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Climate Change and Economic Growth in Nordic Countries: An application of smooth coefficient semi-parametric approach

Abstract:

The economic impact of climate change is usually measured as the amount by which the fluctuations in temperature in a given country can affect the output or GDP of the country in that period. This approach ignores the dynamic indirect effects of climate change on economic growth of a country. Ignoring the indirect growth effects of climate change will lead to a substantial underestimation of the impact of climate change on the future well-being of the countries. Therefore, in this paper we draw some attention to measure the indirect effects of climate change on economic growth. In order to empirically estimate the indirect effects of climate change on economic growth we use the data from the Nordic countries over the past four decade (1960-2000) and a newly developed smooth coefficient semi-parametric approach. Our analysis reveals several interesting results. Firstly, we find strong indication that the way the climate change indirectly effect the economic growth in these countries is highly non-linear. Therefore, any attempt for measuring the indirect effects of climate change on growth by using a linear estimation procedure such as Ordinary Least Square (OLS) procedure will produce biased results. Secondly, our smooth coefficient point-wise estimates of the capital share parameter indicate that the magnitude of the capital share parameter decreases with the increase in temperature.

JEL Classification: E21; O13; Q25

Keywords: Climate change, Economic growth, smooth coefficient
1. INTRODUCTION

Climate change is one of the most defining issues of this century. Climate change is a serious issue and will have severe and at the same time heterogeneous effects on the countries in the world. A main point of concern for any country is that climate change is a multidimensional phenomenon, and as such its negative effects could be much harder, more complex and more uncertain than any other environmental problem. Climate change is a reality and no longer a future concern. According to the United Nations Intergovernmental Panel on Climate Change (IPCC) human activities caused most of the warming over the past 50 years. One of the causes of the global warming is the acceleration in the emissions of Greenhouse gases. There is no question that the continued build-up of greenhouse gases causes the earth to warm. Greenhouse gas emissions are fundamental to our food production and our energy system therefore, there are no easy solutions. Further, it is discussed in the literature that climate change will generate damages that will alter a country’s growth trajectories relative to the case without climate change. Therefore, the ultimate impact of climate change is likely to affect the factors of production and their productivity directly. However, in most of the previous studies on the economic impact of climate change the effects of climate change are assessed separately sector by sector and then added up to form an estimate of the overall change in the well-being of the society (see Nordhaus, 1991; Cline, 1992; Fankhauser, 1995; Tol, 1995; Mendelsohn and Neumann, 1999). This approach is known as enumerative approach. This is a static approach and it ignores the dynamic indirect effects of climate change on economic growth for detailed discussion see Smith et al. (2001) and Tol et al. (2000). Therefore, this paper seeks to fill this gap by empirically exploring both the direct and indirect effects of climate change on economic growth.

According Fankhauser and Tol (2005) the main channel through which the climate change has an indirect impact on economic growth is via capital accumulation. According to them under the constant savings rate the amount of investment in an economy will be reduced if climate change has a negative impact on aggregate output of the country. In the long term this will lead to a reduction in the capital stock and will result in a lower level of per capita income in the economy. Another channel that Fankhauser and Tol (2005) discussed in their paper through which the climate change can also have an indirect impact on economic growth is the savings. According to them in a world with perfect foresight the forward-looking agents can change their saving behaviour in anticipation of a future climate change. However, theoretically it is not clear that this savings effect will be positive or negative. On the one hand, savings rates may go up because agents wish to compensate for the shortfall in future income. On the other hand, climate change reduces the productivity of capital and due to the lower rate of returns on investment agents prefer to invest less and consume more today.

Therefore, in this paper we want to measure the indirect effects of climate change on economic growth particularly, the effects via capital accumulation. We consider the data from five Nordic countries over the period of 1960 to 2000. The reasons for considering the Nordic countries as our sample is because the Nordic countries are experiencing a rapid climatic changes and trend will likely to continue in the future. According to the climate model projections for Europe the average temperature increase will be higher in the Nordic countries. To my knowledge no empirical study has measured the indirect effects of climate change on economic growth before.
The paper is structured as follows. Next section presents a brief review of the literature. The methodology of the paper is discussed in section 3 which includes the theoretical framework followed by the discussions about the channels through which the climate change can indirectly affect the economic growth, and the econometric framework used in this paper. The estimation results are presented in section 4. Section 5 concludes the paper.

2. LITERATURE REVIEW

Although the economic analysis of climate change is comparatively a new area, despite that there are number of studies that estimated the impacts of climate change on economic growth. Most of these studies are empirical in nature. We have reviewed some of the major studies in this area, those are relevant to this paper.

It has been discussed in the literature that climate change can affect the long term growth potential of the countries. Furthermore, the effects of climate change are not homogeneous within and between countries. It is also discussed that the agriculture areas and the coastal zones are heavily affected due to climate change. According to Stren et al. (2006) the global temperature is expected to rise by 2-3°C in the next fifty years. This increase in temperature will have severe consequences on economic development as it will affect the water quality, agricultural productivity and human health.

Akram (2012) conducted a study for 10 Asian Countries he finds a significant negative relationship between the temperature and GDP growth in these countries. Further, he finds that agriculture is the most vulnerable sector that is affected due to the climate change whereas, manufacturing is the least affected sector.

Odusola and Abidoye (2012) conducted a study for 34 African countries they also find a negative and significant impact of climate change on economic growth in Africa. According to them a 1°C increase in temperature reduces the GDP growth by 0.27 percentage points on average in African countries.

Dell et al. (2008) consider a large panel of 136 countries over the period of 1950-2003 and find three primary results from their study. Firstly, they find that higher temperatures substantially reduce the economic growth in poor countries. According to their estimation a 1°C rise in temperature in a given year reduces the economic growth by 1.3 percentage points on average. Secondly, they find that higher temperatures appear to reduce the growth rates not only the level of GDP. Thirdly, they find that higher temperatures have wide ranging effects i.e. reducing agriculture output, industrial output, and creating political instability.

Frankhauser and Tol (2005) provide a theoretical and empirical investigation on the link between the climate change and economic growth. By using a simple simulation model they find that the climate change always have a negative impact on the capital accumulation. According to them indirect effects of climate on economic growth are more important than the direct impact of climate change. By ignoring the indirect effects of climate change on economic growth leads to a substantial underestimation of the impacts of climate change on the future well-being of the society. To the author’s knowledge no empirical paper has estimated the indirect effects of climate change on economic growth therefore, this study is a first attempt to fill that gap and this is the main contribution of this study in the existing literature.
3. METHODOLOGY

There are two approaches that are commonly used in the literature for analysing the impact of climate change on economic growth the enumerative approach and the dynamic approach. In the enumerative approach, the economic impacts of climate change are analysed separately sector by sector. These effects are then evaluated together to obtain an estimate of the total effect of climate change on social welfare (see Nordhaus, 1991; Cline, 1992; Fankhauser, 1995 and Tol, 1995). In this approach, the effects of climate change are analysed by focusing only on one period and intertemporal effects are ignored. Therefore, these studies have failed to provide information on how climate change may affect the long-term economic growth.

In the dynamic approach different specifications of growth models are used by incorporating the climate change as an external shock. The Solow-Swan, Ramsey-Cass-Koopmans, and Mankiw, Romer and Weil models are the most widely used growth models in the literature for analysing the impact of climate change on economic growth. In all three growth models, under the assumption of a constant savings rate, it is found that climate change will result in lower level of output and this will also lead to a proportionate reduction in investment. As a result, in the long run capital stock and consumption per capita will decline, which will result in shrinking of aggregate demand and will adversely affect the GDP.

This paper also uses the dynamic approach to analyze the impact of climate change on economic growth from a different angle. By utilizing the smooth coefficient semi-parametric approach in this paper we will be able to measure the indirect effects of climate change on economic growth through its impact on capital accumulation.

3.1 Theoretical Framework

Dell et al. (2008) incorporated the climatic variables in the production function of their model, which is also used as the baseline for this study. They provided the theoretical basis for incorporating the climatic variable in the growth regression. We begin by specifying a Cobb-Douglas production function with two factors input labour and capital.

\[
Y_t = A_t K_t^\alpha L_t^{1-\alpha}
\]  

(1)

Where, \( Y_t \) is real aggregate income, \( K_t \) represents the physical capital, \( L_t \) is the labour and \( A_t \) is a measure of total factor productivity (TFP) of the country. \( A_t \) is specified as:

\[
\ln A_t = \Gamma X_t
\]  

(2)

Where, \( \Gamma \) is the parameter vector to be estimated and \( X_t \) is the set of variables that effect the total factor productivity of the country. In this paper we consider \( X_t \) as a set of climatic variables to measure the direct impact of climate change on economic growth. For simplification, labour is assumed to grow exogenously at a rate \( n \) and is defined as.

\[
L_t = L_0 e^{nt}
\]  

(3)

Defining \( k_t = (K_t / L_t) \) and \( y_t = (Y_t / L_t) \) as the stock of capital and the level of output per unit of labour respectively, the evolution of capital is governed by:

\[
k'_t = \omega_k^y y_t - (n + \delta)k_t = \omega_k^y k_t^y - (n + \delta)k_t
\]  

(4)
Where, ‘.’ indicates the change over time, $\omega_k^t$ is the fraction of output invested in physical capital in period $t$, and $\delta$ is the rate of depreciation. The steady equation for the capital stock is defined as:

$$k^*_t = \left[ \frac{\omega_k^t}{(n + \delta)} \right]^{\frac{1}{1-\alpha}}$$  (5)

By substituting the value of $k^*_t$ from equation (5) to equation (1) and taking the natural logs we get the reduced form equation for the Solow growth model (see Solow, 1956).

$$\ln y_t = y_0 + y_1 z_t + \frac{\alpha}{1-\alpha} \ln \omega_t^k - \frac{\alpha}{1-\alpha} \ln (n + \delta)$$  (6)

Where, $y_0$ is the intercept term and $z_t$ is the climatic variable use to capture the impact of climate change on economic growth. Later on Mankiw, Romer and Weil (1992) included human capital as another input of production. We can now define the production function after including human capital as a factor of production along with the physical capital as:

$$Y_t = A_t K_t^\alpha H_t^\beta L_t^{1-\alpha-\beta}$$  (7)

Where, $H_t$ is the stock of human capital, the only distinction between the Solow model and the Mankiw-Romer-Weil model is that besides physical capital, the model also includes human capital. Defining $k_t = (K_t/L_t)$, $h_t = (H_t/L_t)$, and $y_t = (Y_t/L_t)$ as the stock of physical capital, human capital, and the level of output per worker. Also assuming that population grow at a constant rate ‘n’ and $\delta$ is the rate of depreciation for both physical and human capital, we get the following reduced form equation for the Mankiw-Romer-Weil model.

$$\ln y_t = y_0 + y_1 z_t + \frac{\alpha}{1-\alpha-\beta} \ln \omega_t^k + \frac{\beta}{1-\alpha-\beta} \ln \omega_t^h - \frac{\alpha + \beta}{1-\alpha-\beta} \ln (n + \delta)$$  (8)

The equations (6) and (8) are the reduced form equations of the Solow and Mankiw-Romer-Weil growth models and these equations will be considered in the empirical estimation.

### 3.2 Empirical Model and Data Description

In the light of the theoretical models we discussed in the previous section the empirical specification for the Solow and Mankiw-Romer-Weil growth models are given as:

$$\ln y_{it} = \alpha_0 D_i + \alpha_1 D_t + \alpha_2 \ln k_{it} + \alpha_3 \ln p_{it} + \alpha_4 \Delta temp_{it} + \varepsilon_{it}$$  (9)

$$\ln y_{it} = \beta_0 D_i + \beta_1 D_t + \beta_2 \ln k_{it} + \beta_3 \ln h_{it} + \beta_4 \ln p_{it} + \beta_5 \Delta temp_{it} + u_{it}$$  (10)

Where, $D_i$, $D_t$ are the country and time specific dummies respectively, $y$ is the real GDP per capita, $k$ is the real gross fixed capital formation as a percentage of GDP, $hc$ is the gross secondary school enrolment rates, pop is the population growth, $\Delta temp$ is the change in temperature used as a measure for the change in climate, and $\varepsilon$ and $u$ are the random error terms.
The selection of the climatic indicator is a critical issue. In this paper we selected the change in average annual temperature as a climatic indicator for two reasons. Firstly, the change in mean temperature has been widely used in the literature as a measure for climate change (see Akram, 2012; Odusola and Abidoye, 2012 and Dell et al., 2008). Secondly, the change in mean temperature has a direct relationship with Green House Gases (GHG) concentrations. It is relatively difficult to relate any other indicator directly to GHG concentrations.

### Table A. Data Sources

<table>
<thead>
<tr>
<th>Name of Variable</th>
<th>Data Source</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Real GDP per capita (y)</td>
<td>WDI</td>
<td>Real GDP per capita annual series</td>
</tr>
<tr>
<td>Physical capital (k)</td>
<td>WDI</td>
<td>Real gross fixed capital formation as percentage of GDP annual series</td>
</tr>
<tr>
<td>Human capital (hc)</td>
<td>WDI</td>
<td>Secondary school enrolment rate annual series</td>
</tr>
<tr>
<td>Population growth rate (pop)</td>
<td>WDI</td>
<td>Population growth rate annual series</td>
</tr>
<tr>
<td>Average Temperature (temp)</td>
<td>Terrestrial Air Temperature and precipitation database, Gridded monthly time series</td>
<td>Annual average temperature is calculated by using the monthly data</td>
</tr>
</tbody>
</table>

### 3.3 Incorporating the Indirect Effects of Climate Change on Economic Growth

As we mentioned in the introduction, the key objective of this paper is to measure the indirect effects of climate change on economic growth. One of the channels, discussed in the literature, through which the climate change can have an indirect impact on economic growth, is via capital accumulation. One of the reasons that the climate change has a negative impact on the accumulation of capital is because the changing climate may affect the longevity of capital. Frankhauser et al. (1999) have pointed out that a continuously changing climate will require more frequent adjustment in the capital stock, especially with respect to defensive expenditures (e.g., the strengthening of sea walls and dykes). The frequent extreme events (e.g., storms, floods, etc.) due to the changing climate also affect the longevity of capital. This effect can be captured with the increase in the speed of capital dilution. The stock of capital is reduced because it is depreciating at a faster rate. Therefore, from the theoretical point of view the effect of climate change on the accumulation of capital is always negative. In order to measure the indirect effect of climate change on economic growth we assume that the capital share parameter estimated in the growth regression is not constant but a decreasing function of the increase in average temperature. In the light of the above discussion we can re-write the empirical equations (9) and (10) as:

\[
\ln y_{it} = \alpha_0 D_i + \alpha_1 D_t + \alpha_2 (\Delta temp_{it}) \ln k_{it} + \alpha_3 \ln pop_{it} + \alpha_4 \Delta temp_{it} + \varepsilon_{it} \tag{11}
\]

\[
\ln y_{it} = \beta_0 D_i + \beta_1 D_t + \beta_2 (\Delta temp_{it}) \ln k_{it} + \beta_3 \ln hc_{it} + \beta_4 \ln pop_{it} + \beta_5 \Delta temp_{it} + u_{it} \tag{12}
\]
The equations (11) and (12) are non-linear and cannot be estimated by using the Ordinary Least Square (OLS) procedure. In order to estimate these non-linear regressions we utilized the newly developed smooth coefficient semi-parametric approach. A brief discussion of the smooth coefficient semi-parametric approach is provided in the next sub-section.

3.4 Econometric Framework

The central issue in equations (11) and (12) of the previous section is the estimation of the functions $\alpha_2(\cdot)$ and $\beta_2(\cdot)$. The estimation approach adopted in this paper is the smooth coefficient semi-parametric approach (see Fan (1992); Fan and Zhang (1999); Li et al. (2002); Kourtellos (2003); Cai et al. (2006); Mamuneas et al. (2006); Ketteni et al. (2007a)). It is a generalization of varying coefficient models and uses the local polynomial linear regression of Stone (1977) and Fan (1992), along with the widely used Nadaraya-Watson constant kernels.

The general description of the method is as follows. The observed sample is given as: \{Y_i, W_i, X_i, Z_i\}, \ i = 1, \cdots, n, \ realization \ from \ an \ i.i.d. \ random \ vector \ \{Y, V, W, X, Z\}\ (for \ notational \ simplicity \ we \ suppress \ the \ observation \ subscript \ i = 1, \cdots, n \ with \ n = N \times T). \ We \ let \ Y \ to \ denote \ log \ of \ real \ GDP \ per \ capita \ and \ let \ Z \ be \ the \ climatic \ variable \ (the \ change \ in \ temperature). \ We \ also \ denote \ by V = \{lnpop, Δtemp\}, W = \{lnpop, lnhc, Δtemp\} and X is the physical capital variable. Appending an error term the equations (11) and (12) can be re-written in the matrix form as:

\[
Y = V\theta + X\Omega(Z) + \epsilon \tag{13}
\]

\[
Y = W\gamma + X\Phi(Z) + u \tag{14}
\]

Where $\Omega(Z)$ and $\Phi(Z)$ are $\alpha_2(Z)$ and $\beta_2(Z)$, the error terms $\epsilon$ and $u$ satisfy the orthogonality condition $[E(\epsilon|V, X, Z) = 0, \ E(u|W, X, Z) = 0]$. The presence of a linear part in above equation makes this model more general than the smooth coefficient model of Fan and Zhang (1999). Following Mamuneas et al. (2006) we use a two-step procedure to estimate equations (13) and (14). In the first-step the variables of the linear part are projected off the other variables to produce the new redefined variables in equations (15) and (16) below and return to the simple smooth coefficient environment of Fan and Zhang (1999) and Li et al. (2002).

\[
Y^* = X\Omega(Z) + \epsilon^* \tag{15}
\]

\[
Y^* = X\Omega(Z) + u^* \tag{16}
\]

Where $Y^*$, $\epsilon^*$ and $u^*$ denote the redefined dependent variable and the error terms respectively.

The coefficients $\alpha_2(Z)$ and $\beta_2(Z)$ are evaluated at the particular value of $Z$, say $z$, is a smooth but unknown function of $z$. One can estimate the smooth coefficient parameters $\alpha_2(Z)$ and $\beta_2(Z)$ using the local least square procedure; see Fan and Zhang (1999), Li et al. (2002) for details.
4. ESTIMATION RESULTS

4.1 Linear Estimation Results

We begin our empirical analysis by estimating the Solow and Mankiw-Romer-Weil specifications of the growth model using the Ordinary Least Square procedure, the results are reported in table 1. First we estimated the Solow model specification with and without climatic variable and the results are reported in columns (1) and (2) of table 1. By looking at the estimation results we can see that all the variables that influence the economic growth are significant and their signs are consistent with the growth theory. However, the change in temperature, which is used as a measure for climate change, is negative but insignificant indicating the climate change does not have significant direct impact on economic growth in these countries.

Next we estimate the Mankiw-Romer-Weil model with and without climatic variable and the results are reported in columns (3) and (4) of table 1. Again the physical capital, human capital and population growth variables are highly significant and have the right signs. Whereas, the climate variable is again insignificant indicating that the results does not change even if we use the different specification of the growth equation.

4.2 Smooth Coefficient Semi-parametric Estimation Results

Now we move to the smooth coefficient semi-parametric estimation of the equation (12) and (13) which is the main contribution of this paper. A test of the null hypothesis of a linear specification against the smooth coefficient semi-parametric clearly rejects the former. First we estimate the Solow model specification by using the smooth coefficient semi-parametric approach. Figure 1 plots the point-wise estimates of the capital share parameter on the vertical axis and the change in temperature on the horizontal axis. Inspection of the figure 1 shows that the indirect effect of climate change on economic growth via its impact on capital accumulation is highly non-linear. Further, there is an inverse relationship between the capital share parameter and the change in temperature. This confirms our initial hypothesis that the changing climate has a negative impact on the accumulation of capital.

Next we estimate the Mankiw-Romer-Weil specification by using smooth coefficient semi-parametric approach. Figure 2 plots the point-wise estimates of the capital share parameter and the change in temperature. Again there is an inverse relationship between the capital share parameter and the increase in temperature. However, the effect is much stronger this indicates that the inclusion of human capital makes the model more sensitive to the change in climate.

5. CONCLUSIONS

This paper reveals some interesting results about the impact of climate change on economic growth in Nordic countries. Firstly, we find strong indication that the way the climate change indirectly effect the economic growth in these countries is highly non-linear. Therefore, any attempt for measuring the indirect effect of climate change on growth by using a linear estimation procedure such as Ordinary Least Square (OLS) procedure will produce biased results. Secondly, our smooth coefficient point-wise estimates of the capital share parameter indicate that the magnitude of the capital share parameter decreases with the increase in temperature. Further, the magnitude of this indirect effect differs across models. The effect is
much stronger in Mankiw-Romer-Weil model (the crucial distinction between the Mankiw-Romer-Weil and Solow model is that the former also includes the human capital besides the physical capital). This indicates that the inclusion of human capital makes the model more sensitive to the climate change.

Inconclusively, we can say that this paper takes an attempt to draw some attention to the fact that the direct impact of climate change is not the only way in which the global warming can affect the future welfare of the countries. One of the important channel that we explored in this paper through which the climate change has an indirect impact on growth is via capital accumulation. By ignoring this indirect effect of climate change on economic growth will lead to a substantial underestimation of the effects of climate change on the future well-being of the countries.
References:


Table 1: OLS Estimation of the Growth Models with Climate Variable  
(Dependent Variable is log of real GDP per capita)

<table>
<thead>
<tr>
<th>Explanatory variables</th>
<th>Solow Model (1)</th>
<th>Solow Model (2)</th>
<th>MRW Model (1)</th>
<th>MRW Model (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \ln k_{it} )</td>
<td>1.096*</td>
<td>1.096*</td>
<td>0.997*</td>
<td>0.996*</td>
</tr>
<tr>
<td></td>
<td>(0.007)</td>
<td>(0.008)</td>
<td>(0.015)</td>
<td>(0.014)</td>
</tr>
<tr>
<td>( \ln pop_{it} )</td>
<td>-0.177*</td>
<td>-0.176*</td>
<td>-0.093*</td>
<td>-0.090*</td>
</tr>
<tr>
<td></td>
<td>(0.029)</td>
<td>(0.029)</td>
<td>(0.028)</td>
<td>(0.028)</td>
</tr>
<tr>
<td>( \ln h_{it} )</td>
<td></td>
<td></td>
<td>0.206*</td>
<td>0.207*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(0.037)</td>
<td>(0.037)</td>
</tr>
<tr>
<td>( \Delta temp_{it} )</td>
<td>-0.004</td>
<td></td>
<td>-0.017</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.020)</td>
<td></td>
<td>(0.021)</td>
<td></td>
</tr>
<tr>
<td>( D_i )</td>
<td>0.048**</td>
<td>0.048**</td>
<td>0.041**</td>
<td>0.041**</td>
</tr>
<tr>
<td></td>
<td>(0.022)</td>
<td>(0.022)</td>
<td>(0.022)</td>
<td>(0.022)</td>
</tr>
<tr>
<td>( D_t )</td>
<td>0.008*</td>
<td>0.009*</td>
<td>0.014*</td>
<td>0.015*</td>
</tr>
<tr>
<td></td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
<td>(0.003)</td>
</tr>
<tr>
<td>Adjusted-( R^2 )</td>
<td>0.97</td>
<td>0.97</td>
<td>0.98</td>
<td>0.98</td>
</tr>
</tbody>
</table>

The values in ( ) are the HAC Standard Errors. "*", "**" represents 1% and 5% significance levels respectively.
**Figure 1:** Smooth coefficient Point-wise estimates of the capital share parameter ($\alpha_2$) (Solow Specification)

**Figure 2:** Smooth coefficient Point-wise estimates of the capital share parameter ($\beta_2$) (Mankiw-Romer-Weil Specification)