Economic Activity and Climate Change in a Structural Framework: A First Approach

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Abstract. The considerable increases in greenhouse gases emissions and the subsequent climate changes are directly associated with the current rates of economic growth. As a result, the increasing environmental problems should result in an effort to accurately measure and control climate changes. In the present paper, we propose a theoretical inter-industry model for analyzing how economic activity, by industrial sector, affects the climate. We believe that the proposed methodology could be utilized for the feedback of the policy formulation procedure and could provide a vehicle for expanding conventional climate change analysis in economics.

Keywords: socioeconomic sphere, environment, climate change, economic growth, input-output.

1 Introduction

Nowadays, the globe is facing numerous challenges: on the one hand there are the problems related to poverty and socioeconomic instability, whereas, on other hand, there are the problems related to the environment and the changing climate. The environmental crisis has resulted in phenomena such as high temperatures, melting of glaciers, floods, rise in sea levels, droughts, water contamination, deforestation, loss of biodiversity, and so on. These problems are, in turn, associated with the unsustainable growth and increasing consumption patterns. In this context, the relation between the socioeconomic sphere and the environment has attracted attention in the literature and sustainable development has become a 'hot' topic in the research agenda of many countries.

For instance, as it was argued by Ayres and Simonis [1] and Bringezu [2] the interaction of the socioeconomic sphere with the environment is closely linked to the amount of material, emissions and energy expanded. As a result, the increasing environmental problems have resulted in an effort to accurately measure and control the climate changes in most developed and developing countries.

Meanwhile, climate change experts are alarmed by the considerable increase in greenhouse gases emissions that are associated with the current (economic) growth rates, and they tend to recommend strong mitigation action. In this framework, the question of climate change is a very important issue and many countries are required

M. Ulieru, P. Palensky, and R. Doursat (Eds.): IT Revolutions 2008, LNICST 11, pp. 225–231, 2009.

to implement new directives, which set long-term quality objectives introduced by the Kyoto Protocol. Of course, several industrial countries worry that economic growth might be harmed if they engage in mitigation.

Put concretely, the main problem that policymakers are, nowadays, facing is to analyze the implications for climate change of several policy trajectories with a view to finding a set of actions that minimize the impact of economic growth on climate change. In the present paper, we are taking one step towards achieving this goal by focusing on a theoretical model for analyzing how economic activity by industrial sector affects the climate.

The paper is organized as follows: section 2 analyzes the relation between energy use, climate change and economics by considering previous studies; section 3 sets out the proposed theoretical model; finally, section 4 concludes.

2 Energy Use, Climate Change and Economic Analysis

Human civilization was built on three pillars: (a) the ability of man to grow enough food to adequately support the population that is engaged in tasks other than growing food; (b) the ability to live in large communities (groups) that are able to support major societal and administrational institutions such as the parliamentary system, the judiciary system and the educational system; (c) the ability to 'exploit' labour in the broader sense and exchange its products. In other words, these three pillars express Society, Politics and Economics.

The march towards a fossil-fuel-dependent economy started as early as in the England of Edward I, for he detested the smell of coal that he banned (in 1306) the burning of coal. In spite of the King's prohibition, eventually the English became the first Europeans to burn coal on a large scale [3]. However, by 1700 a thousand tones per day were being burned in the city of London. An 'energy crisis' soon emerged. England's mines had been dug so deep that they were filled with water. A way of pumping it out on the surface had to be found. The man who discovered how this could be effectuated was Thomas Newcomen (1664-1729); his device burned coal to produce steam, which was then condensed to create a vacuum that moved a piston which pumped the water. The first Newcomen engine was installed in a Staffordshire coal mine in 1712. Fifty years later, hundreds of them were at work in mines across the nation, and England's coal production had grown to 6 million tones per year [4].

The ingenious Scottish James Watt (1736-1819) improved on Newcomen's design and in 1784 William Murdoch (1754-1839) produced the first mobile steam engine. From that time on, the coming 19^{th} century was to be the century of coal. No other fuel source was used for industrial purposes, transportation, heating or cooking. In 1882 Thomas Edison (1847-1931) inaugurated the world's first electric light power station in Manhattan.

In the aftermath of Word War I, when people stoked the coal and wood fuelled stoves, great amounts of CO_2 were released, which are still warming Earth today. Most of the damage was done after 1950 when people kept driving and moving around in their vehicles and kept powering their manual work saving household appliances from inefficient coal-burning energy stations [5]. Most to blame is the baby-boomer generation born in the years following World War II. Half of the energy amounts generated since the Industrial Revolution have been consumed in the last twenty years.

Nowadays, the study of greenhouse gases, global warming and climate change has become a ‘hot’ topic in the literature. The greenhouse gases trap heat near the surface of the planet. As they increase, this ‘trapped’ heat leads to global warming. The warming destabilizes the planet’s climate and potentially leads to climate change. Climate is regarded as the sum of all weathers over a certain period of time, for a region or for the planet as a whole.

Economy fosters climate change in all three stages of its activity, i.e. production, in distribution and consumption. Production needs energy. Supplying energy is a very profitable activity. In the developed countries, energy use grows at the rate of approx. 2% per annum. With such low rates of growth the only way for one sector to expand is to take from another sector’s share.

Distribution also creates pollution, approximately about a third of global carbon dioxide (CO_2) emissions. Consumption is the positive feedback of production; the demand for more products fosters not only technological innovations in business and economic activities but also burdens the planet with acceleration in climate changes; humans are already consuming more of the planet’s resources than is sustainable.

Based on the information on the average surface temperature of Earth from AD 1000 to 2100 we notice that prior to 1900 the average temperature was significantly lower and equal to 13.7^0C ([6] - [9]). Also, the nine out of ten warmest years ever recorded have occurred after 1990.

Since the great explosion of energy consuming machines (i.e. during and after the Industrial Revolution) the fossil-fuelled economy has been nourished principally by coal (19^{th} c), oil (20^{th} c) and gas (21^{st} c) ([10]-[11]). The natural gas resources seem to be sufficient to cover the needs of our economy until 2050. The latter, methane, is the fossil fuel with the least carbon content. So, from a climate change perspective there is a vast difference between burning gas or coal. The energy that is liberated when we burn these fuels comes from carbon and hydrogen. In simple words, because carbon causes climate change, the more carbon-rich a fuel is, the greater its environmental load and the greater climate changes it creates.

The literature on the modeling of climate change in economic analysis is seriously limited. Despite the fact that the theoretical and empirical literature on economic growth addresses many issues that are relevant to the climate change problem it rarely discusses climate change explicitly.

More precisely, most climate change models focus on estimating the cost of mitigation. A few papers use growth models (e.g. [12]) and analyze the consequences of mitigation for growth, but they do not examine how the structure of the underlying growth model constrains the results. In addition, most climate change models analyze the problem in a cost-efficiency framework, and hence do not explicitly model damages (e.g. [13]–[14]). A few climate change models analyze the problem in a cost-benefit framework and explicitly model damages (e.g. [15]), but they usually rely on simplified growth models that are insufficient to address the structural complexity of the relationship between impacts of economic growth and climate change that would be of interest to policymakers.

Undoubtedly, the *Input-Output (IO)* framework is a very powerful tool for environmental analysis ([16]–[17]). Also, *Life Cycle Analysis* (LCA) has been widely adopted during the last decade [18] and there have been some attempts to make use of input-output analysis in studying *Product Life Cycles* (PLC) [19]. Meanwhile, many economists have cast the problem of environmental pollution and climate change in terms of the *Cost-Benefit Analysis* (CBA) framework ([20]–[21]) or even in *neoclassical optimal control* models (e.g. [12]) which are usually based on a Ramsey-type model of economic growth. Finally, the study of climate change and environmental impacts associated with household consumption has also been an area of considerable attention for the last years. A few examples include works looking at the broader range of impacts associated with *Life Style Models* (LSM) in general ([22]–[23]).

3 The Theoretical Model

As we have seen, several studies use the input-output framework for estimating the total emission coefficient per unit of production in each sector of economic activity and for the final demand categories (e.g. [24]-[27]). In this paper, the input-output approach is used in order to calculate *climate change multipliers* for the various industries and expressions of climate characteristics.

The proposed approach recognizes the fact that environmental pollution and the subsequent climate change proceeds at varying rates in different sectors, a fact which is very important for comparison among different countries since the intensive competition in the world market is shaped at the industry level [28].

The proposed approach will be able to identify the (total) climate change in the environment that will be generated in case of a change in an industry's final demand. More precisely, the proposed model answers the following question:

A change in an industry's final demand, what change (as expressed in measurable climate characteristics) will generate in the climate?

The methodology for constructing embodied *climate change indicators* could be built as follows [27]:

Let **Z** be the matrix of intermediate deliveries, **X** the vector of gross outputs, and **Y** vector of the final demands. The input coefficients matrix is obtained as follows:

$$A = Z\,x^{-1} \tag{1}$$

where $\mathbf{x} = diag\mathbf{X}$ denotes the diagonal matrix whose elements consist of vector **X**.

The balance equations can be written as:

$$X = AX + Y\,. \tag{2}$$

Solving the balance equation for **X**, we obtain:

$$X = (I - A)^{-1}\,Y\,. \tag{3}$$

where $\mathbf{(I - A)}^{-1}$ denotes the Leontief inverse.

For each industry *i*, we then define the direct intensity coefficients ($\mathbf{a_{ik}}$) of climate change as quantities expressing climate change (e.g. cm, kgr, etc) ($\mathbf{E_{ik}}$) per gross output (**Xi**), where *k* denotes the type of climate characteristic (e.g. rain, snow, ice, wind, etc):

$$a_{ik} = E_{ik} / Xi \quad (i = 1,2,\ldots,n) . \tag{4}$$

The next step is to calculate the total induced emission, including the direct effects, as follows:

$$e_{ik}' = a_{ik}'(I - A)^{-1} . \tag{5}$$

where an accent denotes transposition.

An critical issue that remains to be addressed is the (technical) construction of the relevant $\mathbf{E_{ik}}$ matrix. It could be based on NAMEA (National Accounting Matrix Including Environmental Accounts) tables which consist of a conventional national accounting matrix extended to include environmental accounts in physical units. Apparently, this highly technical issue, which is obviously extraneous to the scope of our paper, provides an excellent example for future research.

4 Conclusions

Nowadays, the relation between the socioeconomic sphere and the environment has attracted increasing attention given that the world economy is facing numerous challenges related to the environment and the changing climate caused by the unsustainable growth and increasing consumption patterns. As a result, the increasing environmental problems should result in an effort to accurately measure and control the climate changes since the considerable increase in greenhouse gases emissions and the subsequent climate changes are directly associated with the current (economic) growth rates. In this context, the main problem that policymakers are, nowadays, facing is to analyze the implications for climate change of several policy trajectories with a view to minimizing the impact of economic growth on climate change. In the present paper, we propose a theoretical model for analyzing how economic activity by industrial sector affects the climate. We believe that the proposed methodology can be utilized for the feedback of the policy formulation procedure and that with its generality, conformity with theory and simplicity of structure will provide a vehicle for expanding and improving conventional climate change analysis in economics. Some technical issues which remain to be addressed are fine examples for future research in the field.

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