DEVELOPING COUNTRIES AND EMISSION REDUCTION COMMITMENTS
Understanding the Drivers of Environmental Impact

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SUMMARY

While it is true that the emissions of greenhouse gases (GHGs) have come disproportionately from industrialized countries, at the same time, the consequences of an altered environment due to climatic changes are not distributed in the same proportion. The Kyoto Protocol, although a significant step forward in the climate change agendas, is often criticized for its ambitious short term targets and full responsibility only for developed countries that seriously undermines its effectiveness. It has become increasingly imperative to consider potential strategies that allow for the inclusion of developing countries while at the same time are in agreement with the principle of historical responsibility.

Most developing countries view participation in a global climate change treaty as being synonymous with drastic emission cuts and decelerated economic development, and are therefore reluctant to be a part of any binding international climate change treaty. A second dimension to this problem is that for developing countries, addressing climate change, at the national level, poses a fundamentally different challenge with most of these countries continuing to increase emissions as they strive for economic growth. Despite the overwhelming scientific evidence for the link between anthropogenic sources and climate change impacts, there is still a limited understanding of the specific forces driving those impacts. In many cases, a response to climate change, in developing countries is not forthcoming simply due to a lack of understanding or ability to align national climate change policies with the global agenda

Keeping in view the above, this study contributes in two ways

i) Briefly discusses a plausible burden sharing arrangement - the per capita emissions approach - for an all encompasssing global climate change treaty <u>such that negotiations are reduced to two manageable variables.</u>

ii) Conducts a country wise empirical analysis for analyzing the drivers of environmental impact, and their trends, in a sample of 6 developing countries. Our assessment is informed by the well known stochastic reformulation of the IPAT identity, known as the STIRPAT model

The study undertakes a brief analysis the per capita emissions approach, often touted to be as a plausible solution to the dilemma of designing an all encompassing global climate change policy. The approach is modified to include the essential scientific and economic elements of any global climate change solution. The analysis of this modified approach shows that developing countries need not undertake drastic emissions cuts, while being committed to an international climate change solution, such as the proposed one.

While addressing the second objective, the thesis undertakes a time-series analysis within the framework of the STIRPAT model to identify for variations that exist in the relative influence of the drivers of environmental impact across developing countries. Results of the analysis reveal that while population and affluence are the prime drivers of impact, their impact varies significantly across the developing countries. Moreover, population does not exert a unitary impact on emissions as is often simplistically assumed in most studies that undertake such an analysis. The impact is mostly in excess on 1 and in some cases, as the analysis reveals, is also in excess of 2.

Being aware of the role that each of these drivers play in the socio-economic and environmental context within each country, can provide a useful starting point for designing a national response to an international agenda.

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List of Abbreviations

CO_2	Carbon dioxide
GDP	Gross Domestic Product
GHG	Greenhouse gases
GDP	Gross Domestic Product
IPCC	Inter-Governmental Panel on Climate Change
ppm	Parts per million
STIRPAT	Stochastic Impacts by Regression on Population, Affluence and Technology

CHAPTER 1: INTRODUCTION

The threat imposed by climate change, a conjecture only a decade ago, seems a reality now more than ever. The awareness of global warming concerns amongst the international community is reflected in the enormity of research literature that exists across the spectrum of science, economics and sociology. At the institutional level, the debate on climate change is largely dominated by two inter-related issues. Firstly, the future of the Kyoto Protocol, keeping in view its current limitations. Secondly, designing an umbrella framework that includes a burden sharing arrangement suitable for both developing and developed countries while giving due consideration for their differentiated economic conditions. The second concern forms the baseline agenda for this thesis.

As has been seen during recent climate policy negotiations, a critical element has been that of 'suitability and fairness' with respect to the treatment accorded to developing and developed states. On the other hand, lack of consensus on the ultimate objective such as maximum allowable temperature change, absolute level of emissions, concentration levels for GHG or the cost of reduction have also emerged as roadblocks in the process. In addition to this, there is a strong resistance to formal participation in a global climate change treaty, by most developing countries, on grounds of historical responsibility. Formal participation is more than often treated as being synonymous with drastic cuts in emissions. There is no doubt that in the case of developing countries, addressing climate change, at the national level, poses a fundamentally different challenge with most of these countries continuing to increase emissions as they strive for economic growth. Therefore direct emission reduction for GHG reduction is not a viable option.

Our analysis for a solution to the above problem centers around the fact that there exist multiple drivers capable of exerting a significant influence on environmental impact. Therefore a potential way of dealing with the issue could be to assess the drivers of GHG emissions and their related trends in developing countries. Information regarding the same can help illuminate the particular national circumstances faced by the country and inform the international community's policy response. At the same time, such information can serve as a useful starting point for identifying the natural synergies between climate protection and development priorities and consequently aligning the national climate change policy with the international environmental agreement.

Keeping in view the above, this thesis adds to the literature on economics of climate change in the following two ways:

iii) Briefly discusses a plausible burden sharing arrangement - the per capita emissions approach - for a global climate change treaty <u>such that negotiations are reduced to two manageable variables.</u>

iv) Conducts a country wise empirical analysis for analyzing the drivers of environmental impact, and their trends, in a sample of 6 developing countries. Our assessment is informed by the well known stochastic reformulation of the IPAT identity, known as the STIRPAT model

The thesis is structured as follows:

Chapter 2 provides a summary of the review of literature undertaken to explore the current work addressing these two objectives. It begins with providing an insight into the per capita emissions approach. The latter part of the chapter focuses on giving an overview of the existing studies on anthropogenic impacts and climate change and introduces the STIRPAT model, the basis for our empirical analysis model.

Chapter 3 begins with a brief discussion on the science and economics of a propitious climate change policy. It then outlines the per-capita emissions approach. A statistical exercise is then conducted to calculate short and long term emission entitlements for the developing countries, under the proposed modified per capita emissions approach. The baseline model, as suggested by Gupta and Bhandari (1999), is modified to include current scientific and economic considerations. The emission reduction commitments for a chosen sample of five developing countries are outlined under the revised scenario. T

Chapter 4 provides an empirical analysis identifying the relative importance of each of the three drivers of environmental impact i.e population, affluence and technology for a sample of six developing countries within the STIRPAT framework. Most studies until now have relied on the panel data fixed effects model where countries are categorized according to their developed or developing country status and the drivers of environmental impact are assumed to have homogenous effects for countries in the same group. However the dynamics of today's global economy implies that even among countries at similar levels of income, identical drivers of environmental impact might differ in their relative influence on the natural environment due to differences in the socio-economic-political environment within which these operate. The STIRPAT model in Chapter 4 is based on an individual time series analysis using data for 33 years, for each of the chosen countries, to identify the relative intensity of influence of population, affluence and technology on environmental impact. The chosen sample of countries includes India, Pakistan, Philippines, Thailand, Indonesia and China.[1].

Chapter 5 presents the conclusion and recommendations to the study.

The findings in Chapter 3 results confirm that in the presence of an adjusted per-capita emissions approach, such as the proposed one, all developing countries can significantly increase their emissions during the next two decades. In the case of some countries, this approach lays down an emission target that is almost similar to the targets set by the national governments themselves. In general, there is a sufficiently large period available for the developing countries to adjust to an emissions target different from the BAU scenario. In addition to

[1] For selection criteria, refer to Chapter 4.

that, most developing countries can also stand to financially benefit from the generation of 'hot air' and the possibility of selling excess allowances. These earnings can then be reinvested into cleaner technologies and consequently generation of more permits.

Our findings in Chapter 4 confirm the results of earlier studies and refocus attention on population and material affluence as principal threats to sustainability. However in contrast to the results derived from panel data models, our outcome highlights an important point that anthropogenic drivers of environmental impact do not exert a similar influence on the environment for all countries that lie within the same income group. Moreover, our results also contradict the conclusion arrived at by most studies that emission elasticity with respect to population is unity. In such a case, designing uniform policies for countries by categorizing them only on the basis of their income levels, as done by previous studies, might not provide a useful and workable solution for ameliorating climate change. Instead, individual country cases should be considered, as far as possible, to allow for an effective international climate change agenda.

MOTIVATION

- Gupta and Bhandari (1999): 'An effective allocation criteria for CO_2 emissions' *Energy Policy* (27):727-736
- Shi, Anqing (2003). 'The impact of population pressure on global carbon dixide emissions, 1975-1996: evidence from pooled cross country data' *Ecological Economics* 44 (2003) 29-42
- York et al (2003) 'STIRPAT, IPAT and ImPACT: analystic tools for unpacking the driving forces of environmental impacts' Ecological Economics 46 (2003) 351-365
- The growing reality of the threat of climate change as made increasingly evident by unprecedented weather events.
- The intensifying debate over developing country participation in any treaty succeeding the Kyoto Protocol fuelled further by the economic growth achieved by India and China during the last few years

Objective 1

Briefly discuss a plausible burden sharing arrangement - the per capita emissions approach - for a global climate change treaty such that negotiations are reduced to two manageable variables.

Methodolog

- *Introduce the equal per-capita emissions approach, that has received much consensus from both developing and developed countries*
- *Outline the essential scientific and economic considerations for any future climate change strategy.*
- *Incorporate the above into a modified per-capita emission approach scenario and assess the obligations for developing countries.*
- *Baseline model: as proposed by Gupta and Bhandari (1999)*

Objective 2

Conduct a country wise empirical analysis for analyzing the drivers of environmental impact, and their trends, in a sample of 6 developing countries within the STIRPAT framework.

Methodology

- *Highlighting the relation between environmental impact and its drivers: population, affluence and technology.*
- *Understanding the STIRPAT model and collating time series data*
- *Undertake an empirical time series analysis to examine the intensity of impact of population, affluence and technology on environmental impact in developing countries.*

CHAPTER 2: REVIEW OF LITERATURE

2.1 Introduction

This chapter focuses on the literature review undertaken to accomplish the study's objectives. As mentioned in Chapter 1, this study seeks to serve a two-pronged objective. Firstly to discuss a plausible burden sharing arrangement – the per capita emissions approach. Secondly to provide an empirical analysis for analyzing the drivers of environmental impact in developing countries using a time series approach. Section 2.2 provides a brief insight into the arguments put forward favoring the inclusion of developing country in a global climate change treaty. Section 2.3 goes on to discuss the equal per capita emissions approach and the proposed amendments to the same. Section 2.4 details the literature review centered about the second objective. It gives an overview of the existing studies on anthropogenic impacts and climate change and introduces the STIRPAT model, the basis for our empirical analysis model. Section 2.5 briefly discusses the benefits of a time-series approach while analyzing the drivers of climate change.

2.2 Developing Countries and the Global Climate Policy

With the expiration date of the Kyoto Protocol drawing close, the focus has turned increasingly to the question of developing country emissions. Consider the following facts. The compounded annual growth rate (CAGR) of CO_2 equivalent emissions from India, China & Brazil during 1990-2000 shows an overall increase by 4.2, 5 and 6 per cent per annum respectively. In comparison to this, the GAGR figures for USA and Japan stood at 2%. According to the *International Energy*

Outlook 2006, the fastest growth until 2025 is projected in developing countries whose collective emissions are projected to rise 84% (compared to the 35% growth for industrialized countries).[2] One of the most contentious issues in the debate over global climate change is the perceived divide between the interests and obligations of developing and developed countries. Arguments of historical responsibility demands that developed countries – the source of most past and current emissions of GHGs - act first to reduce it. While it is true that the emissions of GHGs have come disproportionately from industrialized countries, at the same time, the consequences of an altered environment due to climatic changes are not distributed in the same proportion. Addressing climate change in this group of countries poses a fundamentally different challenge with emission reduction not a viable option for most in the short run. With per capita income levels much below developed states, developing countries can be expected to continue to increase emissions as they strive for economic growth. Threatened by global warming, while most countries agree on the importance of global greenhouse gas emission reductions, there is still considerable disagreement over the distributional issues that any successor agreement will involve.

Absence of economies with rapidly rising emissions - such as those of India and China – from an international climate change treaty implies that even if Kyoto was fully implemented, it is possible that emissions would continue to exceed removal and GHG concentrations would continue to rise. The inclusion of developing states will be essential to overcome this problem of 'leakage' i.e the

[2] This will take the developing country share of global emissions up to 55% from 48% in the year 2000

possibility that reductions in emissions in industrialized countries under any climate change agreement would be partially offset by emissions in non-participating developing countries. Additionally, global efficiency considerations favor the inclusion of developing countries in any international climate change agreements since the cheapest source of CO_2 emissions abatement are found, not in Annex B countries, but in the developing economies. So can the existing Kyoto Protocol provide the suitable outcome for an international climate change agreement that can serve the interests of both developing and developed countries?

There is a growing scientific and economic consensus on the need for a credible approach to address the threat of climate change. Although the Kyoto Protocol represents a consistent step forward in the international response to the dilemma of global warming, it suffers from some inherent drawbacks that seriously undermine its effectiveness. During the last few years, serious questions have been raised regarding the Protocol's ability to induce sufficient participation and compliance. According to Barrett and Stavins (2002) the Protocol's shortcomings can be attributed to three key architectural elements: ambitious short-term targets, full responsibility (targets) only for industrialized countries and absence for effective instruments for promoting compliance and participation. The need for amending the Kyoto Protocol is as critical as is the necessity for comprehensive participation from both the developed and developing countries.

2.3 The Equal Per Capita Emissions Approach

> *'....on the basis of equity and in accordance with their common but differentiated responsibilities and respective capabilities, parties should act to protect the climate system'*
>
> Article 3, *Principles,* UNFCCC

Limiting global warming to avoid the worst of the potential negative impacts will require a drastic change in the emissions trajectories of both rich and poor countries. One of the defining issues in discussing varied burden sharing approaches has been *whether* and *when* developing countries should take on emission targets and how should differential commitments be set for the developing and the developed states. The Kyoto Protocol adopts the 'target and time-table' approach that sets specific goals in terms of emission targets at given points in time. During the last few years, varying burden sharing rules, centered about considerations of equity and fairness, have been suggested for restricting emissions in developing countries. Rose and Stevens (1993)[3] distinguish between 'allocation based' and 'outcome based' equity principles. In the context of climate change agreements, those based on the former equity principle focus on a fair initial allocation of property rights to GHG emissions, using criteria such as population, GDP and historical emissions or a mixture of them. Agreements based on the 'outcome based principle' focus on a fair outcome of climate protection strategies such as the equalization of net cost per GDP or the requirement that mitigation efforts should not affect the developing states adversely.

[3] **Rose, A** and **B. Stevens** (1993) 'The Efficiency and Equity of Marketable Permits for CO_2 Emissions' *Resource and Energy Economics* 15(1), pp117-146

Traditionally converging per capita emissions has been favored by most developing countries. This has, in the past, been advocated by the governments of China, India, the Africa Group, France, Belgium and Sweden amongst others. It requires all countries to participate and per capita emission allowances converge to the same level until a predefined date so that global emissions lead to a predefined stabilization level[4]. Allowing for equal emissions per capita is a direct application of egalitarian equity. However this approach has been criticized for its over simplicity in treating a great variety of national circumstances. As pointed out by Stiglitz *et al* (2001), a distribution of emissions on the basis of population would imply a large emission reduction for the developed, less populated countries. They further point out that counties that fail to control their rate of population would be effectively 'rewarded' by getting extra entitlement to emissions. Proponents of this approach suggest that with small adjustments, reflecting vertical equity, in the short to medium term, the per capita emissions approach can serve as a successful solution to the current impasse in the climate negotiations. A review of the academic literature reveals the various amendments that have been suggested to the straightforward per-capita emissions entitlement approach. Some authors recommend that a long term per-capita convergence target can be identified and each person can be allocated an entitlement based on the same. The target itself could be flexible and subject to revision as more scientific information becomes available

[4] Grübler and Nakićenović (1994) use this rule to calculate the distribution of the global emission entitlements of 13 world regions with a target of 38% reduction in CO_2 emissions in 2050 compared to 1988.

Another approach representing such an altered framework is the 'Contraction and Convergence' approach. Based on the principle of historical responsibility and equality of rights, it can be best defined as a future international climate regime based on converging per-capita emissions in conjunction with a gradual decrease in global emissions towards stabilization of GHG concentrations (Meyer, 2000). Originally conceived by the Global Commons Institute in the early 90's, it is based on two principles: First, contraction of global carbon emissions in order to achieve a pre-defined CO_2 concentration target; Second, convergence of per capita emissions across the global population. In the short run, this tantamounts to a reduction for the developed states, while those in the developing countries are able to increase their per capita emissions in order to develop economically. Eventually per capita emissions converge at a per-capita level. According to Berk *et al* (2001) [5], a later date of convergence is disadvantageous to developing countries since it results in less cumulative emission permits.

Refinements to the Contraction and Convergence approach have been suggested by many authors. Swen Bode (2003)[6] allocates future emission rights on the basis of equal per capita emissions over time, such that emissions per capita are taken into account both during their evolution and at the time of

[5] **Berk, Marcel. M.** and **Michel den Elzen.** (2001) 'Options for differentiation of future commitments in climate policy; how to realize timely participation to stringent climate goals' *Climate Policy,* Vol(1)
[6] **Bode, Swen.** (2003) 'Equal Emissions per Capita over Time-A Proposal to Combine Responsibility and Equity of Rights'. HWWA Discussion Paper http://www.hwa.de

allocation. A recent study by Hohne *et al.*(2006)[7] recommends a 'common but differentiated convergence' approach in response to the concern that emission reduction obligations in advanced developing countries are delayed and reduced in comparison to the obligations for the Annex-1 countries. Gupta and Bhandari (1999) also favor an equal emissions per capita outlook for all countries in the *long run*. However, keeping in view considerations of historical responsibility as well as horizontal and vertical equity, the authors suggest that an efficiency index should be included, within the equal per capita model, to avoid prescribing abruptly declining emission entitlements for Annex 1 countries. They further go on to argue against the claim that a formulation linked to future population may influence developing countries to unduly increase their population to gain higher entitlements, keeping in view the prevalent policies to limit population, poverty alleviation and the recognition of limits to availability of resources.

The Contraction and Convergence framework integrates the need for climate change policy to be based on comprehensive participation and a clear scientific foundation by incorporating provisions that allow for differentiated reduction commitments and pre-fix a global concentration target. It makes an attempt to look beyond the egalitarian perspective to reconcile and incorporate available scientific knowledge along with economic principles. At the same time, it also allows for developing country participation without affecting their pursuit of economic development and poverty reduction. Ultimately almost any

[7] **Hohne. E., M den Elzen** and **M Weissb** (2006) 'Common but differentiated convergence (CDC): a new conceptual approach to long-term climate policy' *Climate Policy* 2006; 6(2): 181-199

conceivable long term solution to the climate problem will incorporate some crude variation of the contraction and convergence philosophy. Chapter 3 discusses one such plausible solution that incorporates other essential scientific and economic considerations central to any climate change strategy.

2.4 Identifying the Drivers of Climate Change

Successful implementation of a global climate policy regime will require active participation of national governments as it is they who will determine how an international climate change agreement is translated at the domestic level. Despite the overwhelming scientific evidence for the link between anthropogenic sources and climate change[8] impacts, there is still a limited understanding of the specific forces driving those impacts. The Ehrlich-Holdren vs Commoner debate in the early 70's firmly established that population, affluence and technology played a significant role in shaping environmental impacts. Many studies have discussed this relationship using diverse modeling approaches. The IPCC too has, on more than one occasion, pointed out that projections of long term emissions growth depend heavily on assumptions about such critical factors as economic and population trends and the rate of technology development and diffusion. Infact, the IPCC has developed four 'families' of scenarios incorporating different sets of assumptions about these factors. Yet there remains much scope for further empirical analysis. This has also been reinforced by the US National Research Council in one of their recent reports on climate change where they say that

[8] *Global Environmental Change: Research Pathways for the Next Decade* (1999). Committee on Global Change Research, National Research Council, National Academy Press, Washington D.C (1999)

"*Although physical and natural scientists have developed sophisticated models of biogeochemical and other global processes, the dynamics of the anthropogenic drivers of global environmental change are not fully understood"*

One reason for this is the absence of a set of refined analytic tools. Lack of long-term credible data relating to emissions and change in the concentration of GHG over the last 2-3 decades etc creates further barriers.[9] York *et al* (2003) have pointed out to the paucity of appropriate analytic techniques and models that could allow for a precise specification of the functional form of the relationship between anthropogenic driving forces and environmental impacts, to be a prime reason inhibiting social and economic enquiry of the subject. Secondly, the principal tools commonly utilized in climatic research are the two large scale structural models i.e **a)** general circulation models (GCMs) and **b)** integrated climate economy models (DICE Model by Nordhaus, 1992)[10]. These utilize specialized softwares and supercomputers to perform simulations of global weather. However a significant drawback of such models is their large cost as well as their complex and time consuming construction. The correct specification of the model is also open to considerable debate. As discussed by Knapp and Mookerjee (1996), keeping in view the perceived need for policy making, researchers have begun to rely on simple time-series techniques to provide some

[9] A proper awareness of environmental issues, in the academic world and at the level of institutional policies and international organization is quite recent and dates back to the mid 70's. Climate change discussions came to the forefront only about a decade later.

[10] Nordhaus, W (1992) 'The DICE Model: Background and Structure of a Dynamic Integrated Climate-Economy Model of the Economics Of Global Warming'

insight into the interconnectedness between global temperatures and the relevant policy variables. The empirical analysis conducted in this study seeks to make a contribution to that body of work.

2.5 Population, Affluence and Technology as Drivers of Climate Change

A review of the literature on this subject reveals that questions relating to the relationship between climate change impacts and anthropogenic sources have been addressed across the spectrum of social and natural sciences. Two strands of empirical work can be identified under this topic. The first being descriptive in nature and the second takes an empirical approach. Descriptive studies tend to attribute variations in CO_2 emissions to changes in population, affluence and energy intensity. (Engleman-1994; Meyerson-1998). The second strand adopts an empirical approach by focusing on the link between CO_2 emissions and economic growth, regressing emissions on affluence, population and other predictors.

A large amount of attention has been devoted to the casual link between population and environmental impact. Many empirical studies have explored the question whether increases in the atmospheric concentration of CO_2 and other GHGs can be largely attributed to accelerated population growth and have analyzed the underlying statistical relationship between the two. Traditionally researchers have assumed a unitary elasticity of emissions w.r.t population growth. Engelman (1994) adopts a descriptive approach to explore this relationship. His study plots the long term trends in global CO_2 emissions and population. Similar rates of growth of both variables lead him to hypothesize that population growth has been a major factor explaining rising emissions. Using the Granger test of causality and other comprehensive error-correction model, Knapp and Mookerjee (1996) also examine this relationship using global annual data for 1880-1989. Their results suggested a lack of any long-term equilibrium relationship but imply a short-term dynamic relationship from CO_2 to population growth. The causal link between population and global carbon dioxide emissions has also been examined by Shi (2001;2003) by using data for 93 countries. His study concludes that global population change during the last two decades was more than proportionally associated with growth in carbon dioxide emissions. The elasticity of emissions with respect to population was nearly 2 for developing nations, while it was seen to be less that one for high income countries. Furthermore, impact of population change on emissions is more pronounced in developing countries as compared to developed countries. A similar conclusion was arrived at by a study done by O'Neill *et al.*(2001)[11]

The importance of population and economic growth as emission drivers has also been highlighted, by the World Resources Institute[12], using a decomposition analysis technique. According to their report released in 2005, economic growth (measured as increases in GDP per capita) had the strongest influence on emission levels, usually putting an upward pressure on emissions, in cases as diverse as the U.S, India, Indonesia, Australia, and Iran.

[11] O'Neill, Brian C., F. Landis MacKeller, Wolfgang Lutz. (2001). *Population and Climate Change,* Cambridge University Press.
[12] *Navigating the Numbers,* Published by the World Resources Institute (14)

One of the earliest attempts to explain the dynamics between environmental impact, population and human welfare was made by Ehrlich and Holdren (1971). According to them, population growth causes a disproportionate negative impact on the environment. Conventional view, on the other hand, holds that affluence is a prime driver of higher CO_2 emissions. It is a priori not evident that population growth leads to higher environmental degradation. Production technologies, consumption patterns and technological progress play an equally important role in determining the amount and type of emissions.

Economic and scientific research, over the last three decades has culminated into a general consensus among policy makers and researchers alike that posits that growth in population, affluence and technology are jointly responsible for environmental impacts. This consensus is best manifested in the simplified identity known as *IPAT*, that emerged out of the Ehrlich & Holdren (1971) and Commoner (1972) debate. The 'IPAT equation', as it is popularly known, states that environmental impact (*I*) is the product of population (*P*), affluence (*A*) and technology (*T*):[13]

$$I = P * A * T \qquad (\textbf{....2.1})$$

This simple formulation has been chosen by many scholars as a starting point for investigating interactions between population, economic growth, and technological development. (Dietz and Rosa, 1994, 1997; Mackellar *et al*., 1995; York *et al*., 2003; Auffhammer *et al*., 2004). The specification of the IPAT model

[13] The IPAT model represents the efforts of population biologists, ecologists and environmental scientists to formalize the relationship between population, human welfare and environmental impacts.

makes clear that all of the driving forces do not influence impacts independently of one another.

This mathematical identity has been typically used as an accounting equation in which known values of *I*, *P*, and *A* are used to solve for *T*. However it does not prove to be very useful for statistical analysis because of its interpretation of statistical association as causation. The identity merely gives the proportionate impact of environmental change by changing one factor and simultaneously holding the other constant. The development of economic theory requires that hypothesis about the macro-variables and environmental impacts be testable, rather than being simply assumed within the structure of the model. In addition to this, a key to understanding the relative importance of each of the driving forces (*P, A* and *T*) is to model the effects of their rate or pace of growth. The same might have greater environmental impacts than size per se.

In order to overcome this limitation, Dietz and Rosa (1994, 1997) reformulated the IPAT equation as STIRPAT (Stochastic Impacts by Regression on Population, Affluence and Technology) to meet statistical testing requirement and to allow for non proportional effects from the driving forces. Their specification used to perform the regression analysis was as follows

$$I_t = aP_t^b A_t^c T_t^d e_i \qquad \textbf{(....2.2)}$$

The model maintains the multiplicative logic of the *IPAT* framework. The variables a-d can either be parameters or more complex functions estimates using standard statistical properties and *e* is the error term. Such a functional form allows for the presence of non-linear relationships between the driving forces and the environmental impacts. The logarithmic formation of the above functional form yields the following

$$\log I_t = a + b\log P_t + c\log A_t + d\log T_t + e \qquad \textbf{\textit{(.....2.3)}}$$

Such a formation also permits easy computation of the elasticity of the environmental impact with respect to each of the anthropogenic factors. In the absence of any appropriate direct measure of technology, *T* was more than often included in the error term. The STIRPAT model, although originating in ecology is amenable to economic analysis. Factors other than the core components of the model, *P* and *A,* can be added to address economic questions, as long as they are consonant with the multiplicative specification of the model. Technology should be assessed directly rather than as a residual of an accounting format. The STIRPAT model has been successfully utilized to analyse the effects of the driving forces on a variety of environmental impacts. However there is no unanimity on the ordering of significance of the 3 predictors.

Dietz and Rosa (1997) use this model in studies of *global* climate change. They regress total emissions on population size and GDP using data for 111 countries. Their study found that a one percentage point growth in population could yield a 1.15 percent increase in carbon dioxide emissions. However their model does not explicitly include technology as a predictor in the model and it is modeled as a residual term. The proportional impact of population on environmental impact is also reinforced by Rosa *et al* (2004) who use the STIRPAT model to examine the effect of population and affluence on a wide variety of global environmental impacts. As in the previous case, technology is not considered as an independent variable. Another study conducted within the STIRPAT framework attributes economic growth to be the main driver for CO_2 emissions. Using data for different income levels for the period 1975-2000, the study suggests that with regard to developing or low income countries, the impact of GDP per capita is very great. (Fan *et al*, 2006).

Using the fixed effects model approach with time series data for 1975-1996, Shi (2003) tests the hypothesis that the impact of population varies across countries with different income levels. He further goes on to assess the baseline STIRPAT model by introducing affluence and technology. The non proportional impact exerted by population is evident in both cases. Represents a larger fraction of GDP have higher emissions in comparison where the service sector dominates the economy. Overall a 1% increase in GDP raises emission by less that 1%.

Results of a recent (unpublished) study by Rosa, York and Dietz (2007) suggest that the principal factors affecting climate change growth are the growth of population and consumption. The further go on to conclude that the impacts of these two variables are so profound that they could possible outpace any potential benefits from modernization and improving technologies. According to them urbanization, economic structure and age of population have little effect.

2.6 Individual time series analysis: Need and Benefits

Most studies, employing the STIRPAT model or otherwise studying the inter-relationship between population and environmental impacts rely on the simplistic assumption that countries at similar income levels will have similar relationship between the various predictors of environmental impact. As such they can be expected to exhibit similar responses to policy decisions made in this regard. Fixed effects panel data models are most commonly used that allow for a uniform coefficient of population, affluence and technology for all countries in the same income group.

Recent decades have seen rapid growth of the world economy. The last decade has seen many developing countries (India, China, Philippines, Bangladesh) opening up their economies to take full advantage of this accelerated globalization. The integration of the world economy has raised living standards across the world but at the same time has created newer challenges defining the present day environmental impacts. So while the drivers of environmental impact might be the same in different countries, the relative influence exerted by them on the environment will differ according to the structure of the socio economic environment within which they operate.

On one hand, population is known to exert a significant impact on the environment, on the other, environmental impact can continue to grow even as population growth levels off. For example, in China, population growth has slowed dramatically, but consumption of oil and coal and the resulting pollution continue to rise.

Numbers alone do not capture the impact of the interactions between human populations and the environment. Structural shifts in the economy encourage higher rates of rural–urban migration which can be a decisive factor in determining the intensity of the ecological footprint, an underlying factor for assessing environmental impacts. In the 1950's only 18% of people in developing countries lived in cities. In 2000, this figure had risen to 40% (and 76% for developed world). It is estimated that by 2030, 56% of the developing world will be urbanized.

Another outcome of structural shifts in the economy is the changing household dynamics. During the period 1970-2000, the average people living under one roof declined from 5.1 - 4.4 in developing countries while the total number of households increased as a result or rising incomes and urbanization with fewer people in each household, savings from shared use of energy and appliances are lost. As birth rates fall, consumption levels and patterns (affluence), coupled with technology, will take on new importance in determining the state of the global environment.

The rate of technological development such as the extension of basic transport infrastructure can open up previously inaccessible resources and lead to their exploitation and degradation. In addition to this, political mandate and willingness for promoting an efficient use of resources and expensive, more efficient technologies will vary depending on each country's target rate of economic growth.

The above discussion highlights that local modifiers such as population size & movement, technology and industrialization, socio-economic development, and attitude of the political system towards designing the environmental policy and regulatory framework will play an important role in determining the relative importance of the drivers of environmental impact. Therefore, simply using the 'income level' as the defining criteria for homogenizing impacts might not be a very valid assumption. Results from a fixed effects model then might not be a useful starting point for developing national policies.

A realization of the above argument is also evident in the increased emphasis being placed on examining the experience of individual countries so that policy frameworks are tailored and suggested according to their unique circumstances and resources. To date however, few country specific empirical assessments are available. Section II of this thesis, aims to fill the gap in literature and attempts to assess the drivers of GHG emissions (population, affluence and technology) and related trends in developing countries by undertaking a time series analysis for each sample of countries chosen. Such information can help illuminate the particular national circumstances faced by countries and inform the international community's policy responses.

CHAPTER 3: DEVELOPING COUNTRIES AND THE PER CAPITA EMISSIONS APPROACH

Chapter 2 has already introduced the per-capita emissions approach and its variants. This chapter builds on to that discussion by looking at the outcome of a modified per-capita emissions approach that closely follows the one suggested by Gupta and Bhandari (1999). The original model has been adjusted to accommodate for the essential scientific elements and economic principles of a global climate change policy framework. Outcomes of the revised model suggest that, contrary to popular belief, developing countries can be a part of a global climate change treaty without having to undergo drastic emission reductions in the near future.

A short discussion on the essential economic and scientific considerations precedes the revised model to put the proposed adjustments into context.

3.1 The Science and Economics of a Propitious Climate Change Policy

'Climate change poses a serious challenge to our ability to construct equitable global responses to shared problems'

Aldy *et al. (2003)*

It has often being argued that emission quotas allocated in the Kyoto Protocol are the result of political haggling rather than an obvious correlation with the cuts being called for by the IPCC. A review of the academic literature brings to light the economic and scientific considerations that are essential for developing any successor to the Kyoto Protocol.

3.1.1 *Reconcile considerations of both 'equity' and 'common but differentiated responsibility':* While the need for comprehensive participation is obvious, it does not imply a common approach for all countries. Different states will have different vulnerabilities to competitiveness impacts and varying capacities for action. Therefore any future strategy will need to conform to the established principle of *common but differentiated responsibility* while at the same time keeping in view the ethical considerations and distributional issues for welfare losses. Miketa and Schrattenholzer's (2004) summary of five equity principles (Table 2) and their relation to the definition of burden sharing rules in the global policy context serves as a useful reference point in this regard.

Table 2: Five equity principles and their implications for global burden-sharing

Equity Principles	Implication for burden sharing in the context of global climate protection
Allocation Based Principles	
Egalitarian	Supports equal emission rights per capita
Polluter Pays	Supports historical responsibility
Sovereignty	Supports the status quo
Outcome Based Principle	
Horizontal Equity	Supports allowance according to countries' specific circumstances
Vertical Equity	Supports differentiation between rich and poor by considering 'ability to pay'

Source: Miketa and Schrattenholzer (2004)

3.1.2 *Long term flexible targets:* Climate inertia and the ensuing long residence time implies that climate change takes a long time to demonstrate the full extent of the impact of a warming planet. To accommodate for this, any future strategy, while being specific about the short to medium term targets, will simultaneously need to incorporate a framework within which countries can agree to pursue climate change objectives *over time*. Flexibility to incorporate revisions in light of new scientific knowledge is also an essential pre-requisite for motivating technological retrofitment. As highlighted by Barrett (2003) and Stavins and Barrett (2002)**,** the socio-economic and technological inertia that must be overcome in order to reduce emissions sufficiently so as to bring back the global environmental system into balance is a prime reason for adopting a long term perspective.

3.1.3 *Efficiency:* An important economic criterion for a long term policy is its ability to attain emission reductions at the lowest possible cost while maximizing total social benefit. As mentioned before, the cheapest source of CO_2 emissions are found, not in the Annex B countries, but in the developing economies. Their inclusion is therefore critical to an efficient global solution as it would permit relatively low-cost reductions in emissions thus facilitating minimal global welfare loss (Aldy and Frankel; 2004). In addition to economic efficiency, a planned transition from a high-carbon to a low-carbon economy requires continual focus on improved R&D. Such improvements in energy efficiency are the idea behind 'technological efficiency'.

3.1.4 *Stabilization of GHGs in the atmosphere:* A key aspect regarding projections in climate change is the projection of future emissions of carbon dioxide so as to make reasonable estimates of future emission allowances[14]. There exists sufficient scientific evidence in favor of the fact that it is the stock of gases that determine the degree of climate change and not the absolute quantity of emissions emitted per year (Nordhaus and Boyer,2000; Meinshausen,2005; IPCC,2001). With climate sensitivity still under debate, targets based purely on temperature changes can be associated with a broad range of emissions possible while emission oriented targets can correspond to a wide range of temperature scenarios. Focusing on the GHG concentrations can eliminate this ambiguity to some extent.

> Article 2 of the UNFCCC states its ultimate objective as
> *"Stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system"*

3.1.5 *Incorporating safe limits of temperature change:* Emission oriented targets can correspond to a wide range of temperature change scenarios. Hence it is important to keep in mind the desirable temperature change while deciding a GHG stabilization target. Reviews of scientific literature on climate impacts often conclude that an average global warming of 2°C will result in dangerous and irreversible effects, which rapidly worsen above 2°C warming (Meinshausen,

[14] The Intergovernmental Panel on Climate Change's (IPCC) Special Report on the Emissions Scenario (SRES, IPCC 2000) is one of the most comprehensive studies of future emissions projections.

2005).[15] This temperature target is also reflected by a figure known as the 'burning ember', in the Third Assessment Report (2001) of the IPCC. A growing number of studies are now adopting the 2°C threshold as the designated temperature limit above which dangerous climate impacts will occur.

> *"…even at two degrees C, the world is facing extremely serious impacts. Above that level we are spinning out of control-where impacts escalate rapidly and we run an unacceptable risk of catastrophic climate change"*
>
> Hans Verolme, Director-WWF's Global Climate Change Program

To sum up, a suitable international climate change strategy will be one that is able to address the following critical questions:

a) What levels of GHG in the atmosphere are self-evidently too much and how can we avoid such levels?

b) How can the policy differentiate the participation of countries while respecting the principles of 'historical responsibility' and 'common but differentiated responsibility'?

c) Last but not the least, what type of commitment mix will be politically feasible, cost effective and environmentally effective so as to be able to promote comprehensive participation?

[15] The 2°C temperature target has also found much support within the EU. In their communication addressed to the Spring 2007 European Council, during January 2007, the Commission of the European Communities has pressed for the EU to adopt 'necessary domestic measures and take the lead internationally to ensure that global average temperature increases do not exceed pre-industrial levels by more than 2°C'. A recent report titled *Climate Change-the Costs of Inaction* (2006) states that beyond 2°C all regions will suffer from the worsening average effects of climate change, along with intensifying extremes and rising risks of catastrophe.

An optimal solution will then need to begin with defining the ultimate goal – the acceptable level of climate change- and then go on to devise a global emission budget that should be distributed according to some rationally defined, equitable criteria.

On one hand atmospheric concentrations of GHGs cannot stabilize unless total emissions contract and on the other, emissions cannot contract unless per-capita emissions converge. In this regards, the per-capita approach model discussed above seems to strike a balance and provide grounds for consensus. As has been discussed in Chapter 2, advancing towards an equal per-capita national emissions allowance is a worthy goal, particularly if adjusted for disparate national circumstances. These tend to be fundamentally more appealing on grounds of equity and allow greater space for economic growth in developing countries. We discuss here the equal per capita emissions adjusted in the short term, for Annex-1 countries, based on their relative efficiencies as proposed by Gupta and Bhandari (1999). With minor modifications to accommodate for the above mentioned economic and scientific considerations, we calculate the revised model to show that developing countries do not stand to lose out by participation in a global climate change agreement.

3.2 A Modified Per-Capita Emissions Approach

<u>*The Gupta-Bhandari (1999) Model*</u>

Following Gupta and Bhandari's (1999) approach, the per-capita emission model can be developed through the following simple procedure.

Step 1: The Average Per Capita Entitlement at any point of time *t,* is defined as

$$APCEE_t = \frac{WorldEmissions_t}{WorldPopulation_t} \qquad \ldots\ldots\textbf{(3.1)}$$

Step 2: Emission rights (*AE*) for any Country *i* are then determined as global average times Country *i*'s population (*Pop*) at time *t.*

$$AE_t = APCEE_t * Pop_t \qquad \ldots\ldots\textbf{(3.2)}$$

However, as pointed out by other authors before, direct application of the per-capita emissions approach will tend to favor the developing countries, most of whom outdo the developed countries with respect to population numbers. Cognizant of this argument and recognizing that such stringent reduction requirements will be difficult to comply with for the developed countries, Gupta and Bhandari propose the following adjustment. A 25% reduction commitment is proposed for the post–Kyoto period until 2025 for the Annex 1 countries. This equal percentage reduction is then further adjusted to account for the efficiency of production in the Annex 1 states. They justify this by arguing that

a) A higher level of GDP requires higher consumption of energy and reducing the same, in a short time, to match the global average can be both inefficient and unfair

b) Secondly, an efficient economy already uses relatively GHG-benign technology and therefore a stringent reduction of this kind, within the short term, would tantamount to penalizing them for their efficiency.

Therefore, an effective percentage reduction of the following form is suggested

$$\textit{Effective \% Reduction} = (1\text{-}\%\ \textit{reduction}_{time} * \textit{Efficiency Index}) \quad \ldots\ldots(\mathbf{3.3})$$

The efficiency index is then defined as the carbon intensity of a country normalized by the average carbon intensity of a sample of Annex-1 countries as depicted below:

$$EfficiencyIndex_i = \frac{CO_2 emissions_{i,1990} / GDP_{i,1990}}{CO_2 emissions_{annex1,t} / GDP_{annex1,t}} \quad \ldots\ldots..(\mathbf{3.4})$$

* *i* denotes Country and *t* refers to time

Countries above the global average have an index greater than one and those below the average have an index less than one. Such efficiency adjustments make the per-capita emissions approach both horizontally and vertically equitable. For complete discussion and details, the reader is referred to Gupta and Bhandari's paper.

To begin with we need to have estimates of both the world population and the trajectory of world emissions. Keeping in view the fact that CO_2 emissions are one of the most important drivers of radiative forcing thus critical in terms of global warming potential, the reference to 'emissions' here is limited to carbon dioxide only.

The proposed model departs from the original model in one important way. The global emissions trajectory, to which all countries ultimately converge to, in the proposed model, is one that keeps in view two important objectives of controlling global climate change a) attaining the desirable GHG concentration and b) watching the upper thresholds of temperature change.

We then go on to explore the following questions. Does the use of such a global emissions trajectory, based on strict targets for concentration and temperature limits, lead to drastic emission cuts for the developing countries? If not, then how do these new proposed emission levels compare with those of 1990 and 2000 levels.

Our sample of countries includes India, China, Indonesia, Mexico and Brazil. All five developing countries figure amongst the top ten states w.r.t their share of CO_2 emissions as a percentage of world total.[16] Brazil and China together accounted

[16] Being developing states, they currently do not have any binding emission reduction commitments under the Kyoto Protocol.

for 17% of the global anthropogenic GHG emissions in 1990 (not including emissions from deforestation)

Population estimates for the World, India, China and the US were taken from the *UN World Population Projections to 2150.* Those for Indonesia, Mexico and Brazil were taken from projections made by their respective national divisions or ministries. These are summarized in Table 3.1 below**.**

Estimating World Emissions**:** As has been discussed in the previous Chapter many academic studies have clearly established that climate change is the result of a variation in the *concentration of GHG* in the atmosphere rather than absolute emissions. Therefore any meaningful strategy for tackling the latter should have stabilization of GHG as its core objective. Having said that, consideration also need to be given to the sufficient evidence that exists in support of the fact that an increase in the Earth's average temperature of 2°C is now be widely regarded as the threshold for 'dangerous' climate change. Therefore any potential climate change strategy should also be able to demonstrate its ability to limit the temperature change within the 2°C mark with a relatively high degree of certainty.

In order to assess probabilistic temperature evolutions, a study conducted by Meinshausen *et al.*(2004) developed multi-gas emission pathways where the emissions were adapted to meet the pre-defined stabilization targets of 500ppm, 475ppm, 400ppm CO_2 equivalence. Keeping in view the 2°C target, only for a stabilization level of 400ppm CO_2 eq and below can warming below 2°C be roughly classified as 'likely'. The 400ppm pathway is assumed to peak at 475ppm before returning to its ultimate stabilization level around the year 2150. Such an allowance for overshooting sounds reasonable keeping in view the fact that we GHG concentrations are already edging over 380ppm in 2007. For such a pathway, estimated emissions, derived by Meinshausen *et al.* are given in the table 3.1 below. All data was converted from Gt of C to Gt of CO_2 using the conversion factor 1Gt of Carbon = 3.667 Gt of CO_2.

3.3 Results and Discussion

Table 3.1 summarizes the outcome of the adjusted per capita emissions approach. Negative values indicate a percentage decrease over 1990, 2000 levels.

As is evident from the results, under the proposed per-capita solution, all countries, except Mexico, are allowed increased emissions for the next two decades, in comparison to their 1990 levels. Although absolute figures show decreasing emissions, the reductions called for until 2015 are well below 5% for all countries. Research studies show that the potential for 5-7 percent GHG emission reductions lies in improving the efficiency of the exiting installed capacity instead of reducing volumes of production. [17]

[17] Developing countries, with an emerging and rapidly expanding industrial infrastructure, have the particular opportunity to increase their competitiveness by applying energy-efficient best practices from the outset in new industrial facilities.

We compare the figures estimated in Table 3.1, with the most widely cited business-as-usual projections developed by the Energy Information Administration (EIA) of the US Department of Energy in their report titled *International Energy Outlook (IEO).* According to *IEO 2006,* among developing countries, the largest relative growth until 2025 is forecast for Mexico (124%) and for China (118%). For the year 2025, carbon dioxide emissions for Mexico, China, India and Brazil are estimated to be 0.622, 7.86, 1.76 and 0.487 Gt of CO_2 respectively. Comparing the allocated quotas under the proposed models, with the projected emissions of the countries, with the exception of Mexico, each of the other 3 countries are allowed to emit much above their BAU projections. What implications does this excess quota imply?

To begin with, one can expect the creation of significant amounts of 'hot air' that can be traded by the developing countries. Therefore incorporating flexibility in terms of options for full emission trading will be essential to enhance the appeal of such a burden sharing alternative. It is the contention of some authors that such trading incentives will also motivate higher investment into cleaner technologies in the South, by reinvesting proceeds of its permit sales therefore allowing the developing countries to continue selling such permits for a profit. Additionally, developing countries can make use of these additional 'allowed' emissions to attract foreign investment into high volume Clean Development Mechanism (CDM) projects.

Table 3.1: Per-Capita Emission Entitlement

	Units	2010	2015	2025	2050	2075	2100
Fossil Fuel Co2: World	Gt of Carbon	7.988	7.315	5.720	3.150	1.430	0.805
Fossil Fuel Co2: World	***Gt of Co2***	29.292	26.824	20.975	11.551	5.244	2.952
*****1 metric ton of Carbon = 3.667 metric tons of Co2***							
Population World	billions	7.150	7.300	8.039	9.367	10.066	10.414
India	"	1.155	1.23	1.33	1.533	1.595	1.617
China	"	1.342	1.41	1.48	1.517	1.509	1.535
Indonesia	"	0.206	0.259	0.3	0.34	0.385	0.436
Mexico	"	0.113	0.119	0.131	0.139	*n.a*	*n.a*
Brazil	"	0.192	0.202	0.217	0.238	*n.a*	*n.a*
Average Per Capita Emission Entitlement = world emissions at time t / world population							
Country's Entitlement=average per capita emission entitlement (t)*Population (t)							
	Units	**2010**	**2015**	**2025**	**2050**	**2075**	**2100**
World Emissions / World Population	ton per capita CO2	**4.097**	**3.675**	**2.609**	**1.233**	**0.521**	**0.283**
Entitlement for India	Gt of Co2	**4.732**	**4.520**	**3.470**	**1.890**	**0.831**	**0.458**
% change over 1990 levels		598.20%	566.90%	412.05%	178.94%	22.60%	-32.37%
% change over 2000 levels		308.36%	290.05%	199.48%	63.15%	-28.29%	-60.44%
Entitlement for China	Gt of Co2	**5.498**	**5.181**	**3.862**	**1.871**	**0.786**	**0.435**
% change over 1990 levels		129.25%	116.04%	61.02%	-22.00%	-67.22%	-81.86%
% change over 2000 levels		98.39%	86.96%	39.35%	-32.50%	-71.63%	-84.30%

Table 3.1: Per-Capita Emission Entitlement contd...

	Units	2010	2015	2025	2050	2075	2100
Entitlement for Indonesia	Gt of Co2	**0.844**	**0.952**	**0.783**	**0.419**	**0.201**	**0.124**
% change over 1990 levels		465.43%	537.63%	424.44%	180.91%	34.37%	-17.20%
% change over 2000 levels		206.33%	245.45%	184.12%	52.19%	-27.20%	-55.14%
Entitlement for Mexico	Gt of Co2	**0.463**	**0.437**	**0.342**	**0.171**	***n.a***	***n.a***
% change over 1990 levels		23.41%	16.57%	-8.88%	-54.31%	*n.a*	*n.a*
% change over 2000 levels		17.14%	10.66%	-13.46%	-56.50%	*n.a*	*n.a*
Entitlement for Brazil	Gt of Co2	**0.787**	**0.742**	**0.566**	**0.293**	***n.a***	***n.a***
% change over 1990 levels		288.33%	266.44%	179.52%	44.89%	*n.a*	*n.a*
% change over 2000 levels		155.85%	141.43%	84.17%	-4.54%	*n.a*	*n.a*

Additionally, such an adjusted per capita approach offers the following advantages.

First, in addition to being a viable option for developing countries and addressing considerations of equity and efficiency, it also preserves the objective of environmental integrity by keeping in view the GHG stabilization target to present an effective global emissions reduction regime.

Second, realizing that the success of such a model also depends on the continued commitment of the developed states, the 'efficiency index', introduced in Section 3.2 above, prevents any drastic emission reductions for the industrialized states. By specifying the year of convergence of per capita emissions, this adjusted approach gives a clear assurance of an equitable treatment and creates a virtuous circle in which southern countries benefit from an income flow with a clear incentive to invest the proceeds in clean technology.

Third, negotiations are reduced to only *two manageable variables*, i.e **1)** deciding the effective percentage reduction for developed states and **2)** calculating the optimal year of convergence such the GHG stabilization target and 2°C threshold levels are successfully met.

Lastly, by offering a long-term architecture where emissions are allowed to increase for the next two decades, before any reductions are called for, this approach provides developing countries ample opportunity for economic growth and a sufficiently long time-period of research & development of alternative technologies.

The proposed 'adjusted' per-capita emissions approach above has the potential to play an important role in the climate change debate as it focuses on the heart of the problem and incorporates the critical and desirable features discussed in Section 3.1. However decisions about which abatement strategy to ultimately invoke are the result of political negotiations and outcomes of feasibility studies and cost-benefit analysis. The entire process can be extremely long drawn as was made evident during the drafting of the Kyoto Protocol. Negotiation fatigue often results in simply doling out the targets to the various Parties, without a clear mandate on the way forward. While the developed countries are usually better equipped to pioneer technologies and behavioral changes, the developing world lags behind as it struggles with generating opportunities for higher economic growth and meeting the basic needs of its people. More than often, meeting environmental objectives are treated as liabilities synonymous with retarded economic development. There is a lack of clear understanding of how macroeconomic elements underlying the economic agenda can be used to serve a dual, economic-environmental objective

Using this as a starting point, the next chapter provides an empirical analysis of the major macro drivers of environmental impact, to determine a plausible starting point for translating international environmental objectives into national goals.

CHAPTER 4: IDENTIFYING THE DRIVERS FOR CLIMATE CHANGE

A time series approach using the STIRPAT model

4.1 Introduction

"Despite the scientific consensus that humans have drastically altered the environment, we have a limited knowledge of the specific forces driving those impacts"

York *et al.*(2003)

Previous attempts to examine the impact of population, affluence and technology on emissions or environmental impact have until now, mostly categorized countries into 3-4 broad income categories and the simplistic assumption of homogenous impacts within each group is made. Fixed effects panel data methods are employed to estimate the corresponding slope coefficients for the predictors. However as discussed in Section 2.6, the dynamics of today's global economy implies that even among countries at similar levels of income, identical drivers of environmental impact might differ in their relative influence on the natural environment due to differences in the socio-economic-political environment within which these operate. The empirical analysis conducted in this Chapter seeks to assess the extent of this variation among similar predictors of environmental impact. Results of such an assessment provide a useful starting point for addressing the increasing need for examining the experience of individual countries in order to design policy frameworks particular to their unique circumstances and resource endowments.

Specifically, the analysis looks at the varying impact of population, affluence and technology on environment in a sample of developing countries. Time-series data is used within the framework of the STIRPAT model (Dietz and Rosa; 1994, 1997) to examine the same. The origin, refinements and the current stochastic form of the STIRPAT model have already been introduced in Chapter Two. Previous studies using this model have analyzed the relationship that exists between environmental impacts and explanatory variables such as population, affluence and technology. (Shi, 2001; Fan *et al*, 2006; Dietz and Rosa, 1997).

This chapter is organized as follows: Section 4.2 presents the analytical approach to the STIRPAT model and the construction of the variables. Section 4.3 describes the sample and offers a descriptive analysis of the variables. Empirical findings and discussions are presented in Section 4.4

4.2 The STIRPAT Model: An Analytical Approach

Reiterating the functional form of the STIRPAT model:

$$I_t = aP_{it}^b A_{it}^c T_{it}^d e_{ti} \qquad \textit{(.....}\textbf{\textit{4.1}}\textit{)}$$

After taking logarithms, the model takes the following form for time-series data:

$$\ln I_{it} = a + b(\ln P_{it}) + c(\ln A_{it}) + d\ln(T_{it}) + e_{it} \qquad \textit{(.....}\textbf{\textit{4.2}}\textit{)}$$

The unit of analysis is the country. Subscript *i* denotes the country, *t* denotes the year and *e* is the error term. Since both dependant variable and predictors are in logarithmic form, the coefficients can be interpreted as changes in percentage terms.[18] Over the years, the meaning of both *P* and *A* have remained largely unchanged. Affluence is typically operationalized as GDP per capita. For assessing the effects of economic growth on environment, this standard and relatively well-measured variable is considered appropriate (Dietz and Rosa, 1994). In contrast to this, there is no one single defined proxy of *T*. Shi (2003) uses two economic variables namely manufacturing output as a percentage of GDP and services output as a percentage of GDP as a measure of technology. Till date, limited applications of this renovated identity have been made. This can be attributed to the lack of data availability and marginal quality of the ones available.

While cross sectional and panel data studies have been undertaken for comparative analysis in economics and sociology, this topic still remains to be thoroughly and empirically addressed. First, in addition to the arguments laid down in section 2.6, and as pointed out by Dietz and Rosa (1994), individual country time series analysis can be critically important in contextualizing the estimation of model where coefficients change over time and in addressing the heterogeneity bias arising from unmeasured country specific variables. Second, while technology has been discussed to have a significant influence on the environment and has been an integral part of the IPAT / STIRPAT formulations, there remains much ambiguity on a suitable proxy for the same.

[18] Empirical analysis conducted by Dietz and Rosa(1994) for assessing the best fit of the STIRPAT model shows that the coefficient of determination of a log-linear model is only slightly lower that the one in the log polynomial model. Hence it seems to be reasonable to use a log-linear specification.

4.3 Data Sets

A 33 year period is considered for the empirical analysis beginning 1970 to 2002. Affluence is measured by GDP per capita (constant 2000 US$). Two sets of variables are used as a measure of population. The first model is estimated using data for total population. The second model considers population aged 15-64 only.

As has been pointed out by some authors (Dietz and Rosa; Shi) use of total population might tend to oversimplify facts. The impact of population change on emissions might also be affected by patterns of consumption associated with the age-composition of population. Countries with a higher percentage of working age population (15-64) will consume more energy and resources hence producing more emissions. Having said that, estimating Model 1, will be useful to look at the varying impact exerted due to the difference in population sizes

Technology in this paper is measured by energy intensity that is energy used per constant 2000 PPP$ of GDP (kg of oil equivalent per constant 2000 PPP$). The higher is the energy intensity the lower is the efficiency of the economy and therefore higher CO_2 emissions. Another potential proxy for technology is carbon intensity (metric tons of CO_2 per thousand 2000 US$) However paucity of long-term data for the same restricts its usage. Following (Dietz and Rosa, 1997), environmental impact is measured by kilotons of CO_2

emissions[19]. Keeping in view its effect on atmospheric systems via its global warming potential carbon dioxide emissions is one of the most important drivers of radiative forcing. Therefore it is capable of serving as an appropriate indicator for environmental impact. In addition to that, availability of long-term credible on CO_2 emissions is another positive in its favor. [20]

The data used in this study are from the World Bank's World Development Indicators Online. Complete data sets are listed in Appendix D. For our model, the nature of the causation between all the predictors and CO_2 emissions is considered unidirectional and all predictors are considered to be strictly exogenous.

In order to assess potential variations in the influence of population, affluence and technology on CO_2 emissions within developing countries, the empirical analysis is undertaken for 6 developing countries in Asian region. Countries were selected using the following filtering criteria. To maintain focus on developing countries in Asia, the two regional economic co-operation blocs of SAARC and ASEAN were looked at. Only countries that qualified as low-income or lower middle income were considered[21]. A look at the past emissions record (1970-2002) for each country revealed great variations across the region. While

[19] Carbon dioxide emissions are those stemming from burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid and gas fuels and gas flaring.
[20] CO_2 emissions as an indicator of environmental impact has also been used in other studies such as those of York et al (2003), Rosa et al (2004).
[21] Following the classification provided by the World Bank

Bhutan accounted for only 4Kt of CO_2 in 1970, Pakistan was already over 20000 Kt. For our analysis, we further shortlist countries according to their CO_2 emissions burden and consider only those with emissions of at least 10,000Kt and above beginning 1970.

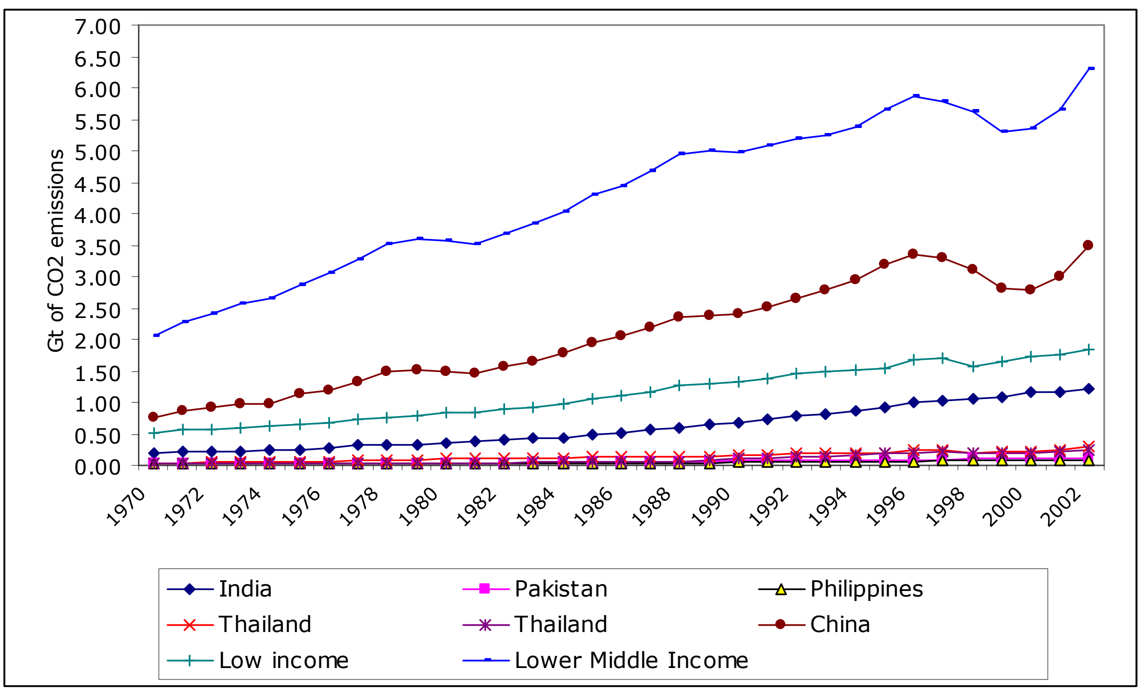
Such filtrations eventually narrow down the sample to India, Pakistan, Thailand, Philippines and Indonesia. China, a lower-middle income developing country, currently the world second largest emitter of GHG is also covered under the study. Considering China's current rate of growth of the manufacturing sector, exports and domestic demand, researchers have concluded that she is all set to overtake the US as the world largest emitter of GHG by 2010.

Table 4: Definition of variables used in the study: 1970-2002

Variable	Definition	Unit of Measurement
Carbon dioxide emissions	Carbon dioxide emissions are those stemming from burning of fossil fuels and the manufacture of cement.	Kilotons of carbon dioxide per year
GDP per capita	Gross domestic product divided by mid year population	USD per capita per year in constant 2000 prices
Population	Total population per year	Number
Population 15-64	Population in the working age group	Number
Energy Intensity	Energy used to produce 1$ of GDP (in terms of 2000 PPP$) calculated as kg of oil equivalent per constant 2000 PPP$	Kg/$

Fig 1 shows the annual statistics on CO_2 emissions for our sample of countries. For purposes of comparison, aggregate CO_2 emissions for low income and lower middle countries have also been included. India, classified as a low income country according to World Bank classifications, has consistently made up for almost 50% of all low income country emissions. Likewise, CO_2 emissions of China (a lower middle income country) have contributed to almost 50% of all lower middle income country emissions. China is currently the world's second largest emitter of GHG after the United States.

Fig 1: Comparison of CO_2 levels for the developing country income levels.



4.4 Regression Results, Analysis and Discussion

We treat CO_2 emissions as the dependant variable and set up the STIRPAT model, one for each country. Both the dependant and the independent variables are in log form. As discussed before, the analysis seeks to assess both the impacts of population size as well as patterns of consumption associated with age-composition of population.

The first model henceforth referred to as Model 1, regresses CO_2 emissions on total population, GDP per capita and energy intensity. Its functional form is as follows:

$$LnCo2ems_{it} = \phi + \beta_1 LnPop_{it} + \beta_2 LnGDPpc_{it} + \beta_3 LnEI_{it} + u_{it} \qquad (.....\mathbf{4.3})$$

where u_{it} is the error term.

Model 2 is tested with population in the age-group 15-64 otherwise referred to as working population. The regression is as follows

$$LnCo2ems_{it} = \delta + \eta_1 LnPop1564_{it} + \eta_2 LnGDPpc_{it} + \eta_3 LnEI_{it} + \lambda_{it} \qquad (.....\mathbf{4.4})$$

Following Shi (2003) and York *et al.* (2003), for simplicity sake, we assume that there exist no interdependencies between the variables on the right hand side in the equations above.[22] EViews 3.1 was used to estimate the regression results. A visual examination of the sample correlograms of the time series data confirms non-stationarity. Non-stationary time series invalidate the assumptions of standard

[22] From a theoretical point of view, we cannot expect this assumption to be always fulfilled. In particular, one cannot expect that GDP per capita is completely independent of population growth.

asymptotic theories. Equilibrium theories involving non-stationary variables require the existence of a combination of variables that are stationary. Further investigations using the Augmented Dickey Fuller Unit Root Test reveal that the unit root hypothesis is accepted for both the dependant and the independent variables in all the sample countries. In this case, the original undifferenced series is said to be integrated of order 1 or I(1). From Engle and Granger's original definition, cointegration refers to variables that are integrated of the same order[23]. The two-step Engle-Granger test for cointegration is employed to determine the existence of such a relationship. An ADF test on the residuals of the estimated cointegrating regression (Equation 4.3) leads to a rejection of the unit root hypothesis thus confirming the cointegrating relationship.

Cointegrating regressions imply that there exists a long term or equilibrium relationship between the variables although in the short run there may be disequilibrium. The error term in the cointegrating regression can be treated as the 'equilibrium error' and hence can be used to tie the short run behaviour of CO_2 emissions to its long run value. In other words, the error correction model (ECM), as it is popularly known, combines the long run cointegrating relationship with the short-run dynamics. We employ the ECM as proposed by Engle and Granger, to correct for this short run disequilibrium.

[23] An important point to keep in mind is that cointegrating regressions do not satisfy the assumptions of the classical linear regression model and the OLS estimator is said to be super-consistent.

The ECM formulation takes the following form for Model 1

$$\Delta LnCo2ems_{it} = \alpha_0 + \alpha_1 u_{t-1} + \alpha_2 \Delta LnPop_{it} + \alpha_3 \Delta LnGDPpc_{it} + \alpha_4 \Delta LnEI_{it} + \varepsilon_{it}$$

(…..4.5)

where Δ denotes the first difference operator, ε_t is a random error term and u_{t-1} is the one period lagged value of the error from the cointegrating regression in Equation 4.3. The absolute value of α_1, the adjustment co-efficient, shows how fast the dependant variable, ΔLnCo2ems, changes in response to the deviations from the equilibrium relationship made in the previous period.

Likewise, the ECM formulation for Model 2 takes the following form

$$\Delta LnCo2ems_{it} = \hat{\alpha}_0 + \hat{\alpha}_1 \lambda_{t-1} + \hat{\alpha}_2 LnPop1564_{it} + \hat{\alpha}_3 \Delta LnGDPpc_{it} + \hat{\alpha}_4 \Delta LnEI_{it} + \varepsilon_{it}$$

(…..4.6)

where $\hat{\alpha}_1$ is the adjustment co-efficient and λ_{t-1} is the one period lagged value from the cointegrating regression in Equation 4.4. Lagged values of the dependant variable, when tested within the model, proved to be insignificant and were therefore dropped.

Table 1 reports the results of the cointegration equations between CO_2 emissions, population, GDP per capita and energy intensity. Besides the estimated coefficients on the emissions, population, GDP per capita and energy intensity variables, the table also reports the Durbin-Watson (DW) statistic for the cointegration equations.

The coefficients for population, GDP per capita and energy intensity have the expected sign (positive), except for 1 or 2 exceptions. The signs of the speed of adjustment coefficients are in accordance with convergence towards long run equilibrium. Their values indicate fairly fast adjustment.

Table 1: Model 1 ECM Results

Coefficients	α	Ln Popn	Ln GDP pc	Ln EI	DW
India	-0.71 (4.11)	4.29** (2.15)	0.44* (1.52)	0.12 (0.38)	2.08
Pakistan	-0.67 (-4.70)	-2.5 (-1.19)	0.79** (2.20)	0.02 (0.07)	2.2
Philippines	-0.52 (-2.81)	1.27* (0.42)	1.50*** (5.92)	1.14*** (4.4)	1.89
Thailand	-0.85 (-3.8)	5.97*** (2.08)	1.33** (2.83)	0.52* (1.67)	1.6
Indonesia	-0.45 (-3.3)	1.25 (0.38)	1.55*** (4.35)	0.20 (0.60)	1.7
China	-0.26 (1.72)	-0.002* (-0.41)	1.59 *** (4.91)	1.46*** (4.97)	1.5

*Value in parentheses indicate t-statistics ***significant at 1%, ** at 5%, * at 10%*

Table 2: Model 2 ECM Results

Coefficients	**α**	**Ln Popn (1564)**	**Ln GDP pc**	**Ln EI**	**DW**
India	-0.60 *(3.44)*	2.21 *(0.87)*	0.46 *(1.45)*	0.21 *(0.61)*	1.98
Pakistan	-0.84 *(-5.28)*	2.72 *(1.47)*	0.87** *(2.45)*	-0.01 *(-0.07)*	2.07
Philippines	-0.52 *(-2.77)*	2.46 *(0.56)*	1.48*** *(5.79)*	1.14*** *(4.37)*	1.88
Thailand	-0.86 *(-4.18)*	6.37 *(1.46)*	1.20** *(2.50)*	0.52 *(1.64)*	1.5
Indonesia	-0.39 *(-2.99)*	-3.25 *(-0.65)*	1.75*** *(4.80)*	0.24 *(0.69)*	1.7
China	-0.43 *(-2.45)*	1.17 *(1.12)*	1.55*** *(5.98)*	1.47*** *(6.05)*	1.6

*Value in parentheses indicate t-statistics ***significant at 1%, ** at 5%, * at 10%*

Discussion

Through quantitative analysis of population, GDP per capita and energy intensity within developing countries, the study finds that:

Overall, population exerts a significant effect on CO_2 emissions. The population coefficient is positive and significant for all cases with 2 exceptions. Our results in Model 1, corroborate with those of Shi(2003) and the Malthusian approach that claims that environmental degradation takes place because of the pressure that population puts on the resources (Malthus, 1967). Furthermore, they also support Shi's general findings that that population is not proportionally associated with

CO_2 emissions. However our results contradict Shi's results concerning the fact that the elasticity of emissions with respect to population is nearly 2 for the developing countries. Infact, results of Model 1 indicate that among developing countries, the impact of population varies significantly and the emission elasticity with respect to population is much in excess of 2 for some cases. The case of India and Thailand evidence the same.

In the case of Thailand, a closer look at the demographics and the household structure could explain for this high impact:

1. The nuclear family setup is more prevalent than the traditional extended family arrangement. While population grew at 1.1% during 1990-2000, households grew at 2.4%. (*the average size of the household dropped from 5.7 to 3.0 during 1970-2000)*[24]. Large families tend to synergize their energy use which is lost in smaller nuclear families.
2. With rapid increase in GDP pc, Thai households are spending more on commercial energy. Electric power consumption growth has been close to 200% during 1980-2000 and close to 125% during 1990-2000

The demographics and its structure, in India, offers a different explanation from that of Thailand. There are 2 main areas via which increasing population is exerting an increasing impact

1. *High population growth rate (2%) and an associated increased demand for energy and electricity*: Share of coal in electricity production has

[24] This trend appeared in the Population and Housing census of Thailand (2000)

increased from 50% during the early 70's to almost 75% in the late 90's i.e from 60 bn KWh to 410 bn KWh. Since coal remains the main resource for energy generation, households indirectly are consuming the same.

2. *Unplanned Urbanization - Transportation fuels and Rural Urban Migration:* While total population grew at a little over 2% from the 70's to late 90's, urban population grew at more than 3.5% during the 70's & 80's and then at hovered around 2.5% since the mid 90's. In contrast, rural population grew at less than 2% pa during the three decades. Urbanization when conducted in a planned manner brings with it both greater accessibility to modern fuels and higher household income levels. However in the case of India, research studies have conclusively proved that rates of rural-urban migration have greatly exceeded rates of urban job creation compounding the problem of urban poverty & urban squalor. An outcome of this has been inappropriate waste disposal and treatment leading to higher level of GHG emissions.

With respect to population aged 15-64, results from Model 2 indicate that coefficients are insignificant in most cases. This need not imply emission levels in these countries are not affected by patterns of consumption associated with the age-composition of population. A more detailed break up such percentage of population aged 15-64 staying in urban/rural areas and income levels for population aged 15-64 could provide a better estimate. Unlike developed countries, intensive rural-urban migration in the developing countries plays an important role in determining the demographic influence on the environment. Model 2 was then further estimated by replacing population (15-64) with percentage of urban population however coefficients for the latter did not reveal any significant information. For the remaining discussion we confine our comments to results obtained from Model 1.

The affluence effect is likewise, significant for all countries but the emission intensity of affluence varies significantly among the group. For lower income economies of India and Pakistan, the emission elasticity with respect to GDP is less than one, while for the lower middle income economies of China, Thailand, Philippines and Indonesia, the emission elasticity with respect to affluence is greater than one. We look at the structure of the economies to get a better insight into this varying impact.

In the case of India and Pakistan, the share of the agricultural sector in the GDP has been constantly falling during 1970-2000. While for India it declined from 46% to 23%, for Pakistan it was 37% to 30%. At the same time, the share of industry has also showed a decline in the case of India and has hovered at the same level of percentage contribution for Pakistan. On the other hand, the service sector has grown to be the biggest contributor to the GDP. While in India its share move up from 33% to 50% between 1970-2000, for Pakistan it grew from 41% to 51% during the same period.

On the other hand, in the case of China, Thailand and Indonesia, the largest contribution to the GDP has come from the industrial sector. Table 3 outlines the same.

Table 3: Percentage contribution to GDP by the Industrial sector

	1970	**1985**	**2000**
China	38	40	46
Thailand	41	49	51
Indonesia	19	36	46

Technology measured by energy intensity, does not prove to be a significant driver for the chosen sample of developing countries. The model was also tested by using ‘percentage contribution to the GDP by the manufacturing and service sector’ as a proxy for technology. The coefficient of technology still remained insignificant.

To conclude, our results illustrate that population and affluence are key determinants of national environmental impacts and that their relative influence varies across the the chosen sample of countries. Contrary to what has been concluded by most previous studies, our results show that the emission elasticity with respect to population is significantly different from unity, even within the group of developing countries. Serious efforts to achieve sustainability must focus on the key drivers of impacts: population and affluence.

CHAPTER 5: CONCLUSION

5.1 Concluding Remarks

The first part of the analysis (*Chapter 3*) presents the proposed 'adjusted' per-capita emissions approach that has the potential to play an important role in the climate change debate as it focuses on the heart of the problem by incorporating critical desirable features such as GHG stabilization and thresholds for temperature change. The solution, while being comprehensive in its coverage and inclusive of developing countries, does not impose drastic emission cuts in the immediate future. It allows for a sufficient adjustment period during which some developing countries are infact allowed an emission quota greater than the emissions projects of a BAU scenario, thus creating opportunities for revenue generation from the excess 'hot air'. Finally, it reduces negotiations are reduced to two manageable variables i.e **1)** deciding the effective percentage reduction for developed states and **2)** calculating the optimal year of convergence such the GHG stabilization target and 2°C threshold levels are successfully met.

The latter part of the study (*Chapter 4*) conducts a time-series analysis on the determinants of environmental impacts, measured by carbon dioxide emissions, during the period 1970-2002 for a sample of six developing countries in the Asian region. Our assessment is informed by the well known stochastic reformulation of the IPAT identity, known as the STIRPAT model. In this model, population, affluence as measured by GDP per capita and technology as measured by energy intensity are used as the predictors. Recognizing that a) using total population data oversimplifies its impacts and b) it is the working population that exerts maximum influence in determining consumption patterns, the model is also tested with population aged (15-64) as a predictor.

Our results suggest that population and affluence are key determinants of national environmental impacts across the chosen sample of countries. Additionally, contrary to what most studies conclude, there is significant variation across the emission elasticity of population and emission elasticity of affluence, within the group of developing countries.

Serious efforts to achieve sustainability must focus on individual countries' key drivers of impacts as well as their relative importance in driving environmental impact.

5.2 Extending the Study Further

The analysis makes some simplistic assumptions that need to be treated and interpreted with caution. To begin with, the study assumes that there is no interdependence between the predictors of the model. However theoretically this might not be always true. Evidence of interdependencies between the predictors especially between population growth and development of per capita income could be accounted for by using an elaborate simultaneous equations model. Further research with more data containing new exogenous variables would contribute to providing more robust results.

Lacking consistent definitions, widely available measures and time series data for a sufficiently long period, our analysis does not estimate the effects of cross-national variation in institutions, culture, political economy or other factors that are plausible mediators of the effects of population and affluence.

The study uses energy intensity as a proxy for technology. However variations in the level of penetration or the levels of use of technology might not be adequately reflected in such a measure. Identification of other appropriate proxies for technology could help in arriving at more robust results.

There is not much time-series data available on the use of non commercial forms of bio-energy that are an important part of the rural structure in the chosen sample of developing countries. Agriculture and livestock farming are an equally important source of GHG emission. In addition to that, land use changes and forestry have also been important sources of CO_2 emissions for countries like Indonesia. However there exists no proxies to account for these and no time series data to capture these elements in an analysis such as the one undertaken in this study.

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