability of Pennsylvania's physical assets to climate change is needed before an economy-wide analysis can be conducted that is anything more than speculative.

10.0 Outdoor Recreation and Tourism

The PACIA concludes that climate change in the Pennsylvania will have negative impacts for some outdoor recreation activities (notably winter sports and trout fishing) and positive impacts for other activities (warmwater fishing, swimming and boating, golf, and outdoor exercise). The outdoor recreation activities that will be most severely impacted are snow- and ice-based recreation such as skiing, snowmobiling and ice skating and ice fishing. There is very high confidence in the direction of these impacts. Projections for Pennsylvania are that, even with increased snowmaking, ski season length under the B2 emissions scenario will decrease by 29 percent in western Pennsylvania and by 32 percent in eastern Pennsylvania by the end of the century. The economic viability of ski resorts is questionable with such short seasons. Dispersed snow-based recreation such as cross country skiing and snowmobiling is at even more risk. Pennsylvania's climate is already marginal for these activities. As a consequence of warming and less snowfall, the number of days when conditions are suitable for cross country skiing or snowmobiling in Pennsylvania is projected to decrease under the "low" B2 scenario by 61 percent in north-central Pennsylvania and by 75 percent in eastern Pennsylvania by the end of the century. Higher emissions scenarios would imply more severe impacts. Because snowmaking is not practical, there are few adaptation opportunities for these activities.

Increased temperatures will reduce the number of stream stretches that can support wild trout populations. The direction of this impact is established with high confidence, though the magnitude of the impact is uncertain. Increased stocking can serve as a partial substitute for lost wild trout habitat, but some waters will become too warm to support even stocked trout. A reduction in the availability of cold-water fishing does not mean that fishing activity will decline, however. In fact, the evidence is that total demand for fishing days will most likely increase, due to a longer season with pleasant weather and due to a desire to be near water on hot days. The direction of this impact is established with medium confidence.

It is difficult to project whether climate change will have either a positive or a negative impact on hunting participation. The most important game species in Pennsylvania are fairly widely distributed, and tolerant of different climates. Changes in forest composition could affect wildlife abundance, but the direction the impact is difficult to predict. Similarly, changes in weather could affect hunter behavior, but again the direction of the impact is difficult to predict.

Likewise, participation in non-consumptive forest-based recreation such as hiking and camping could be affected by climate change. Higher temperatures will lengthen the season for such activities, but could make them less enjoyable in the middle of summer. Changes in forest composition could also affect these activities. The direction that climate change might impact these activities cannot be established.

Climate change is expected to increase participation in non-fishing water-based recreation activities such as swimming and boating, due to a longer summer season and higher mid-summer temperatures. Similarly, participation in outdoor sporting and exercise activities such as golf, tennis, and biking are expected to increase, due to a longer season. There is high confidence in the direction of these impacts, though quantitative estimates of the changes in participation are unavailable.

A longer summer recreation season could induce more tourist visits to Pennsylvania. A study conducted for the PA DCNR (Shifflet and Assoc 1998) found that 15.9 million travelers visited Pennsylvania for the purpose of outdoor recreation, spending $4 billion in the state. Half of these visits occurred during the summer months (June, July and August). An increase in spring and fall temperatures could lengthen the summer tourism season, increasing the total number of outdoor recreation tourist visits to the state, though school calendars could limit the potential for travel during the shoulder seasons. Further, increased regional temperatures could induce more tourism travel to Pennsylvania by residents from nearby warmer areas such as the Baltimore-Washington area. Increased tourist visits to Pennsylvania would generate increased sales in service industries. However, a lengthened warm season and higher mid-summer temperatures could also induce Pennsylvania residents to take more trips out of state, to cooler areas to the north or to the Atlantic Coast. The direction of the net impact of warmer temperatures on outdoor recreation tourism spending is therefore impossible to predict.

One particular area of concern regarding outdoor recreation and tourism is the potential impact of climate change on fall leaf viewing. As temperatures rise, some or all of the areas of the state that currently are dominated by northern tree species (maple, beech and birch) will transition to southern species (oak and hickory) that are considered less colorful in the fall. Studies have been conducted on the potential economic impact of lost fall tourism in more northern states, particularly Vermont. There, fall leaf viewing accounts for 8 percent of tourist visits (Lin et al. 1999). An analogous estimate for Pennsylvania is not available, however the Shifflet and Associates study found that total visitation during October, including visits for leaf viewing, accounts for less than 8 percent of total outdoor recreation tourist visits. To the extent that leaf viewing becomes less attractive due to changes in forest species, this visitation will decline to an unknown extent. However, higher October temperatures could make other outdoor activities more attractive, offsetting the impact on visitation of a change in fall colors.

In sum, climate change can be expected to make Pennsylvania less suitable for some outdoor recreation activities, but more suitable for others. The consequences of changes in outdoor recreation and tourism for the Pennsylvania economy will depend on the effects of climate change on the composition and location of recreation activities, and total spending on these activities. Because climate change is projected to positively impact some outdoor recreation activities and negatively impact others, it is impossible to project with any confidence the net effect of climate change on the total outdoor recreation participation and spending. In any event, the literature on outdoor recreation participation and spending does not suggest that the total impact of climate change on outdoor recreation participation and spending will be large. In consequence, the impact of climate change on overall economic activity related to outdoor recreation and tourism in the Commonwealth to mid-Century is therefore highly likely to be small, whether positive or negative. While the impacts of climate change on the overall economy may be negligible, particular locations and activities may be more acutely affected, such as communities in which ski resorts are significant.

11.0 Economy-Wide Impacts (Agriculture, Forest and Energy Impacts)

The Economic model projects that the impacts of climate change on Pennsylvania's gross state product (GSP) will be small. The model results when the agriculture, forestry and energy impacts are considered together, GSP in 2050 decreases by 0.09 percent in the pessimistic case for forestry and increases by 0.02 percent in the optimistic case. By comparison, Pennsylvania's real (inflation-adjusted) GSP grew by an average of 2.1 percent per year during 1997-2008, and is projected by the Economic model to grow by 2.7 percent per year between now and 2050 in the model's baseline scenario.

In both the optimistic and pessimistic cases, climate change increases average prices paid by Pennsylvania households and businesses—the GDP price index rises by about 0.2 percent in each case. This works to reduce consumption expenditures by households in both cases. However, in the optimistic case there is a significantly greater increase in Pennsylvania exports to other states and countries (1.6 percent) than in the pessimistic case (0.7 percent). The additional exports are enough to raise GSP in the optimistic case. Key economic indicators at ten year time steps for the optimistic and pessimistic cases are shown in Tables 11.1a,b and 11.2a,b respectively.

Table 11.1a. Agriculture, Forestry, and Energy (optimistic) Changes in Macroeconomic Indicators, Pennsylvania.

Agriculture, Forestry, and Energy Impacts case (optimistic) vs. Baseline case - % difference						
	Pennsylvania					
Year	**GDP**	**Consumption**	**Investment**	**Government**	**Net exports***	**GDP price index**
2010	0.00%	0.00%	0.00%	0.00%	-0.07%	0.01%
2020	0.00%	-0.02%	0.01%	-0.03%	-10.78%	0.04%
2030	0.00%	-0.04%	0.02%	-0.06%	1.66%	0.08%
2040	0.01%	-0.06%	0.04%	-0.10%	1.50%	0.14%
2050	0.02%	-0.07%	0.07%	-0.17%	1.57%	0.21%
Difference in average annual growth rate, 2007-2050	0.000%	-0.002%	0.002%	-0.004%	-0.037%	0.005%

* Includes both intra- and international trade

Table 11.1b. Agriculture, Forestry, and Energy (optimistic) Changes in Macroeconomic Indicators, Rest of US.

Agriculture, Forestry, and Energy Impacts case (optimistic) vs. Baseline case - % difference						
Year	Rest of US					
	GDP	Consumption	Investment	Government	Net exports*	GDP price index
2010	0.00%	0.00%	0.00%	0.00%	-0.03%	0.01%
2020	0.00%	-0.01%	0.01%	-0.02%	7.82%	0.04%
2030	0.02%	-0.02%	0.04%	-0.06%	0.82%	0.09%
2040	0.05%	-0.02%	0.07%	-0.11%	0.89%	0.15%
2050	0.09%	-0.01%	0.13%	-0.19%	1.08%	0.24%
Difference in average annual growth rate, 2007-2050	0.002%	0.000%	0.003%	-0.004%	-0.026%	0.006%

* Includes both intra- and international trade

Table 11.2a. Agriculture, Forestry, and Energy (pessimistic) Changes in Macroeconomic Indicators, Pennsylvania.

Agriculture, Forestry, and Energy Impacts case (pessimistic) vs. Baseline case - % difference						
Year	Pennsylvania					
	GDP	Consumption	Investment	Government	Net exports*	GDP price index
2010	0.00%	0.00%	0.00%	0.00%	-0.06%	0.01%
2020	-0.01%	-0.02%	0.00%	-0.03%	-10.23%	0.04%
2030	-0.08%	-0.09%	-0.07%	-0.01%	-0.08%	0.04%
2040	-0.10%	-0.13%	-0.07%	-0.06%	0.23%	0.09%
2050	-0.09%	-0.14%	-0.03%	-0.13%	0.66%	0.16%
Difference in average annual growth rate, 2007-2050	-0.002%	-0.003%	-0.001%	-0.003%	-0.016%	0.004%

* Includes both intra- and international trade

Table 11.2b. Agriculture, Forestry, and Energy (pessimistic) Changes in Macroeconomic Indicators, Rest of US.

Agriculture, Forestry, and Energy Impacts case (pessimistic) vs. Baseline case - % difference						
Year	Rest of US					
	GDP	Consumption	Investment	Government	Net exports*	GDP price index
2010	0.00%	0.00%	0.00%	0.00%	-0.03%	0.01%
2020	0.00%	-0.01%	0.01%	-0.02%	7.44%	0.04%
2030	0.02%	-0.02%	0.03%	-0.06%	0.78%	0.09%
2040	0.04%	-0.02%	0.06%	-0.11%	0.85%	0.15%
2050	0.08%	-0.02%	0.11%	-0.18%	1.03%	0.23%
Difference in average annual growth rate, 2007-2050	0.002%	-0.001%	0.003%	-0.004%	-0.025%	0.005%

* Includes both intra- and international trade

Leaving aside the primary climate sensitive and primary energy intensive sectors, impacts of climate change on prices and production in the model's sectors are generally small for both the optimistic and pessimistic cases (Tables 11.3a,b and 11.4a,b). The exceptions are food processing and wood products, two of the secondary climate sensitive sectors. The other secondary climate sensitive sectors and secondary energy intensive sectors show only small changes in prices and production.

Table 11.3a Sectoral impacts (percent difference from base case with no climate change in 2050) of the optimistic Agriculture Forestry and Energy sector scenario for Pennsylvania.

Pennsylvania			
Sector	Prices	Output	Employment
Grains_and_oilseeds	-5.86%	6.53%	7.79%
Fruits_vegetables_nuts	-4.32%	20.53%	10.25%
Greenhouse_products	0.36%	0.18%	0.17%
Other_crops	0.58%	2.98%	2.75%
Beef	11.28%	5.92%	10.84%
Dairy	3.92%	1.61%	12.55%
Poultry_and_eggs	2.67%	7.47%	7.72%
Other_animal_production	5.05%	6.71%	6.31%
Forestry	-21.62%	32.38%	14.88%
Other_agric	0.91%	2.86%	2.47%
Oil_gas	0.16%	-0.22%	-0.28%
Coal	0.37%	0.17%	-0.10%
Other_mining	0.23%	-0.12%	-0.04%
Electricity	1.17%	1.95%	2.10%
Nat_gas_distr	0.24%	-0.09%	-0.10%
Water_and_sewage	0.17%	-0.02%	-0.02%
Construction	0.03%	0.08%	0.00%
Food_tobacco	0.95%	2.44%	2.78%
Wood_products	-4.06%	4.80%	2.34%
Pulp_paper	-1.14%	-1.78%	-2.55%
Petro_products	0.28%	0.05%	-0.19%
Chemicals	0.25%	-0.02%	-0.09%
Rubber_plastics	0.04%	0.02%	-0.06%
Nonmetallic_metals	0.15%	-0.08%	-0.16%
Primary_metals	0.12%	-0.38%	-0.41%
Other_mfg	0.07%	-0.25%	-0.30%
Transportation	0.15%	-0.06%	-0.11%
Furniture	-0.08%	0.28%	0.08%
Services	0.20%	-0.01%	0.00%
Insurance	0.17%	-0.05%	-0.03%
Healthcare	0.17%	-0.07%	-0.03%
Tourism_related	0.27%	-0.04%	0.00%

Table 11.3b Sectoral impacts (percent difference from base case with no climate change) of the optimistic Agriculture Forestry and Energy sector scenario for Pennsylvania.

Rest of US			
Sector	Prices	Output	Employment
Grains_and_oilseeds	-5.96%	7.44%	11.48%
Fruits_vegetables_nuts	-4.41%	5.69%	3.95%
Greenhouse_products	0.36%	0.10%	0.07%
Other_crops	0.40%	0.55%	0.27%
Beef	13.96%	-9.97%	0.40%
Dairy	11.05%	-7.00%	2.00%
Poultry_and_eggs	5.96%	-3.79%	0.83%
Other_animal_production	6.07%	-4.17%	-0.95%
Forestry	-20.07%	19.25%	5.06%
Other_agric	1.00%	2.59%	2.26%
Oil_gas	0.13%	-0.18%	-0.20%
Coal	0.39%	0.33%	-0.03%
Other_mining	0.24%	-0.02%	-0.15%
Electricity	0.67%	0.83%	0.88%
Nat_gas_distr	0.20%	0.05%	0.03%
Water_and_sewage	0.23%	0.15%	0.13%
Construction	0.06%	0.14%	0.04%
Food_tobacco	1.35%	-0.93%	-0.54%
Wood_products	-4.00%	5.30%	2.75%
Pulp_paper	-1.16%	1.36%	0.87%
Petro_products	0.29%	0.09%	-0.19%
Chemicals	0.29%	0.17%	-0.04%
Rubber_plastics	0.00%	0.05%	-0.07%
Nonmetallic_metals	0.15%	-0.04%	-0.10%
Primary_metals	0.12%	-0.29%	-0.32%
Other_mfg	0.08%	-0.26%	-0.35%
Transportation	0.15%	-0.12%	-0.21%
Furniture	-0.15%	0.55%	0.28%
Services	0.23%	0.00%	-0.01%
Insurance	0.19%	-0.10%	-0.10%
Healthcare	0.22%	-0.03%	-0.03%
Tourism_related	0.31%	-0.03%	0.01%

Table 11.4a Sectoral impacts (percent difference from base case with no climate change in 2050) of the pessimistic Agriculture Forestry and Energy sector scenario for Pennsylvania.

Pennsylvania			
Sector	Prices	Output	Employment
Grains_and_oilseeds	-5.88%	6.65%	8.01%
Fruits_vegetables_nuts	-4.33%	20.73%	10.43%
Greenhouse_products	0.32%	0.27%	0.29%
Other_crops	0.55%	3.09%	2.84%
Beef	11.26%	6.02%	10.95%
Dairy	3.85%	1.66%	12.68%
Poultry_and_eggs	2.64%	7.52%	7.79%
Other_animal_production	5.01%	6.70%	6.33%
Forestry	-11.77%	-28.31%	-29.77%
Other_agric	0.45%	-0.69%	0.82%
Oil_gas	0.13%	-0.12%	-0.13%
Coal	0.34%	0.30%	0.05%
Other_mining	0.21%	-0.02%	0.09%
Electricity	1.12%	1.96%	2.12%
Nat_gas_distr	0.21%	-0.07%	-0.05%
Water_and_sewage	0.11%	-0.06%	-0.05%
Construction	0.01%	0.00%	-0.03%
Food_tobacco	0.94%	2.43%	2.83%
Wood_products	-2.60%	0.29%	-1.60%
Pulp_paper	-0.94%	-2.56%	-3.22%
Petro_products	0.24%	0.07%	-0.11%
Chemicals	0.23%	0.01%	0.00%
Rubber_plastics	0.05%	0.01%	-0.02%
Nonmetallic_metals	0.14%	-0.05%	-0.06%
Primary_metals	0.11%	-0.24%	-0.24%
Other_mfg	0.05%	-0.19%	-0.19%
Transportation	0.11%	-0.03%	-0.03%
Furniture	-0.06%	0.11%	0.00%
Services	0.14%	0.00%	0.04%
Insurance	0.13%	0.01%	0.06%
Healthcare	0.10%	-0.10%	-0.02%
Tourism_related	0.22%	-0.06%	0.00%

Table 11.4b Sectoral impacts (percent difference from base case with no climate change in 2050) of the pessimistic Agriculture Forestry and Energy sector scenario for Rest of US.

Rest of US			
Sector	Prices	Output	Employment
Grains_and_oilseeds	-5.98%	7.45%	11.51%
Fruits_vegetables_nuts	-4.42%	5.68%	3.96%
Greenhouse_products	0.35%	0.10%	0.07%
Other_crops	0.38%	0.55%	0.29%
Beef	13.94%	-9.98%	0.40%
Dairy	11.04%	-7.02%	1.99%
Poultry_and_eggs	5.95%	-3.80%	0.83%
Other_animal_production	6.06%	-4.18%	-0.95%
Forestry	-17.27%	16.91%	4.71%
Other_agric	0.98%	2.58%	2.23%
Oil_gas	0.12%	-0.17%	-0.19%
Coal	0.37%	0.31%	-0.02%
Other_mining	0.22%	-0.02%	-0.13%
Electricity	0.65%	0.82%	0.88%
Nat_gas_distr	0.19%	0.05%	0.03%
Water_and_sewage	0.22%	0.14%	0.13%
Construction	0.07%	0.12%	0.04%
Food_tobacco	1.36%	-0.95%	-0.54%
Wood_products	-3.37%	4.58%	2.44%
Pulp_paper	-0.96%	1.15%	0.74%
Petro_products	0.28%	0.09%	-0.17%
Chemicals	0.28%	0.16%	-0.03%
Rubber_plastics	0.02%	0.01%	-0.08%
Nonmetallic_metals	0.14%	-0.06%	-0.11%
Primary_metals	0.11%	-0.29%	-0.31%
Other_mfg	0.07%	-0.26%	-0.34%
Transportation	0.14%	-0.12%	-0.20%
Furniture	-0.12%	0.45%	0.22%
Services	0.21%	-0.01%	-0.01%
Insurance	0.17%	-0.10%	-0.10%
Healthcare	0.20%	-0.04%	-0.03%
Tourism_related	0.30%	-0.04%	0.01%

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12.0 Appendix

Model Description

The main features of the recursive dynamic inter-regional computable general equilibrium (CGE) model of the Pennsylvania economy and data construction are described in this appendix. The model is based on the modeling framework of Rausch and Rutherford (2008)—which calibrates the model to the IMPLAN state-level accounts—and the static regional modeling applications of Sue Wing (2007) and Sue Wing and Kolodziej (2008). As described below, the model used in this analysis extends these previous models to allow for the simulation of climate change impacts on factor productivity and demand for goods and services

A.1. Producers

Table A-1 provides a list of the 32 production sectors included in the model. Each of the 32 industries is assumed to be a profit maximizer where output is produced using a constant returns to scale technology. For each sector *j* in region *r* at time *t* this can be expressed as:

$$QO_{j,r,t} = f(K_{j,r,t}, L_{j,r,t}, A_{1j,r,t}, ..., A_{n,j,r,t}, g(t)), \quad \text{(A.1)}$$

where $K_{j,r,t}$, $L_{j,r,t}$, and $A_{i,j,r,t}$ are capital, labor, and intermediate inputs, respectively and g(t) represents autonomous technological change which improves total factor productivity. A nested Cobb-Douglas-constant elasticity of substitution (CD-CES) functional form was adopted in the model. By nesting production functions, the model can account for different elasticities of substitution within the same functional form. For example, the elasticity of substitution between energy and materials can take on a different value than that for capital and labor. Figure A-1 below displays the nesting structure of the production sector.

Table A-1. Production sectors included in the model

Grains and oilseeds
Fruits, vegetables, and nuts
Greenhouse products
Other crops
Beef
Dairy
Poultry and eggs
Other animal production
Forestry
Other agricultural products
Crude oil and natural gas
Coal mining
Other mining
Electricity
Natural gas distribution
Water and sewage
Construction
Food processing (food and tobacco)
Wood products
Pulp and paper
Petroleum products
Chemicals
Rubber and plastic products
Nonmetallic metal products
Primary metals
Other manufacturing
Transportation
Furniture
Services
Insurance
Healthcare
Tourism and related industry

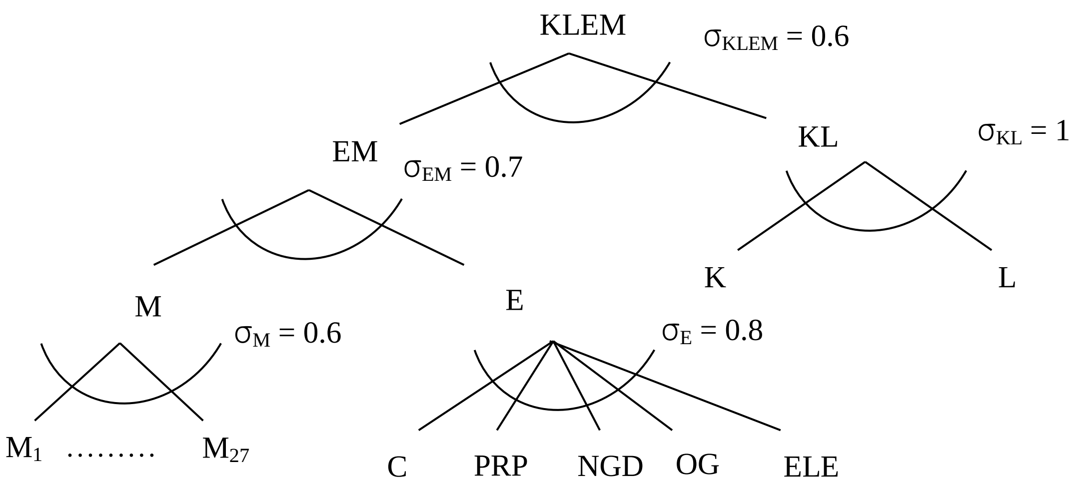

Figure A-1 – Nesting structure in the Production Sector

As shown in Figure A-1, the top nest of the CD-CES production function consists of a Cobb-Douglas aggregate of value-added (i.e., capital (K) and labor (L)), and a CES aggregate of energy (E) and non-energy materials (M) inputs with an elasticity of substitution (σ_{KLEM}) of 0.6 between the KL and EM aggregates. The second tier separates the EM aggregate into an energy composite and a non-energy materials composite, both CES aggregates with elasticities of substitution (σ_M and σ_E) of 0.6 and 0.8, respectively. The non-energy materials composite includes the 27 non-energy materials listed in Table A-1. The energy composite includes coal mining (C), petroleum refining and products (PRP), natural gas distribution (NGD), oil and gas extraction (OG), and electricity (ELE).

Output in each producing sector is allocated to the domestic, intranational, and international markets assuming a constant elasticity of transformation (CET) functional form where the elasticity of transformation between products allocated to these three markets is assumed to be two. Prices paid by purchasers of industry output include a tax on production calibrated to benchmark data and the prices of capital and labor purchases by industry include taxes on capital and labor also calibrated to benchmark data.

A.2. Consumers

The consumer sector is modeled as a utility-maximizing representative consumer that derives utility from the consumption of commodities, is assumed to supply labor inelastically, and is the owner of capital stock. The household sector in each region receives income from the employment of labor and capital. Therefore, private income in region *r* at time *t* can be written as:

$$Y_{r,t}{}^{p} = YL_{r,t} + YK_{r,t}, \qquad \text{(A.2)}$$

where YL denotes labor income from supplying LS units of effective labor, and YK denotes capital income from supplying KS units of effective capital. YL is equal to:

$$YL_{r,t} = PL_{r,t}\, LS_{r,t}\,. \tag{A.3}$$

where PL represents the wage rate received by households. The relationship between labor demand and supply is described below. LS is a function of the working age population (POP^W) and an index of labor quality (q^L); i.e.,

$$LS_{r,t} = POP^{w}_{r,t}\, q^{L}_{t}\,. \tag{A.4}$$

In each region, household income is allocated between consumption ($VCC_{r,t}$) and savings (S^P). In this model we use a simple Solow growth model formulation with an exogenous savings rate ($s_{r,t}$) to determine private savings ($S^p_{r,t}$):

$$S^{p}_{r,t} = s_{r,t} Y^{p}_{r,t} = Y^{p}_{r,t} - VCC_{r,t}\,. \tag{A.5}$$

The household savings rate is chosen to mirror the observed rates in the benchmark data set. Household utility is a nested CES function of consumption goods financed by household income net savings. The nested structure adopted in the model is shown in Figure A.2

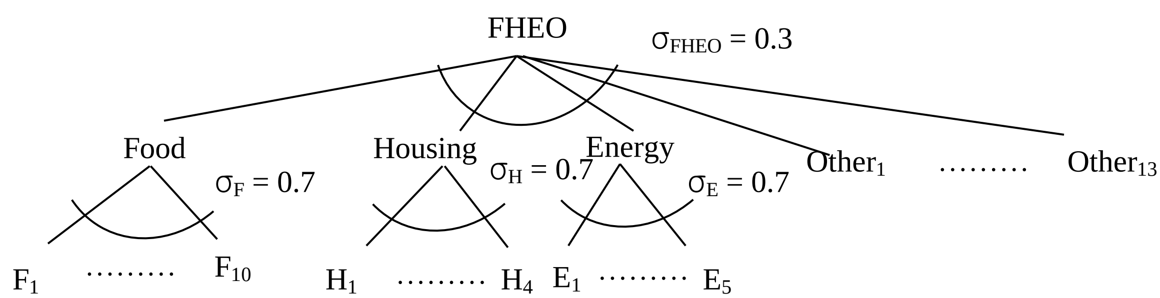

Figure A.2

Household utility, therefore, is a CES function of a food composite good, a housing composite good, an energy composite good, and 13 other (i.e., non-food, non-housing, and non-energy) goods.

A.3. Government and Taxes

In the model, the government has two major roles: to collect taxes and to purchase commodities using public revenue. Public revenue comes from direct taxes on capital and labor paid by industry and taxes on output paid by purchasers of goods and services. Total government expenditure is the sum of commodity purchases. Government purchases of specific commodities are determined through maximization of a Cobb-Douglas utility function of the 32 commodities where government consumption shares are derived from benchmark data.

A.4. Capital, Investment, and Labor

Capital stock in a given region *r* at time *t* in the model is the accumulation of region-specific investment net depreciation; i.e.,

$$K_{r,t} = (1-\delta)K_{r,t-1} + I_{r,t}, \tag{A.6}$$

Total investment by region in a given year in the model is determined by household savings. As described above, following the Solow growth model formulation, household savings is an exogenously-determined share of household income. This share is set to follow the observed rates in the benchmark data set. The capital depreciation rate is set exogenously at 5 percent across all regions.

Imperfect mobility of capital across regions and industries in a given year is captured in the model through the use of composite CET-CES function. Capital is allocated across industries in a given region based on differences in industries' returns to capital. The elasticity of transformation of capital across the different industries is assumed to be one so as to preserve the benchmark industry-specific capital shares. The CES aggregation of capital across regions is assumed to be Leontief, thus limiting the mobility of capital across regions in a given year.

Investment final demand is distributed to the individual investment goods sectors through fixed shares, $\alpha^{I}_{i,r,t}$, derived from benchmark data:

$$PS_{i,r,t}I_{i,r,t} = \alpha^{I}_{i,r,t}VII_{r,t} \tag{A.7}$$

where $PS_{i,r,t}$ is the supply price of investment good *i* in region *r* and $VII_{r,t}$ is total value of investment. Total investment in region *r* at time *t*, $I_{r,t}$, therefore can be written as:

$$I_{r,t} = I_{1,r,t}^{\alpha^{I}_{1,r}} I_{2,r,t}^{\alpha^{I}_{2,r}} \ldots I_{n,r,t}^{\alpha^{I}_{n,r}}. \tag{A.8}$$

Similar to capital, labor is also assumed to be imperfectly mobile across industries and regions in a given year. As with capital, a CET-CES function is used to allocate labor to the 32 industries based on returns to labor and to aggregate labor across regions. The elasticity of transformation is assumed to be one; thus, labor is allocated to industries to preserve the benchmark values shares of labor. The elasticity of substitution is assumed to be zero, thus limiting the mobility of labor across regions in a given year.

A.5. Intra- and International Trade

Trade flows are modeled using the Armington approach where imported goods are considered to be imperfect substitutes for domestic goods. The total supply (*QS*) of commodity *i* in region *r* is represented as a nested CES function of the domestic (*D*) and traded good (*M*); i.e.,

$$QS_{i,r,t} \;=\; A_0\left[\alpha^d D_{i,r,t}^{\rho} \;+\; \alpha^m M_{i,r,t}^{\rho}\right]^{\frac{1}{\rho}} \quad \text{(A.9)}$$

where the traded good is a composite of the domestically traded good and internationally traded good. The elasticity of substitution between the domestic and traded good is assumed to be four while the elasticity of substitution between the domestically and internationally traded good is assumed to be eight.

There are two prices of imports to buyers in the model: an intra-national trade price of good *i* and the price of foreign exchange. The numeraire in the model is assumed to be the price of foreign exchange; thus, prices in the model are relative to the overall international goods price.

A.6. Markets

The economy is in equilibrium in period *t* when prices clear the market (i.e., supply equals demand) for the 32 commodities and two factors (i.e., capital and labor). The supply of commodity *i* must satisfy the total of intermediate and final demands:

$$QS_{i,r,t} \;=\; \sum_j A_{i,j,r,t} \;+\; C_{i,r,t} \;+\; I_{i,r,t} \;+\; G_{i,r,t} \;+\; X_{i,r,t}\,,\;\; i \;=\; 1, 2, \ldots, 32. \quad \text{(A.10)}$$

where $QS_{i,r,t}$ equals the total supply of good *I* in region *r* at time *t*; $A_{i,j,r,t}$ is the inter-industry demand for good *i* by industry *j*; $C_{i,r,t}$ is the final demand for good *i* by the consumer sector; $I_{i,r,t}$ is the final demand for good *i* by the investment sector; $G_{i,r,t}$ is the final demand for good *i* by the government sector; and $X_{i,r,t}$ is net exports of good *i*.

In the labor and capital markets, we assume that labor and capital are fully employed. In this model without foresight, investment equals savings—i.e., there is no market where the supply of savings is equated to the demand for investment. As described in Section A.4, the sum of savings by households is equal to the total value of investment. Domestic prices relative to the price of foreign exchange adjust to hold the current account balance at its exogenously determined level.

A.7. Parameters, Exogenous Variables, and Data Sources

The key source of data for the model is the Minnesota IMPLAN group (MIG) state-level social accounting matrices (SAMs) for 2007. These state-level SAMs are constructed using data primarily from sources such as the Bureau of Economic Analysis (BEA), the Bureau of Labor Statistics (BLS), and the US Census. These social accounting matrices trace the flow of commodities and payments across all sectors of the regional economy in a given benchmark year. From this we derive labor and capital incomes, tax revenue by type of tax, and expenditures on specific commodities by the household, government and foreign sectors. Payments to capital and labor are combined with employment and capital input data to construct the compensation rates for labor and capital in each sector. The tax rates included in the model are not statutory rates but derived by dividing revenues by the related denominator—i.e., value of industry output, and capital and labor payments.

The exogenous variables in the model include total population, working age population, saving rates, depreciation rate, government taxes, rates of productivity growth, and rates of improvement in capital and labor quality. An important parameter affecting the growth rate of the economy is the household savings rate, s_t. We assume the household savings rate is constant over time, set at the observed rate in the 2007 benchmark data set. Labor supply in the model (equation (A.4)) is the product of population and labor quality improvements. Population projections for the state of Pennsylvania were obtained from the State Data Center of the Pennsylvania State University at Harrisburg. Population projections for the rest of the US were obtained from the US Census.

The composition of the work force changes over time with a larger proportion of educated workers, larger or smaller proportion of more experienced workers, and an older average age. We capture such changes in the model with the q_t^L index in equation (A.4). Given the expectation of higher educational attainment in the future, we assume that labor quality grows at 2.5 percent per year initially, falling to a growth rate of 0.5 percent per year by the end of the modeling period. An adjustment for improvements in future capital quality is also made in the model. This quality change refers to the shift in the composition of capital towards assets with shorter life. As with labor, we assume that capital quality rises by 2.5 percent per year initially, falling to a growth rate of 0.5 percent by the end of the modeling period.

In addition to growth in capital stocks, population growth, and labor and capital quality improvements over time, economic growth in the model is driven by improvements in total factor productivity (TFP). An improvement in TFP implies that fewer inputs are required to produce a unit of output. For Pennsylvania and the rest of the US, sectoral TFP improvements in the model were chosen to generate estimates of growth in output and employment that replicate published state-level projections by industry from sources such as the Bureau of Economic Analysis (BEA). The model also assumes improvements in autonomous energy efficiency of 2 percent per year over the modeling period, consistent with published forecasts.