Macroeconomy and Environment: A Panel Data Analysis

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CERTIFICATE

This is to certify that the dissertation entitled **MACROECONOMY AND ENVIRONMENT: A PANEL DATA ANALYSIS** submitted by me in partial fulfillment of the requirements for the award of **MASTER OF PHILOSOPHY** has not been previously submitted for any other degree of this or any other university.

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We recommend that this dissertation be placed before the examiners for evaluation.

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To

Ma, Baba and Didi

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The responsibility of any error and omissions, however, is entirely mine.

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Chapter 1

1. Introduction

Conflict and contradiction are two inseparable outcomes in the process of the development of human knowledge and in its sophistication. The manifestation of this phenomenon is vivid whenever the concern is over an economic issue where various nations across the globe face mutually conflicting economic interests with the prime objective of maximizing their own welfare. The debate regarding international trade, openness and environment is not an exception to that. Long back economists have recognized the fact that any successful and sustainable development strategy has to strike a balance between the interests of international trade and the concern for global environment. However, these sometimes-conflicting imperatives have been, and remain a potential source of conflict in the international political economy.

Both economists and environmentalists are concerned over the matter and debate regarding international trade, openness and environment, i.e., they are broadly concerned with the cause and effect relationship between the environment and international macroeconomy. Economists take interest in investigating how environmental rules and regulations impinge on the pattern of international division of labour and capital and also the quantum and distribution of the gains, if any, accruing from such division. On the contrary the environmentalists are focusing on the way the environment; both at local and global level, are getting affected by the massive expansion of international trade, which has resulted from a significant increase in 'openness' of various nations worldwide. So one can obviously generate an impression that the relationship shared by international trade and environment can be viewed as a two-way one, i.e., one impacts and in turn gets influenced by the other. Looking at the positive, economists and environmentalists share a common perspective. Both groups believe in the system of interdependent relations between international trade and environment and both are concerned about the efficient use of scarce resources. Each of the groups cares just as much as the other about the planet's future and the quality of life, but the free traders disagree with the environmentalists about the means. The environmentalists tend to favour restrictions on trade in order to curb resource depletion, protect higher environmental standard, and eliminate environmentally lax production methods. The free traders, on the other hand, argue that trade restrictions are legitimate if trade is found to be the direct cause of environmental damage, or if restrictions is the last resort to enforce an international agreement concerning transnational pollution.

Starting with Adam Smith (1776) and David Ricardo (1817), various economists have described free international trade as an engine of growth and wealth and also as a source of welfare gains. According to them the voluntary exchange of commodities induces favourable patterns of specialization and therefore leads to an improvement in the international division of labour. With the inception of free trade, each country is driven to utilize its comparative advantage (to some feasible extent) and to produce what it can most efficiently. Thus global output increases and each country experiences some gains from trade. However, the environmentalists do not subscribe to this opinion. They cite several arguments against free trade. Firstly, the models postulated by the free trade economists make several assumptions that are practically invalid. Secondly, they opine that due to international trade some countries (mainly developing) may specialize in the production of pollution intensive goods thereby causing environmental disruptions. These countries may experience welfare losses and in case of transboundary pollution other adjacent countries too may be worse-off with free trade than without it. Thirdly going by the logic of mainstream economic theory, if international trade raises the global output and consumption, it will fetch associated waste-management problem. The fourth concern relates to the trade in hazardous waste. Waste importers are likely to be less well prepared than the exporters to store or process hazardous substances. Moreover, it is often argued that the possibility to export problems reduces the incentives to solve them, i.e., to employ sound environmental policies that reduce the quantity of toxic waste created. The fifth argument deals with the aspect of 'transportation'. Environmentalists opine that there is a cumulative chain of causation in the sense that trade requires transport, transport requires energy and energy utilization damages the environment. Sixthly, environmentalists focus their attention on the impact of free trade on the third world countries. It is argued that the dependence of these countries on imports will increase with the incessant persuasion of free trade policy, be it due to the behaviour of multinational corporations, or due to declining terms of trade. This would prevent them from adopting sound environmental policy measures. Therefore, according to the environmentalists the policy of 'opening up' as an instrument of growth might actually harm the environment in a developing country thereby dampening the prospects of sustainable development as deterioration in environmental standard is incompatible with the phenomenon of sustainable development. With these contrasting arguments, economists and environmentalists have given birth to the debate regarding 'openness, development and environment' vis-à-vis the developing nations.

The issue raged an international debate in recent days. This is mainly because of two reasons. The first reason emerges from the swift structural changes that are taking place in the world economy over the last two-decades. Since the world economy is changing its shape, environmentalists can argue, that is affecting the pattern and quality of environment. And there lies their objection. The second reason is an overwhelming upsurge in the public awareness of actual and potential threats to the natural environment over the last few years. Concerns about deteriorating ambient quality and natural resource depletion have raised the specter of 'irreversibility'- the apparition that irreparable damage is being done to the planet through the exhaustion of finite natural resources, the contraction of biodiversity and the cumulative destruction of air, land and water resources. A revelation of this concern is the severe pressure felt by the governments, particularly in the developed industrial nations, to design policies to address environmental degradation. If we assume that environmental quality is a 'normal good' (like in most theoretical models on this topic), i.e., environmental consciousness amongst the public grows with an increment in their income then the second reason can easily be explained. With the increment in income people have started getting more and more alarmed about the local and global environment.

Since the last decade of the last century, the global economy is gradually culminating towards a very liberalized regime of 'openness' through the phenomena of international trade and international finance. Many countries, with the examples of Australia and New Zealand in their mind, are trying to achieve the path of development through a sustained increase in openness that, they believe, will result in an export led growth. The process of liberalization has initiated in the East European nations through the indulgence in trade relations with the other part of the world. This can be attributed to the collapse of Soviet Union. In the sphere of underdeveloped and the third world countries too, a major structural shift in the economic policies, particularly in trade policies, is taking place over the last two decades or so. These underdeveloped economies were traditionally inward looking and they believed in the persuasion of import substitution policies with an enormous state control in the production process. As a part of liberalization policy and also as a part of reform, these economies are gradually opening their markets to the outer world and also pursuing export promotion policies driven by market forces. So the global economic scenario is steadily changing. It can be anticipated that in the coming days most of the economies are going to rally under one global economic order and hence there will be a massive and significant rise in the volume of international trade through an increased 'openness' worldwide. These changes, which seem to be long lasting, have brought the relation between openness, development and environment in the forefront. From this standpoint, the need to study the implication of the impact of new liberalized regime of openness on local and global environment, is increasingly gaining more and more importance.

It might seem that openness and environment, and environmental issues more generally, have attracted widespread attention only recently. But by and large this is illusory because of the fact that a similar debate raged some almost twenty five-thirty years ago, only to die down in the late 1970s. Many reasons can be put forward as to why these issues came and went, only to come back again more strongly. However, the important aspect for the present purpose is that much of the current agenda was debated and analyzed in earlier years. Many of the insights gained through remain relevant today. The recent resuscitation of the concern for local and global environmental quality has generated many queries relating to the impact and span of environmental regulations on the international trade patterns and the gains from trade. From the developing country's perspectives two hypotheses that have been put forward in the literature need immense care and attention. These are:

A) Industrial Flight Hypothesis

This states that since the developing and underdeveloped countries have a relatively weaker environmental norms and regulations and a relatively low environmental standards compared to the developed industrial countries, because of increased openness 'dirty industries' will shift their operations from the outer world to these underdeveloped countries. As a result there can be a 'flight' of dirty industries from the developed to the underdeveloped nations. Hence openness may act as an instrument for environmental deterioration.

B) Pollution Haven Hypothesis

This states that in addition, the lowly developed countries may deliberately undervalue their environment in order to attract new foreign investment, which will gradually culminate to turn the underdeveloped countries as pollution havens. Some economists have even went ahead to argue that this could lead to an unhealthy competition amongst the developing nations as they might continue to lower their environmental standards to attract more and more foreign investments. This, according to them, might result in what is called "race to the bottom policy" vis-à-vis the environmental norms and regulations.

Both phenomena (industrial flight and pollution havens) could lead to excessive pollution in LDCs. Not too many empirical researches have been carried out on this aspect. So there is a vast opportunity of investigation regarding whether increased openness is accompanied by a sharp decline in environmental standard in developing nations or whether openness actually widens the gap between the environmental standards of developed and developing nations. What is the relevant policy prescription in this regard? According to some economists it can only be opined that if there is a trade-off between openness or international trade and state of the environmental quality, some interventions might seem to be appropriate to maintain a decent environmental standard.

Having discussed the relation between openness and environment, let us turn our attention to the relation between macroeconomy, environment and the concept of sustainable development. According to Barbier (1994) environment is an 'asset', or form of 'natural capital' that must be managed to 'sustain' economic development. One of the most important decisions that an economy needs to take is what amount of economic rent can be extracted through exploitation of stocks of this 'natural capital' and reinvesting in other reproducible economic assets and human resources, in order to meet both current and future economic opportunities. For an underdeveloped country this decision is of paramount importance because of the following fact. The set of most important problems for an underdeveloped nation is poverty eradication, income and employment generation. Maintenance of a decent environmental does not figure in that set, as that cannot be the topmost priority for an underdeveloped nation. On the other hand, for an underdeveloped economy to achieve a sustainable growth path, a balance between economic activities and environment has to be maintained. So environmental policy, as it stands, is a policy in between.

Inherent to the concept of sustainable development is the notion that the earth's 'environmental capital', comprising all the stocks of renewable and non-renewable environmental resources that provide us utilities in the form of goods and services, is scarce. This scarcity of 'environmental capital' has given birth to two main issues. These are the establishments of the sustainable stocks of the various components of environmental capital and the attribution of property and user rights of these components to countries and economic agents. For the prevalence of economic efficiency, both issues need to be resolved. A strictly scientific determination of the sustainable quantum of environmental capital is nearly impossible; given the uncertainty that surrounds the ecological-economic interactions, the scope of substitution possibilities between environmental capital, man-made capital, human capital, social capital and the phenomenon of economic growth and capacity-enlarging technological improvements. But what is possible is the realization that environmental management is absolutely essential for sustainable development and the effect of different stages of development on environment are different and is subject to change with the passing of time. This realization does not have any reference to time; it is valid since the ancient age of civilization.

Economic prosperity and changes in the environment are inseparable across all corners of the globe and it dates back to the historic age. The invention of agriculture and the subsequent improvement in the related techniques have not only drastically altered the pattern and distribution of land and labour use in the production processes but also generated some surplus labour to engage them in various other non-farm activities. Since the inception of industrial revolution, a series of innovations took place. The endless stream of product and processes that were created through those innovations stimulated the exploitation of more and more natural resources, thereby satisfying ever expanding new wants but also creating unknown pollution problems. With the passing of time the dearth of vital fuels and other natural resources made the society aware of the fact that the economy depends on ecology and environmental services provided by the environment.

Of late, many growth theories have tried to highlight the role of environment. Malthus's dismal predictions for economic development were based on one-sided attention to natural resource constraints. But on the other extreme, the standard neoclassical growth model stresses the roles of capital and labour, ignoring natural resources and confining knowledge creation to exogenous technical progress. It was in the 1970s that exhaustible natural resources and pollution have started to get some considerations into neoclassical growth models. However, long-run economic growth was independent of the state of environment, they were still either absent in these models, or driven by exogenous factors such as technical progress and growth of population. But the scenario changed since the 1990. From the early 1990s onwards, the 'endogenous growth theory' emerged in the literature. Models on general equilibrium growth were developed. These models incorporated environmental variables and allowed the aggregate economic growth rate to be determined endogenously. The models try to formalize and link two main ideas that are already present in earlier literature. First, knowledge creation is the ultimate source of growth in a physically bounded environment, as stressed by, for example, Simon (1981). Second, growth can be sustained only if the economy maintains constant rates of energy and material throughput, as in Daly's (1973) 'steady state economy'.

Economic growth and physical conditions of the environment interact with each other. Economic activities may result into environmental problems but on the contrary the deterioration in the physical conditions of the environment could also hinder economic prosperity. To highlight and understand these interactions between ecology and economy, there is a need to build up models connecting these two. In general the models that capture the interaction between economic growth and environment relate the following building blocks: a) the technology block, b) the preference block, (form together the economic sphere in which productions and allocations take place and are determined) and c) the ecology block (reflects how environmental variables evolve). In particular, the elementary model structure can be represented by a production function, a utility function and a natural resource growth function.

The environment–economy links (the connections amongst the model blocks) are manifold. First, the environment is one of the major sources of resources for the economy. Second, the environment is a sink for wastes. Third, the environment may enter as an argument in the utility function, because environmental quality is in general a normal or sometimes even a luxury good so that it has an amenity value. Fourth, the environment exhibits a productive capacity as well, and hence it enters the production function. Finally, part of economic activity may be directly devoted to cleaning up spoilt parts of the environment, that is abatement and recycling may take place.

The simplest model can be written in terms of the following three equations

$$\dot{N} = E(N) - R \qquad \text{(natural resource growth function)}$$

$$\dot{H} = Y(N,R,H) - C \qquad \text{(knowledge production function)}$$

$$W = \int_0^{\infty} U(C,N)e^{-\theta t}\,dt \qquad \text{(intertemporal utility function)}$$

Where N is an indicator of environmental quality, R is the use of services from the environment in production, Y is the aggregate economic activity (production), H is the stock of (man-made) knowledge, and C is the consumption of man-made goods, U( ) is instantaneous utility, and θ is time preference; all variables depend on time index t.

The model in the above three equations can be considered as a representative of many of the environmental-endogenous growth models, and serve as an illustration of the basic mechanisms at work. The models found in the literature are typically much more detailed.

Having discussed some of the aspects of the environment-macroeconomy relation, we now take a look at the state of affairs prevailing in the underdeveloped countries with respect to that relation because it is the underdeveloped countries that need to make a policy choice subject to the trade-off between growth and environment. The underdeveloped nations, in general, depend on their natural resource base to a significant extent. The available physical indicators suggest that the natural asset base of the poor, underdeveloped resource-dependant economies are being rapidly run down. But what is very surprising to see is that these economies remain in a fundamental state of 'underdevelopment' and in many cases fail to generate sufficient long-term sustainable economic growth necessary for the 'take-off'. This implies that development in many poor economies remains essentially 'unsustainable' owing to the fact that the net depreciation of their natural asset base (and increase in population) is not being compensated by investment in renewable human, physical and natural capital. Clearly, then, a major factor affecting the long-term development prospects of poor economies is their helplessness to place a higher priority on policies for efficient and sustainable management of the natural resource base to maintain the 'capital' required for the transition to and achievement of long-term sustainable economic development goals.

There is also evidence that in many underdeveloped economies depletion and degradation of natural resources such as croplands, forests etc may be responsible factors that destabilize the institutional and economic conditions necessary for innovation and sustainable development. It is really puzzling to see that despite the relative abundance of natural resource endowments in many underdeveloped countries, incidences of resource scarcity and conflicts over resource use and allocations can be sufficiently severe to cause widespread social unrest, friction and even violent conflict. The result is continual disruption of the stable institutional and policy environment necessary for these countries to generate sufficient human capital, sophisticate research & development, utilize existing technological knowledge available domestically and internationally and produce and disseminate new technologies throughout the economy. To overcome these problems a poor and underdeveloped country needs proper domestic policies supplemented by international cooperation. The relevance of international cooperation emerges from the fact that degradation of environment not only impacts the local geographical area but the phenomenon has a global dimension as well.

When an underdeveloped agro based economy starts developing through a gradual shift of emphasis from agriculture to industries, machines and other types of capital-intensive factors of production start getting more and more importance in the overall production process. This transformation generally raises the level of pollution in that country because of the higher pollution-intensity of machines and other types of capital-intensive factors of production. Now is that rise in the level of pollution everlasting? Can the situation be reserved in course of the successive phases of development? Can international cooperation act as a panacea for this environmental degradation from the global sense? Should the underdeveloped nation go for more openness? These questions are of paramount importance and needs to be taken care of by any study that deals with economy-ecology relationship. The next few chapters try to answer to this questions. The next chapter briefly surveys the relevant literature. The third chapter deals with the dynamics of the relation between per capita income and environmental quality (EKC, to be very specific) during the successive stages of development of an LDC and the policy implication of such relation. Since there is a need to formulate a representative figure that can capture the overall environmental standard of a nation, in the fourth chapter we try to construct an overall index of environmental quality (totally depending upon the availability of data) and then see the impact of income, openness, urbanization, indebtedness etc on that indicator. Hence this chapter tries to outline the dynamics of overall environmental quality with respect to general macroeconomic activity. Once this is done, the policy implications become imperative. Next comes the question of sustainability of the developmental process that can ensure a perpetually decent environmental standard. Hence, the fifth chapter concludes the discussion on the relation between macroeconomy and environment from the point of view of sustainable development.

Chapter 2

2. Literature Survey

On realizing the fact that macroeconomy, economic growth and environmental quality are intrinsically related; one can feel interest in analyzing the extent and span of such relation. Many questions, in this connection, can deserve special attention of the researchers. Is incessant economic prosperity of the globe going to fetch ever-greater harm to the environment? Or, on the contrary, can economic growth serve as a panacea for the problem of environmental degradation on its own? If it is not, what should be design of policies to tackle the obstacle? Various studies have to address these questions. In this chapter we try to describe a few of them.

Environment affects human lifestyle through various dimensions. Our lives are affected by the quality of air we breathe, the quality of water we drink, the beauties and bounties of nature, and the vast diversity of species with which we come into contact. In the sphere of economic activities too, the capacity of the resources at our disposal to produce goods and services are linked to climate, rainfall, forest, mineral and the fertility of the soil. The condition of our health is directly linked with the surrounding environment. We feel displeasure from excessive noise and crowding and also from the danger of nuclear catastrophe. So to maintain a decent and sophisticated standard of living one should care and protect the environment from any aberration beyond the tolerance level. All of these environmental aspects are affected by economic growth at local, national or at global level in some or other ways. To formulate and evaluate a 'sustainable development' strategy our attention should focus on the linkage between growth and environment in as comprehensive manner as possible.

Many endogenous growth models have taken care of the exhaustible and renewable natural resources by describing them as arguments in the production function of various goods and services. So if all other things remain the same, i.e., the structure of output vector and the technique of production remain invariant over time, then any change or damage to those exhaustible and renewable natural resources are obviously going to affect the quantum of economic activities throughout the world by affecting the process of production. Similarly, biodiversity; although difficult to quantify, plays an important tacit role in the production process. This is precisely the reason why protection and conservation of forest, river and other exhaustible natural resources are of paramount importance. Any unscientific tinkering with these 'natural capital' can hamper the production process thereby dampening the prospects of future growth and sustainability of an economy. Economic development and international trade, through a significant change in the usage of inputs of production including 'natural capital', can result into an alteration in the structure and pattern of the output vector that an economy produces. Since technology is tradable, any import or export of new technology is very likely to modify the input vector by, say, permitting capital deepening or through the generation of labour augmenting; natural resource saving production methods. And many economies; especially the developed economies have shown a remarkable creativity in harnessing new technologies to conserve natural resources. In general, this kind of change in economic activity may result into an improvement or degradation in the quality of environment, which needs to be thoroughly assessed.

In order to do so, let us enter into a very specific arena regarding the growth versus environment debate, which is known as "Environmental Kuznets Curve (EKC)" in the literature. This debate has gained importance in the 1990s. According to EKC some pollutants follow an inverse-U-shaped relation with respect to the relevant country's per capita income. This, in common parlance means that when a country is in the initial stage of development, pollution will increase with the increase in per capita income. Then pollution will reach a zenith when the country in question will attain a certain level of per capita income. Since then with further increment in per capita income, pollution will decline. Environmental quality is the analog of pollution. Hence going by the logic of EKC, environmental quality deteriorates during the early phase of development of a country and after reaching a certain feasible limit starts improving with further development. Now this phenomenon has a striking similarity to the 'bell-shaped" time-series pattern of income inequality described by Simon Kuznets (1955). Thus the environmental aspect of this time-series pattern came to be known as "Environmental Kuznets Curve".

Economic development is a slow but incessant process. However, development is realized in different stages through which a country or an economy has to pass. Now if the EKC hypothesis remains valid throughout the stages of development, growth in per capita income will create stress on the environment at the beginning but eventually the same growth in per capita income will serve as a panacea to environmental deterioration. So the culmination of development will result in improving environmental standard. Thus, some economists argue that environmental degradation can be looked upon as a spontaneous outcome in the path of development, which will automatically get reversed after an LDC reaches a certain level of per capita income. This view has raised a few very pertinent queries. Since, according to them, economic growth is ameliorative for the environment, can an LDC afford to relax? Or, should it intervene with a proper set of policies to maintain a decent environmental standard juxtaposed with the persuasion of policies to initiate economic growth? Does that set of policies exist in reality? Or, if the LDC decides to sacrifice environment at the cost of growth to a certain extent, what amount of deterioration in environment can it allow and for what amount of growth? Since many nations across the globe (like India, China) are passing through the initial stage of development and are very likely to pollute environment due to rapid industrialization, what will be the policy design to address global environmental problems, such as, 'global warming'?

The answers to all these questions could partly be searched through investigation regarding the existence of EKC, at least for some pollutants that harm the environment. In doing so, these days; some economists have started to describe the inverted U-shaped relationship between income and environmental pressure as "stylized fact", a generally applicable notion revealing that environmental pressure decreases after a particular level of income has been reached (cf. World Bank, 1992; Beckerman, 1992). Hence in a sense these economists are referring to a very smooth relation between environment and development. But to describe the existence of EKC as a stylized fact, sound and convincing empirical findings asserted by logical explanations is desirable.

This chapter deals with the literature survey in the following way. First, we shall try to describe the background of the literature on EKC. Second, we shall mention about some famous studies that have been carried out by some leading economists on the regularities in the relation between environmental pressure and income. This will capture some noted studies on EKC.

After the literature survey on EKC we shall turn our attention to the aspect of international trade and environment. Here also we shall try to describe some of the empirical and theoretical studies that have been carried out by various economists highlighting different aspect of the trade and environment debate. Thus we shall have a glimpse of the existing literature on economy and environment from both macroeconomic and international viewpoints.

1) Environmental Kuznets Curve

A. *Background*

Production depends on its inputs like raw materials, natural resources, and energy etc. Hence consumption or the uses of these inputs use to determine the volume of production and growth of an economy. Thus growth and consumption of these inputs become related to each other. Now, till 1960s, it was believed that the consumption of these inputs grows at the same rate as economic growth. This belief resulted in the assertion that there was a "Limits to Growth" (Meadows et al, 1972) as the natural resources were exhaustible. This conjecture was challenged by Malenbaum (1978). He found that for some developed economies, the ratio of consumption of certain metals to income was diminishing in 1970s. Malenbaum's findings were in contrast with "Limits to Growth". He went on to derive an inverted U-shaped relation between the intensity of metal use and income. He concluded that intensity of metal use has a tendency to diminish after an economy attains a particular level of income. Several other economists found the same phenomenon for the period after 1973. With the availability of data on some environmental indicators during the 1990s, economists started taking interest in examining whether or not the U-shaped curve hypothesis proposed by Malenbaum held good for the relation between some pollutants and income. Grossman and Krueger (1991) were the first group of economists to find such a relation. Their study was followed by several other similar studies. Grossman and Krueger again worked on the same topic in 1995 and have emerged with the same outcome. Panayotou (1993) gave the nomenclature of the observed U-shaped relation as "Environmental Kuznets Curve (EKC)". Let us explain EKC in terms of the following diagram (figure 1).

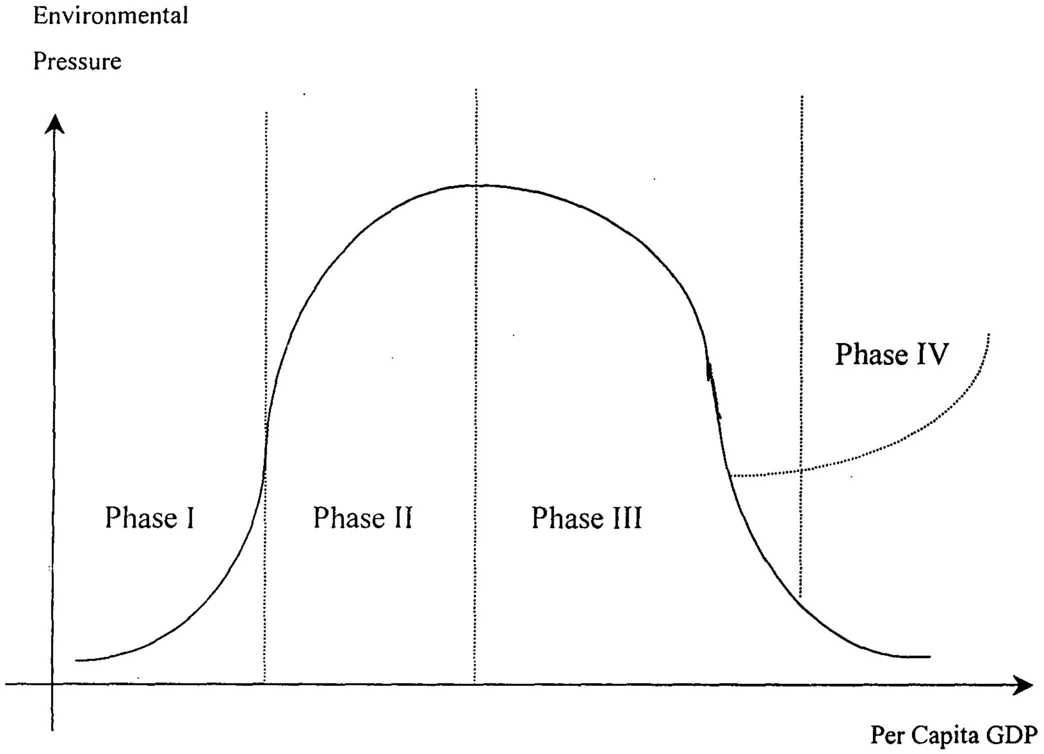

Figure 1: Relation between income growth and environmental pressure

As in figure 1, growth of per capita income, during the first phase of economic development, is accompanied by a faster growth of environmental pressure. The environmental stress keeps rising but its rate of rise falls short of the growth rate of per capita income during the subsequent periods. This stage of development is marked by phase I and phase II respectively in figure 1. Now comes the turning point. On reaching a particular level of per capita income, environmental pressure starts declining despite further growth in per capita income. This is called the 'de-linking' of environmental pressure from per capita income. This entire stage is captured by phase III. If this trend of de-linking is incessant, then there emerges a genuine EKC. But some economists like Opschoor (1997) have found a phase of "re-linking" of environmental pressure with per capita income, which is reflected by the dotted curve in phase IV. Now if phase IV prevails, instead of a U-shaped EKC, we get an N-shaped curve.

B. *Empirical Studies*

Before mentioning about some famous empirical studies on this topic, let us briefly explain the general model that has been used in those studies. To study the relation between environmental stress (pollution) and per capita GDP these models have taken the help of a reduced-form equation, which we shall discuss shortly. Instead of using this reduced-form approach, alternatively those studies could have taken the help of structural equations relating environmental regulations, technology, industrial composition to GDP, and then could have linked the level of pollution to the regulations, technology and industrial composition. But, there are certain advantages in the reduced-form approach over the other approaches. a) Reduced-form model reveals the direct effect of per capita GDP on pollution. If the structural equations were estimated, one would need to solve back to find the net effect of income changes on pollution, and confidence in the implied estimates would depend upon the precision and potential biases of the estimates at each step. b) If we use reduced-form model, then we don't need to collect data on pollution regulations and the other technological parameters (that re subject to change with successive phase of development), whose validity are not beyond any question and moreover these data sometimes do not exist at all (mostly in underdeveloped countries) or even if it exists, it might not be comparable across the cross sectional units of study. So it is better to work with reduced-form equations relating environmental pressure and per capita GDP and more so when there is a hypothesis relating these two in the form of EKC. This is the main reason why these studies have used the reduced-form model.

Now let us describe the reduced-form equation in detail.

Suppose ‘i’ denotes the cross-sectional units. Cross-sectional units may represent a local region, a city, a state, a country, or even a continent. Let ‘t’ denote the time variable. This time variable may be a day, or a month, or a year etc. since equation 1 does have both cross-sectional and time-series feature; it essentially represents a panel-data model.

$$S_{it} = \alpha + \beta_1 Y_{it} + \beta_2 Y^2_{it} + \beta_3 Y^3_{it} + \beta_4 Z_{it} + U_{it} \qquad (1)$$

In equation (1),

S_{it} = the value of environmental stress indicator (pollution) for ‘i^{th}’ cross-sectional unit at time period ‘t’.

The explanatory variables are ‘Y’s and Z.

β_k = the relative impact of k^{th} explanatory variable on S_{it}. $k = 1, 2, 3, 4$

Y_{it} = per capita GDP for the ‘i^{th}’ country at time period ‘t’.

Z_{it} = other variables that impact the quality of environment and can act as factors behind environmental deterioration. Researches significantly differ from each other vis-à-vis their consideration of Z_{it}. Different researchers have used different variables as a reflection of Z_{it}.

U_{it} = the error term for ‘i^{th}’ cross-sectional unit at time period ‘t’.

Now equation (1) can well represent an EKC depending upon the value of ßs. In fact the equation can generate the following shapes for the relevant curve.

1) If $\beta_1 > 0$ and $\beta_2 = \beta_3 = 0$, then equation (1) represents a monotonically increasing relation between per capita GDP and the environmental stress.

2) If $\beta_1 < 0$ and $\beta_2 = \beta_3 = 0$, then equation (1) represents a monotonically decreasing relation between per capita GDP and the environmental stress.

3) If $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 = 0$, then equations (1) shows a U-shaped quadratic relation between environmental stress and per capita GDP exactly opposite to the shape of EKC.

4) If $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 = 0$, then equations (1) reflects an inverted U-shaped EKC. This is the true shape of EKC reflecting a quadratic relation between pollution and per capita GDP.

5) If $\beta_1 > 0$, $\beta_2 < 0$ and $\beta_3 > 0$, then equations (1) represents a cubic polynomial having an 'N' shape. This implies a rising pollution level during the initial stages of development which is succeeded by a declining level of pollution in the next stage and finally according to our diagram, a re-linking of pollution to per capita GDP in phase IV.
6) If $\beta_1 < 0$, $\beta_2 > 0$ and $\beta_3 < 0$, then equation (1) reflects a cubic polynomial just opposite of 'N' shape.
7) If $\beta_1 = \beta_2 = \beta_3 = 0$, then equation (1) shows that environmental stress is invariant to per capita income and this generates a straight line parallel to the horizontal axis.

Amongst the above outcomes, only case 4 represents a true shape of EKC. However, case 5 partly reflects EKC with the 're-linking' phenomenon in the later phase of development. Various econometric studies have used equation (1) or log-linear transformation of that to test the validity of EKC. These studies have used different environmental indicators as well as different set of cross-sectional units and time periods. So it's obvious that their inferences would differ from each other. One can arrange the most talked about studies on this topic with respect to time. These are Shafik and Bandopadhyay (1992), Lucas et al. (1992), Panayotou (1993), Selden and Song (1994), Grossman and Krueger (1995), Holtz-Eakin and Selden (1995). [1]

The following table, taken from the source mentioned in the footnote, briefly describes the studies that have, by and large, used equation 1 to investigate the relation between environmental stress and per capita GDP. Since this table is inserted with a view to compare and contrast different studies, pollutants having the availability of at least two estimates are included. At least one study, for each pollutant has reported the existence of EKC.

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[1] This part and the next part draw heavily from the article "The Environmental Kuznets Curve Hypothesis" by Sander M.de bruyn and Robeijn J.Heintz in "Handbook of Environmental Economics"

Table 1

(Overview of empirical studies that have used model (1) to estimate the relation between pollutants and income)

Authors	Methods[a] (ols/gls or fe/re)	SO_2 (peak) (through) type[b]	Part.[c] (peak) type	NO_x emis. (peak)	CO_2 emis. (peak)	Faecal coliform (peak)	1/ Dislvd oxygen (peak)[d]	Defrstn.	Exch rates	Addnl. Varble.
Grossman and Krueger, 1995	GLS (re)	N (4100) (13000) conc.	EKC (6200) conc.	-	-	EKC (8000)	EKC (2700)	-	PPP	Lagged income
Shafik and Bandopadhyay, 1992	OLS (fe)	EKC (3700) conc.	EKC (3300) conc.	-	MI	N (1200) (11400)	MI	Flat	PPP	Variety of other variables
Panayotou, 1993	OLS (pcs)	EKC (3000) emis.	EKC (4500) emis.	EKC (5500)	-	-	-	EKC (1200)	MER	-
Selden and Song, 1994[e]	GLS (re, fe)	EKC (10300) emis.	EKC (10300)	EKC (11200)	-	-	-	-	PPP	Population density
Torras and Boyce, 1998	OLS (pcs)	N (3400) (14000) conc.	Flat	-	-	Flat	N (5100) (19900)	-	PPP	Inequality variables
Holtz-Eakin and Selden, 1995	OLS (fe)	-	-	-	EKC (35400)	-	-	-	PPP	-

Notes

N= N-shaped curve, U=U-shaped curve, EKC=inverted U-shaped curve, MI= monotonically increasing curve, Flat = all parameters except intercept are insignificant. Peaks rounded at US $100.

[a]GLS = generalized least square, OLS = ordinary least square, re = random effect, fe = fixed effect, pcs = pooled cross section.

[b]Conc = concentrations, emis = emissions, PPP = purchasing power parity, ER = market exchange rate.

[c]Particles differ with respect to how these are being measured.

[d]Dissolved oxygen is an indicator for environmental quality, not degradation, and for these reasons the authors have taken the inverse of dissolved oxygen. Hence an EKC in fact reflects a U-shaped curve and monotonically decreasing pattern found by Shafik and Bandopadhyay reflects continuous deterioration.

[e]Turning points for models with population density, for SO_2 using random effects, for particles and NO_x using fixed effects.

Other studies not included in the table deal with:

Study	**Methods**	**Pollutants**
De Bruyn et al. (1998)	Time-series	SO_2, NO_X, CO_2 emissions
De Bruyn (1997)	Various	SO_2 emissions
Ekins (1997)	Various	Multidimensional indicator
Horvath (1996)	OLS (fe, pcs)	Energy consumption
Kaufmann et al. (1998)	GLS (fe, re)	SO_2 concentrations
Liddle (1996)	OLS (fe)	SO_2, NO_X emissions
Lucas et al. (1992)	OLS (fe)	Toxic intensities
Suri and Chapman (1998)	OLS (fe)	Energy consumption
Xepapedeas and Amri (1995)	Probit	SO_2 concentrations, dissolved oxygen

Having seen the divergences between the inferences made in the above studies, one might be interested in knowing as to where the divergences come from. The differences in the outcomes could easily be attributable to :

I) The variation in the choice of environmental quality indicator across the researches; different economists have taken different indicators,

II) Variation in the set of countries/regions and also in the time periods chosen by different researchers,

III) Different methods were used to convert different currency units into a single comparable unit,

IV) Differences in the techniques of estimation, i.e., OLS, GLS, random effects, fixed effects, pooled cross section analysis,

V) Dissimilarity in the selection of 'Z_{it}', i.e., in the consideration of 'other variables' that impact the quality of environment and can act as factors behind environmental deterioration

Out of these five factors, we very briefly discuss the relatively important ones.

Sample of countries

One of the striking variations amongst researches is seen in the selection of countries. For example, if two different researchers used different database for disjoint set of countries, their conjectures were very likely to differ from each other even when the researchers have taken the database from the same institution. Moreover, the selection of only a few countries having extremely high tendency to pollute, might significantly influence the outcomes for the whole set of countries. Also to show the robustness of the result researchers must take into consideration that different countries are in different state of development, i.e., their position with respect to wealth are significantly diverse. Hence there is a need to divide the set of countries with respect to their wealth and then to carry out the same research for each group of countries (low-income, high-income etc). We suspect that most of the studies haven't carried out an analysis of this sort, as most of them don't even mention the names of the selected set of countries.

However, in some cases in our study we shall try to do this by splitting the set of countries with respect to wealth and also by splitting the time period to verify the robustness of our result.

Exchange rate

To compare and contrast the per capita incomes of different nations with different national currencies, one must deflate them by some exchange rate or some other factor. To estimate the regression equation of pollution on income, different researchers have used different exchange rates. Some of them used "purchasing power parity (PPP)" factor and some have used "market exchange rate (MER)". But their divergence is significant; especially for the erstwhile socialist countries having strict import restrictions.

Methods of estimation

As we have mentioned above, different studies have employed different econometric techniques that automatically resulted in the variation in their predictions. "The importance of country specific effects in a panel of countries has been highlighted by Liddle (1996). This favours the use of fixed and random effects estimates that capture country-specific effects such as latitude. Stern et al. (1996) have argued in favour of generalized least squares (GLS) methods to correct for heteroscedasticity that may be present in the errors. For example, pollution data may be more accurately measured in higher-income countries, or large countries may average out variations in emissions within their economies."[2]

In our study, we shall try to use various econometric regressions as has been suggested.

Choice of 'other variables'

The choices of 'other variables' in the form of 'Z_{it}' (going by equation 1) have been widely apart from each other. Economists have differed in its selection according as their understanding of the importance of the same. The most commonly used 'other

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[2] "The Environmental Kuznets Curve Hypothesis" by Sander M.de bruyn and Robeijn J.Heintz in "Handbook of Environmental Economics"

variables' are population, urbanization and lagged-income. However, suspicion can be raised regarding the use of lagged-income with current income as this can result into severe multicollineraity among the explanatory variables that may ultimately lead to a biased estimate of the parameters.

2) International Trade and Environment

In the earlier sections we have seen that macroeconomic activity impacts the environment both at local and global level. Similarly environment in a country is affected by the economic activities performed within and beyond the country. The relation shared by income and domestic environment can throw some light on how domestic economic activity influences the environment. On the other hand the relation between international trade and environment, both at domestic and global level, refers to the way in which international economic activity influences the environment. This relation is particularly important for the present days. The world economy is passing through a very liberalized regime of international trade these days. Since the last two decades we are watching a significant structural change both at national and global level. This has resulted in a massive increase in the volume of international trade over the last two decades. And as a consequence of that, various debates regarding the impact of this increase in international trade on environment are gradually gaining importance. In this part of the present chapter we shall try to see the basic nature of this relation and shall have a very brief survey of the economic literature on this aspect. Before going to the literature, let us first see the basic theoretical nature of the relation between international trade and environment and the way they can be reconciled.

The World Bank and the World Trade Organization (WTO), often accused of insensitivity to environmental problems and the new reality of global environmental governance, has for many years been investigating ways of reconciling international trade and the environment. However, failure to introduce a formal environmental mandate in to the international trade regime and the collapse of the 1999 WTO ministerial meeting in

Seattle could hardly have highlighted more sharply, or more publicly, the contentious nature of the trade-environment relationship.

The recent resuscitation of the concern for global environmental quality has generated many queries relating to the impact and span of environmental regulations on international trade patterns and gains from trade. In presence of a trade-off between the two, choices have to be made from among alternative policy approaches, and these alternatives vary greatly with respect to their cost structure and efficacy. Hence it is opined that some interventions are necessary, depending upon their cost structure and effectiveness, to maintain a decent environmental standard. Economists like Bhagwati and Srinivasan have opined that there should be two types of policies to keep a balance between these two apparently conflicting issues. In their opinion trade should be dealt with trade policies and environment should be taken care of through environmental policies.

Economists and researchers focus their attention on the following:

A) Trade and environmental policy links,

B) The resultant competitiveness,

C) Industrial location,

D) International cooperation on the environment and

E) The political economy of environmental policy making.

Many economists have tried to examine the impact of environmental policy on the existing standard results of international trade. These kinds of researches have taken place both at theoretical and empirical level. Some of the theoretical analyses are carried out by Siebert (1977, 1985), Pethig (1976), McGuire (1982), Baumol and Oates (1988) and Blackhurst (1977). Siebert summarizes the main results of many of these studies regarding the impact of environmental policy on comparative advantage. These studies basically point to the following fact.

If any production process damages the environment then as long as the damage to the environment is not internalized properly into the costs of production, a non-optimal allocation of resources exists. In an open economy characterized by the absence of environmental regulation, this means that the pattern of trade is also likely to be non-optimal owing to the externality in production. In this circumstances the question that arises is should trade patterns be altered to overcome the problem of externality so that it reflect the opportunity cost of environmental damage? In theoretical trade literature the environment is most often treated as a 'third' factor of production (in addition to the assumption of labor and Capital in the 2 x 2 model). Similarly, many endogenous growth models also have started to incorporate environment in the production function. Now a nation is thought to have an environmental abundance if its assimilative capacity is large enough, i.e., a relatively greater ability to tolerate (absorb) pollutants. As Blackhurst (1977) points out, assimilative capacity is influenced not only by the physical ability of water, air and land to absorb waste, but by the level of pollutants the society is willing to tolerate.

If we assume (purely theoretically) that nations have identical production, pollution, and abatement functions for a particular good, then in free trade, one would expect the country with relatively larger assimilative capacity to specialize more in the pollution-intensive good, which is pretty similar to the outcome stated in the Heckscher-Ohlin model. This is based on the assumption that in autarky, the country richly endowed with assimilative capacity will have relatively weaker environmental norms and regulations and this would give rise to a price advantage in the pollution-intensive good for that country. However, as long as the cost of pollution is not internalized, the price advantage is overstated. There might occur an over specialization in this good. Now, a unilateral imposition of environmental regulations by the environmentally rich country will impose 'environmental control cost (ECC)'on its producers. This will simply erode their price advantage relative to the foreign country. In a game theoretic framework, this will reduce the locational disadvantage of the environmentally scarce nation. We should, therefore, expect a shift in specialization, where the environmentally scarce country increases production of pollution-intensive good. Unilateral regulations not only change the pattern of trade, but also might increase pollution in the other country-even when no transnational pollution exists ('pollute thy neighbour via trade'). In this setting environmental policy can be used as an important determinant of the quantum of trade, which implies that environmental policy does have the potential of substituting trade policy to alter the pattern of trade. Now the environmentally scarce nation can retaliate with an appropriate environmental policy depending upon its preferences. In this situation where both countries adopt optimal environmental regulation, such that production costs now include the true (social) costs of pollution, then, one would expect world output of the pollution-intensive good to fall. Thus optimal regulation in pollution in both countries can alter the pattern of trade to reflect the relative assimilative capacities of both the countries involved. It is unclear, then, whether or not unilateral restrictions move the pattern of trade closer to the optimum pattern. This was essentially a two-country framework. In more than two-country framework the situation can be more complicated. But this analysis provided the dynamics of trade regulations and environment in the simplest possible framework.

From this very brief summary of the theoretical models, there appears to be a case for concern that developed countries with more stringent environmental regulations could experience a loss in comparative advantage in the affected sectors. It has also become understandable that some shifting of resources out of the pollution-intensive sector is desirable, to the extent that present trade patterns do not accurately reflect relative assimilative capacities.

This amount of theoretical understanding was needed to present a brief overview of the theoretical literature that has come out in the recent years. At the end, we shall try to describe some of the empirical studies on this aspect as well.

A. *Theoretical Studies*

Having briefly discussed the crux of theoretical models on the aspect of international trade and the environment, let us now turn our attention to some of the theoretical studies that have emerged in the literature during the recent years. Lots of theoretical modeling has been done on this. Hence the theoretical literature is really voluminous. We shall try to have an overview of a few of those.

In the last few years we have seen economists and environmentalists engaging in a very lively debate over the impact of international trade on the environment. There is still much that they are not clear about the influence of trade liberalization on environmental quality. According to Antweiler, Copeland and Taylor "the debate over the role international trade plays in determining environmental outcomes has at times generated more heat than light. Theoretical work has been successful in identifying a series of hypotheses linking openness to trade and environmental quality, but the empirical verification of these hypotheses has seriously lagged."

"North-South" Trade and the Environment

Copeland and Taylor (1994, Quarterly Journal of Economics) have developed a model of north-south trade to encompass the interaction between national income, pollution and international trade. The word 'north' is used in the literature to describe a developed rich industrial nation having, by and large, strict environmental norms. On the other hand, the catchword 'south' implies a less developed, less industrialized low-income nation having a weak environmental regulation. In their model, they considered two countries (engaged in bilateral trade), each producing a stream of good having distinct pollution intensity. Now if these goods are arranged in order of their pollution intensity, then, the richer country specializes in the relatively cleaner good having relatively lower pollution intensity. It chooses stronger environmental protection as well. Copeland and Taylor decomposed the effect of international trade on pollution in three smaller effects, namely, scale, composition and technique effect. Their most striking result was that though both economic growth and international trade can increase national income but their impact on pollution are different. They made two suppositions. They assumed trade reduces international differences in factor prices and the good that has greater pollution intensity has a higher relative price in richer country, in autarky. With this set of assumptions they have shown that economic growth has different impact on pollution in a liberalized free trade scenario than in autarkic scenario. Their ultimate conclusion was pollution goes up with the flow of free trade, but the effects of trade on individual countries are different. Pollution goes up in rich 'north' with the enlargement of its production possibility. On the other hand, the same reason lowers pollution in 'south'. Global pollution is diminished through a unilateral transfer from 'north' to south'.

Inter-Sectoral Externality and the Environment

Copeland and Taylor, in the next model (August 1995, NBER Working paper 5242), considered the aspect from a very different angle. This time they were interested in assessing the influence of international trade when externalities, originating from pollution in a particular sector, do have the capability of affecting the other sectors. Hence they developed a two-sector dynamic model. They considered "Smokestack" as the pollution generating manufacturing sector and "Farming" as the environmentally sensitive sector. The pollution generated from the production of "Smokestack" has an ill effect on the productivity of the "Farming" sector. They justified their selection of "Smokestack" as the pollution intensive in the following words: "There is already ample empirical evidence linking the emissions of 'Smokestack' industries to reduced fishing and agricultural yields, to negative effects on the value of standing forests, and to beach closures that hurt tourism. Current estimates of environmental damage suggest that such external effects are not negligible. Pearce and Warford (1993, p.28) report damage estimates from a low of 0.5-0.8% of GNP for the Netherlands, to 4.6-4.9% of GNP for Germany, to a high of 10%of GNP for Poland." In this model the motive for trade arises from the generation of pollution as the former can "....spatially separate incompatible industries." Assuming that the world gains in terms of productivity through the separation of incompatible industries, they postulated that the separation could benefit or harm the world depending upon the distribution of the productivity gains. If the incompatible industries concentrate in 'some' nations, it will result in the depletion of utilities there. Trade, in their opinion, can initiate a negatively reinforcing cycle of environmental degradation and productivity losses that leaves a 'dirty' product exporter worse off in trade. They concluded that the effect of trade would depend on the magnitude of world income spent on "Smokestack". If it were high, both the trading partners would gain if they were characterized by no environmental regulation, and if the share were low the exporter of "Smokestack" would experience a real income loss accompanied by a negatively reinforcing process of environmental degradation.

Differences in Income, Factor Abundance and the Environment

Copeland and Taylor, again, in January 1997 (NBER Working paper 5898), presented another model of international trade and environment. This time the model was much more simplistic and understandable. This paper analyzed the interaction between differences in income and differences in primary factor abundance across countries in the determination of the resultant pattern of trade. This paper also took into account the impact of differences in the pollution policy across the nations on the pattern of trade. In their earlier model of 1994, the authors assumed the demand for environmental quality to be a normal good. This feature resulted in the high-income countries choosing for a stricter pollution regulation and specializing in relatively clear goods. Hence in that model liberalization enabled the shift of polluting industries in the developing nations. But the present model (1997), as it seems, is an improvement over its earlier version in the sense that this time both the income effect and the factor abundance effect on pollution are considered. So the ultimate effect of trade on pollution depends on the relative strength of these two factors in the current model. The authors proceeded describing a [2(countries) x 2(goods) x 1(primary factor) x 2(total number of factors)] framework with the assumptions of 'north' being richer than 'south' and capital using industry is more pollution intensive though both industries pollute. If 'factor abundance' dominates over the 'income gap' between 'north' and 'south', trade will induce a shift of pollution intensive industries in capital abundant 'north' despite its stringent pollution norms and this will result in depletion in the level of world pollution. 'North' will experience a rise in pollution while in 'south' pollution will decline. On the contrary, if income gap between the nations dominates over the factor abundance feature, exactly opposite outcome will emerge. The authors considered the phenomenon of capital mobility as well. They showed that capital mobility might increase or decrease world pollution. They concluded by saying, "....in the case where 'north' initially exports the pollution intensive good, increased capital mobility may raise world pollution from its free trade level. Since this case seems to be empirically relevant during the development process, the concerns about the environmental effects of capital mobility by Daly and Goodland (1994) and others should be given close scrutiny. It should be noted however that free trade plus capital mobility leave world pollution unchanged from its autarky level."

Scale, Technique, Composition Effects and the Environment

In the next paper by Antweiler, Copeland and Taylor (August 1998, NBER Working paper 6707) used econometric techniques to theorise how 'openness' to international goods markets affects pollution concentrations. They developed "a theoretical model to divide trade's impact on pollution into scale, techniques and composition effects and then examine this theory using the data on sulfur dioxide concentrations from the Global Environmental Monitoring Project." Their model has 3 salient features. First, by using a panel dataset they empirically distinguished between the negative environmental consequences of scalar increases in economic activity (which they called the 'scale effect') and the positive environmental impact of an increment in the income that call for cleaner production methods (which they call as the 'technique effect'). Their estimate showed that a 1% increase in economic activity had twofold effect on concentration. On one hand it increased the concentration by approximately 0.3% and on the other hand the accompanying increase in income brought down the same by approximately 1.4% via a technique effect. Secondly, they showed the way through which trade generated compositional changes in output affected the pollution concentrations. After characterizing the countries in terms of dummy variables, they found that that openness had very little consistent impact on pollution concentrations. Thirdly, they found that growth's impact on pollution lied in where the growth came from. Pollution tends to decrease when the growth originates from further trade or neutral technical progress where as pollution may rise when growth comes from capital accumulation. They concluded the model in this fashion: starting "....with a theoretical specification that gave pride of place to scale, technique and composition effects and then showed how its theoretical decomposition is useful in thinking about the relationship between openness to international markets and the environment. In our empirical section we adopted a specification directly linked to our earlier theory." In summary they found that international trade created a negligible change in pollution concentration when it changed the pollution intensity of national income through composition effect. On the other hand technique and scale effect pulled down the pollution. Considering all these effects simultaneously, they found free trade was good for the environment.

Globalization and the Environment

Theodore Panayotou in a paper ('Globalization and Environment', CID Working paper 53, July 2000) tried to investigate the issue of globalization and its environmental consequences from different angles. He tried to find out the link between the two, the issues relating to the multilateral economic agreements on trade, finance, investments and intellectual property rights that affect environmental sustainability, and lastly he tried to review the priority policy issues affecting multilateral economic agreements and environment. He identified the trade related environmental effects under 6 categories, e.g., scale effect, structural effect, income effect, product effect, technology effect and regulatory effect. According to him only income effect is positively related to trade (as people become richer, they willingness to spend for the environment goes up); all other effects might have a positive or a negative impact on environment. He concluded by saying that to sustain global economic growth juxtaposed with the benefit of the environment, environmental and trade policies should be more and more integrated. He was in favour of more integration and cooperation among nations across the globe. Panayotou's most ambitious expectation lied in the last line of his article. He felt "....new institutions of more effective and equitable global governance can be created to bring together governments, the private sector and civil society in a dialogue to achieve consensus for action in dealing with globalization-induced volatility, inequality and threats to environmental sustainability."

Trade Policy, Environmental Policy and the Environment

Copeland, in another paper ("Trade and environment: policy linkages" in 'Environment and Development Economics', 2000) tried to investigate whether trade policy and environmental policy should be linked. This issue emerged from the controversy created by two groups of authors, Grossman & Krueger (1993) and Daly & Goodland (1994). The former authors unsupported the policy of 'race to the bottom' where as the latter group of author feared that such a tendency might exhibit on the part of the developing nations with the inception of free trade regime. Copeland found that in a game theoretic framework trade liberalization without constraints on environmental policy and without transboundary pollution, nations would engage in a non-cooperative game vis-à-vis pollution policy. Trade won't be Pareto optimal if there were no negotiations regarding environmental policy. If pollution becomes global countries would differ in their approaches to link trade and environmental policy. In such a scenario, obviously countries exporting pollution-intensive good would choose to separate trade and environmental policy where as the countries importing pollution-intensive good would prefer to link the two. However the real world does not go by the view that trade matters should be dealt with trade policy and environmental matters should be dealt with environmental policy. Many countries strategically link these two to pull the terms of trade in their favour. According to Copeland "all trade liberalization agreements are incomplete contracts that eliminate and restrict some but not all instrument of protection. When tariffs are eliminated governments face the same incentives to protect as they did prior to the trade agreement, and hence they look for alternative instruments of protection. While environmental policy is not a first-best trade policy, it may become an attractive substitute for trade protection if more favourable instruments are constrained by the treaty. In this case, the signing of a trade agreement may create non-cooperative game in pollution policy."

International Capital Flow, MNCs and the Environment

Eskland and Harrison in a paper ("Moving To Greener Pastures? Multinationals And The Pollution Haven Hypothesis" NBER Working paper 8888, April 2002) tried to investigate the financial aspect of the trade and environment debate. They tried to examine whether private multinational foreign capital moves to create "pollution haven". Using a simple model they found that environmental regulations at home impact the outward investment in an ambiguous manner in the sense that this sort of regulations could lead a firm to increase or decrease its investment in both the home country and in the country having lax environmental standard. To resolve this ambiguity, they focused on three aspects. First, they analyzed the pattern of foreign investment in developing countries to see whether there was any evidence, which reflected increasing costs of pollution intensive activities at home. Second, they compared multinational firm's behaviour both in host and developing countries. Third, they tried to test the nature of US investment that went abroad during 1980s and early 1990s with respect to the variations in pollution abatement costs across different sectors of the economy. In eventuality they found "....some evidence that foreign investors locate in sectors with high levels of air pollution, the evidence is weak at best." They also found that foreign firms were efficient because they used cleaner energy-technologies. With regard to US bound overseas investment, they concluded by saying that though the nature of US investment in foreign countries was inclined to industries having high pollution abatement costs, the results were not robust across specifications.

B. *Empirical Studies*[3]

Environmental Control Cost and the Pattern of Trade

Now it is time for us to take a brief look at the survey of the empirical literature that has come into existence. Until now the quantum of empirical studies taken place in this area is very small in comparison to the theoretical studies. But still various empirical studies have tried to encompass the debate regarding trade and environment from various angles. Numerous studies have tried to estimate the impact of 'Environmental Control Cost (ECC)' on industry price and output, and on the trade balance. The methodologies are different and are quite varied. This makes comparisons between studies very difficult and complicated. However, one can point out some generalizations as:

a) By and large the depletion in output caused by ECC is small and insignificant, although its significance can be relevant for some individual sectors.

b) Estimates of total ECC incurred by a polluting industry is also tend to be very low, making the abatement cost a very negligible fraction of the total industry cost on average.

c) There is a very little evidence of any significant impact of ECC on the pattern of trade.

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[3] This section draws heavily on "Trade and the Environment: A Survey of the Literature", by Dean J M in Background Paper for "World Development Report, 1992", The World Bank

In one of the earliest studies, Walter (1973) tried to assess the role of environmental policy in international trade. He was interested in examining the polluting content of U.S. trade. His approach was based on Leontief's famous input-output model. Given the environmental regulations prevalent during that period, if export goods were found to be relatively pollution-intensive compared to import goods, then U.S. regulations used to discourage the export sector. Using the data of 1960s he calculated the direct ECC and overall ECC (direct and indirect) for 83 goods and services in the U.S. Using an input-output analysis, he tried to determine the so-called 'overall environmental-control loadings', i.e., the ratio of ECC, including those of intermediate inputs, to the final price of the output. This was then multiplied by the value of U.S. exports and imports to obtain the environmental-cost component of U.S. trade. It was shown that, on an average, the abatement-cost content of U.S. exports is slight higher than that of U.S. imports. This suggested that the U.S. were relatively well endowed with environmental resources compared to the rest of the world. Walter concluded that ECC are trade neutral at best and marginally damaging to U.S. export industries at worst. So by and large trade pattern remained invariant to environmental regulation in his study. However, the impact of international differences in environmental regulation was not analyzed, which remained as one of the major shortcomings of his study.

Both the U.S.DOC (1976) and Yezer and Philipson (1974) studies (as summarized by Ugelow, 1982) looked at the effects of ECC on output in a few industries. Both these studies have found that the percentage decrease in output attributable to the imposition of ECC (direct and indirect) for 14 industrial sectors averaged less than even one percent. Ugelow suggested that this underestimated the impact on output, since it only included incremental costs attributable to federal legislation.

Richardson and Mutti in 1976 tried to formulate a general equilibrium analysis. They estimated domestic and import market demand and supply equations for 81 industries. In their analysis the assumptions about domestic elasticity of supply varied to a significant extent. These authors used an input-output matrix to calculate both direct and indirect ECC. But in the conclusion Richardson and Mutti opined that one could not assess the impact of ECC on international trade until one could account for four very important factors in the form of inter country difference in controls, the financing of controls, the inter-country difference in macro policy and the exchange rate flexibility.

Robinson's research (1988) is important because of several reasons. First, it updated the study made by Walter (1973) on the pollution content of U.S. trade. Estimates were made for 1973, 1977 and 1982, using input-output tables for 1973 and 1977. Secondly, Robinson presented an estimate of ECC elasticity of trade balance. He calculated the impact of a one-percent change in ECC on the trade balance. He deliberately did not go for the complication of general equilibrium refinements as discussed by Richardson and Mutti (1977), rather he purposely assumed the full pass-through of ECC to prices. Thus he tried to generate an upper-bound estimate of impacts on trade. His conclusion was somewhat different from the earlier studies. Robinson concluded that the comparative advantage of U.S. had shifted away from goods that had high abatement costs in the U.S. This conclusion was quite in tone with the theoretical modeling of two countries where one country has strict environmental norms but the other does not have the same, something we have stated earlier. In that framework, a unilateral imposition of environmental norms could lead to a flight of dirty industries to the country having a weaker environmental norm. Robinson's findings justified this theoretical argument. Moreover, when he made the same calculation for the bilateral trade between U.S. and Canada, he found no change in the ratio of abatement content of U.S. imports to U.S exports between 1973 and 1982. Thus he hypothesized that this might be due to the presence of similar ECC in the two countries. This also justified the theoretical framework where both countries have the same sort of environmental norms and regulations.

Tobey (1990) took a totally different route to verify whether or not ECC had any impact on U.S. comparative advantage. Following earlier work on shifting patterns of trade by Bowen (1983) and Leamer (1984), he employed a cross-section 'Heckscher-Ohlin-Vanek' (HOV) model. Starting with 64 agricultural and manufacturing industries, Tobey calculated the total ECC as a percentage of total costs of production. He classified Pollution-intensive industries as those, which had an ECC/TC ratio of more than 1.85 percent. He identified 24 industries that fell in this category. In this type of model, very expectedly, one would include a measure of environmental endowment, to ascertain whether or not environmentally rich nations export more of the pollution-intensive good, like Patrick Low and Alexander Yeats did in their paper of 1992. But at the same time environmental endowment is difficult to measure. Tobey, however, was interested in the effect of ECC on trade patterns. His first test, therefore, involved the insertion of a dummy variable as an additional explanatory variable to capture the ECC stringency, which was essentially a qualitative variable. Presumably, in an HOV model of this type, Tobey was implicitly assuming that more stringent ECC were correlated with environmental scarcity in a negative fashion. He was thinking that an environmentally scarce nation would have lax environmental regulations. Thus the dummy variable should have a negative coefficient. In addition to problems with measuring stringency, his taxonomy ignored the fact that countries might be currently pursuing a non-optimal environmental regulation as a part of long term planning for investment and output growth. In that sense stringency was a poor indicator of environmental endowment. If the stringency dummy was correlated with ECC, then this might still be a good test of whether relatively high ECC tended to decrease net exports. Tobay found no significant impact of stringency of ECC on trade patterns. But as an evaluation of his study one must say that his procedures were innovative and novel.

Empirical studies on 'Pollution Havens' and Industries

Another fear that has been voiced in the literature regarding the relatively low environmental standards in developing countries compared to the industrialized nations; is the possibility of 'dirty' industries shifting their operations to these developing nations (the industrial flight hypothesis). In addition, LDCs may purposely incessantly undervalue the environment (through laxity in environmental norms and regulations) in order to attract new investment from overseas (the 'race to the bottom' hypothesis). This could lead the developing nations to become a 'pollution haven' for 'dirty' industries. Both phenomena could lead to a non-optimal (excessive) pollution in LDCs.

As has been argued above, some shift in the production of pollution-intensive goods might be optimal, since countries possess different assimilative capacities to absorb pollutants (i.e., different environmental endowments). However, as Pearson (1987) pointed out, there was no a priori reason to believe that increased output in the environmentally abundant country would be captured by multinationals as opposed to domestic firms. Moreover in his opinion there was also no reason to believe that LDCs were relatively environmentally abundant compared to the DCs, which could initiate the process of 'flight' of the 'dirty' industries to these LDCs.

Duerksen and Leonard (1980) examined trade and investment data to determine if ECC differentials had led to industrial flight towards LDCs. One of the striking parts of their results was that host countries that received the most overseas investment in pollution-intensive paper, chemicals, metals and petroleum refining were other industrial countries and not the LDCs. They concluded that there was no evidence of widespread relocation of U.S. industries to pollution havens. A study by Knodgen (1979) of West German also found this conclusion.

Walter (1982) looked at the trends in FDI by firms from Western Europe, Japan and the United States for the period of approximately 1970 to 1978. He examined trends in FDI both in terms of industry mix and destination. He found no evidence that foreign FDI was shifting towards states with more lenient environmental standards.

Patrick Low and Alexander Yeats (1992) formulated a very interesting model to outline the dynamic behaviour of the total volume of trade in 'dirty' goods and the distribution of 'dirty' industries across countries over time. Their study encompassed the period of 1968-1988. They tried to highlight the change in the pattern of overall trade in 'dirty' goods and their locational origin for that period. To figure out this change they used the concept of 'Revealed Comparative Advantage (RCA)'. RCA is defined as the share of an industry of particular country in total export of manufactures of that country relative to the total export of that industry in the world trade in manufacture. This reveals a country's comparative advantage in a particular industry as reflected in actual trade flows.

In algebraic notation

$$RCA_{ij} = (x_{ij} / X_{tj}) / (x_{iw} / X_{tw})$$

Where RCA_{ij} is the revealed comparative advantage of industry ‘i’ in country ‘j’.

x_{ij} = export of good ‘i’ from country ‘j’

X_{tj} = total exports of manufactures from ‘j’

x_{iw} = total world export of industry ‘i’

X_{tw} = total world trade in manufactures.

A country (j) is said to have a revealed comparative in industry ‘i’ if the relevant RCA_{ij} exceeds unity. A value less than unity implies revealed comparative disadvantage. The novelty of this definition is quite simple. If the RCA for any particular industry exceeds unity, it means that the industry has a larger share in the country’s total exports than it has in total world trade. In other words the industry figures more prominently in the country’s export than it does in world trade. This must be a reflection of the fact that the country has a comparative advantage in the industry and therefore has specialized in its production. But the question of ‘dirty’ industry needs a slightly different interpretation. That is instead of taking a particular country and ranking its industries according to the RCAs. We need to take the ‘dirty’ industries only and then find the ranking of the countries in terms of their RCAs. So the authors modified the definition as

$$RCA_{ij} = (x_{ij} / x_{iw}) / (X_{tj} / X_{tw})$$

The interpretation of the ratio remains the same. Now the next question the authors considered was the selection of ‘dirty’ industries. They considered ‘dirty’ industries as those that spent one or more than one percent of their value of sales on pollution abatement, while, at that time, the average abatement expenditure-sales ratio for all industries taken together in US was 0.54 percent. Then they calculated the RCA value for all the industries. Once this calculation was made, the identification of ‘dirty’ industries got over and the countries having an RCA value of more than unity in 'dirty' industries were also identified. Then those countries were divided into 'north' group and 'south' group of countries. Now over the period of 1965-1988, the authors have found that the number of 'dirty' industries had significantly gone up in 'south'. But since the authors had not made a conceptual distinction between the way a country specialized in 'dirty' industries and the way it attracted the 'dirty' foreign firms or industries to relocate their operation on its homeland, it remained vague whether the 'south' specialized in 'dirty' industries or the foreign 'dirty' firms relocated their operation on the 'southern' soil. The fact that became vivid was the emergence of 'south' as a prominent location for the 'dirty' industries.

Policy Responses to Loss of Competitiveness and the Environment

To facilitate the efficient allocation of resources through internalizing negative externalities, OECD countries agreed to a "polluter-pays principle" (PPP) regarding the financing of ECC in 1972. As argued above, the theoretical implication of this principle lied in the loss of comparative advantage in the pollution-intensive sectors for the country with relatively high ECC. Hence one could imagine that empirically, at least some sectors might experience a significant loss in competitiveness. To counter this one proposal was considered in the form of subsidization of ECC so that industries in countries with 'high standards' would not experience the anticipated loss in comparative advantage. And this happened in realty. Despite the introduction of PPP scheme, OECD countries had indeed implemented numerous subsidies to cover ECC. This would simply pinpoint that GATT would need to distinguish subsidies to attain environmental goals, from other subsidies, which ostensibly give firms an 'unfair' advantage in trade.

The study of Richardson and Mutti (1977) provided some evidence on this issue. They compared and contrasted the impact of ECC on the U.S. industry output under the PPP scheme and under another scheme where ECC were subsidized. The subsidy was introduced as a compensation for the levying of an identical tax on the value added of each industry. Richardson Mutti, using several models, found that the subsidization scheme made the distribution of environmental control displacement across industries more equal, as compared to PPP results. That is, the subsidy scheme reduced the relative disincentives faced by the industries most severely impacted by ECC.

As an evaluation we can say that government subsidies, which compensated firms for the cost of meeting regulations, inhibit the optimal shift of resources away from the pollution-intensive industries. Thus, in terms of economic efficiency, there does not seem to be any reason for the avoidance of loss of comparative advantage through use of subsidies to meet ECC. In addition, the economic literature on pollution had long argued that tax schemes on marketable permits were usually more efficient method of internalizing pollution costs than subsidies. This suggested that subsidies used to attain environmental goals were likely to be a guise to avoid the losses in competitiveness, and should not be allowed by GATT. If there were any role for GATT here, it would be to attempt to discern if a country's environmental regulations were below those, which are locally optimal. Only in such cases might a countervailing duty be justifiable.

Transnational Pollution and the Environment

When the pollution generated from the production process in a particular country affects the environment beyond its geographical boundary, it is called transnational pollution. Most of the theoretical and empirical modeling does not deal with transnational pollution. However, there are two main concerns which link transnational pollution to international trade, and hence to GATT. First, are trade barriers an appropriate way to monitor and diminish transnational pollution? If so, in what way must GATT rules be revised to allow for this? Second, how will domestic regulations to control transnational pollution affect trade patterns? These issues also arose in the analysis of production of pollution (above), where the damages from such pollution were within national boundaries. Do the answers change considerably if the external costs generated by production cross-national borders?

Baumol and Oates, in 1988, tried to investigate the theoretical question of the optimal policy response in presence of transnational externalities. They argued that an internationally optimal tax on emissions was required. And its optimality lied in the fact that it should be equal to the marginal damage, generated in all countries taken together.

Given national sovereignty, however, this policy is practically unlikely to be implemented. As an elaboration we can consider countries A, B and C, where A is the polluter and B and C are victims of transnational pollution. Country A might establish an emission tax based on marginal cost-benefit calculations within its own borders. Countries B and C, likewise, might impose tariffs equal to the marginal damage suffered by their own nationals. In this setting, the prices and allocation of resources that result, would, in all probability, be an aberration from the optimal outcome. Since the prices in A are not directly affected by the tariffs of B and C, it will not fully reflect the true social cost of A's production. Similarly, the import duties set in B and C will not account for the full social cost of their consumption. In all countries, prices for polluting good will be too low relative to the outcome in comparison to the theoretical 'internationally optimal tax'. Baumol and Oates concluded that there was no set of tariffs capable of sustaining the Pareto optimal, which would be yielded by the optimal tax. They were of the opinion that tariff, as a second best policy option, could move the global economy towards a 'quasi-optimum', or to be used as a threat to achieve compliance to an internationally agreed upon target.

International Cooperation and the Environment

It is not worth-mentioning that from the perspective of global welfare, there is always a need for an international cooperation on the environmental aspects. Various economists have attempted to analyze the alternative policy approaches to address the phenomenon of international environmental externality. The paper by Diwan and Sadafi demonstrated how in a situation of less than perfectly functioning markets for capital and emissions, the opening of one market and not the other might lead to a harmful environmental outcome. They tried to establish the case for compensation in a situation where developing and developed country's environmental priorities differ to a significant extent, and where developing nations were expected to respond to industrial country concerns. This is essentially a game theoretic structure, where the developing country behaves like a 'follower' of the developed industrial country vis-à-vis environmental policies. While industrial countries worry about such issues as climate change and biodiversity and the other global aspects, developing countries are much more preoccupied with domestic problems such as health and various forms of local pollution. Under the assumptions of the model developed by Diwan and Shafik, the negative effects of inappropriate compensatory mechanisms could be significant. This analysis stressed the importance of making efficient choices from alternative options once a policy course had been decided upon.

Sadafi and Low, in one paper, talked about the possibility of having alternative forms of international cooperation, ranging from binding agreements to loose coordinating agreements. Again a game theoretic model was used to highlight the conditions under which an implicit cooperation amongst the players (countries) might be efficient in terms of environmental outcomes in case of a binding agreement. The model could work among countries that posed a credible threat against each other. They cited the reason for the countries to become interested in implicit cooperation from the angle that though an establishment of binding international agreements might prove costly and elusive, it might be an outcome that 'Coase' had talked about in the presence of a conflicting scenario. However, the search for international commitments could deviate attention from the main objective in the sense that it could restrict countries from taking domestically based action, and left the environment worse-off.

At an evaluation of the literature, let us categorically state that most of the literature on this topic has been written from the political perspectives, if any, of developed countries and in most of the cases the concern over the environment of the developing countries has not been properly revealed. A very common argument from the developed country's perspective is that more stringent regulation in one country is the cause of loss in competitiveness. On the contrary, the environmentalists of the developing nations argue that these stringent laws in developed countries have resulted in industrial flight and development of pollution heavens. To counter this argument, economists, mainly from the U.S., have tried to show there is no evidence to support these hypotheses. It is because of these arguments and counter arguments with the passing of time; the literature on this aspect is gradually becoming more and more enriched.

International trade viewed through an environmentalist's lens can appear rather sinister. Trade is seen as an anti-environmental force driven by the desire for increased profits, jobs, consumption and production, which irrevocably leads to the detriment of the global natural environment. The supporters of free trade, on the contrary, regard some of the environmental agenda with distrust. They point to the dangers of protectionism (blocking foreign producers from entering domestic markets under the guise of politically correct environmentalism), and the use of trade penalties, to enforce unilaterally determined environmental standards on others.

Regardless of what factors are at fault, the pressing reality is that distortions created by market and policy failures prevail in the global economy. Therefore, we must ask ourselves: In the presence such distortions, does trade exacerbate environmental damage? The GATT sees trade as a 'magnifier'. If the policies necessary for sustainable development are in place, trade promotes development that is sustainable. Conversely, if such policies are lacking, trade may contribute to a skewing of development in an environmentally damaging direction (also true for most other economic activities in the country). Case studies show how trade liberalization effort in Ghana and Nigeria resulted in extensive forest clearing to grow cocoa and cotton cash crops, simply because there was no clearly defined land titles.

But, as far as the developing nations are concerned, we should always keep one prime aspect in consideration. From the viewpoint of the developing nations across the globe, there is always a need to form an alliance in order to bargain with the developed nations as and when environmental conflicts emerge in the bilateral and international economic scenario. This can protect their environment and the livelihood of the people, which are, and have been, and will remain one of the prime objectives for achieving a steady and sustainable path of development.

Chapter 3

3. Environmental Quality and Income

In this chapter we shall try to see the relation between income and environmental quality and also examine whether or not EKC exists for a few pollutants for our set of samples and depending on the outcome we shall try to discuss the policy implication of the same, if any. This will portray the behaviour of environmental quality during the successive phases of development. We shall try to do this econometrically with the help of data on around 40 nations across the globe covering the last two decades (1980-1999). And finally we shall try to explain the possible set of factors behind our finding, which will emerge at the end of the econometric analysis. We shall also try to see the relevant policy implications, if any, of the same.

A. Description of the Data & Econometric Analysis

Before entering into econometric analyses for the relation between various pollutants and macroeconomic variables, we need to mention about the difference between our study and some of the already published studies. The novelties of our study are the following:

1) Not too many studies have been carried out at the country level. In most of the studies local or city or state level data were considered. We tried to consider country level pollution data and tried to see their behaviour with respect the per capita income and population.

2) The number of countries and number of years (1980-1999) covered in our study is more than most of the other studies. So the results are, by and large, general.

3) We have tried to run various types of regressions and have reported the result of the same. Most of the other studies, at least in the published articles, have reported about a few regressions.

4) In order to check the robustness of our result, we have stratified the panel with respect to wealth of nations and decades (i.e., 1980-1989 and 1990-1999) in some cases

where it was necessary and then ran the same regression. Moreover in some cases we used country and year dummies to capture country specific and year specific effects. Sometimes we have used slope dummies too. This reveals which set of countries is more prone to pollute.

5) Dataset, on any economic aspect, always suffers from the problem of multicollineraity and heteroscedasticity; be it to a small extent or to a large extent. Therefore, one should try to reduce these problems as much as possible by taking remedial measures. When we ran GLS regression, we allowed for heteroscedasticity and autocorrelation amongst the panels and then checked the result. We didn't incorporate lagged-income in our model as that could generate multicollineraity among current and lagged-income, which, truly speaking doesn't have many remedies.

At the very outset, let us categorically say that a ***severe dearth of environmental data*** limits the scope of any study relating to environmental indicators and macroeconomy. This dearth is more pronounced in developing countries like ours.[1] We have used the panel data published by "Oak Ridge National Laboratory (ORNL)" in USA for total CO_2 emissions by countries for the year 1980-1999. The data on SO_2 and NO_2 are taken from the website **www.emep.int/emis_tables/tab1.html** as no other source was available in panel form (for different countries and across years). All other data are extracted from the CD-Rom "World Development Indicators 2001 (WDI)"[2] published by "The World Bank". This CD-Rom brings out some amount of environmental data covering only a few environmental indicators. To maintain parity within the dataset, we used the same CD-Rom for financial variables too. We have chosen those countries,

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[1] "Organization for Economic Cooperation and Development" and "World Resource Institute" publish comprehensive environmental data in the CD-Rom format. These are respectively called "Environmental Data Compendium" and "World Resources". But these are not available in India and moreover are very expensive, which is beyond the capability of general students. These dataset remained unavailable to us despite repeated search. In any case, these datasets are trustworthy.

[2] This CD-Rom is also very expensive. But fortunately enough, a few research organizations like "Institute of Economic Growth (IEG)" New Delhi, and "Indian Council for Research on International Economic Relations (ICRIER)" New Delhi, subscribe to this CD-Rom. We got help from both of these organizations. We express our gratitude to them.

which had a population of more than 15 million in the year 1999 and whose data were available in WDI, with a few exceptions.

(1) Methodology

Sometimes data on some chosen countries and for some years were not available. But to use a 'balanced panel' (for running a few advanced regression in "Intercooled Stata-6"), this unavailability of data had to be overcome. Hence we had to interpolate and extrapolate for the same. This is done only in those cases where the data is not available for at most three successive years. Countries, which were initially being selected but which didn't have data on some variables for more than three successive years were eventually removed from the study.[3] But we realize that this interpolation and extrapolation do not change the structure and the character of the dataset dramatically.

Since we are going to use **panel data techniques**, we first briefly present a resume of panel data.

A longitudinal, or panel, dataset is one that follows a given sample of individuals over time, and thus provides multiple observations on each individual in the sample. The estimation in panel data incorporates both the cross-sectional and time-series aspect. So the source of error in panel comes from both the angle of the scale effect that is the cross-sectional effect and the time-series effect.

Following are some oft-cited advantages of panel data over cross section or time-series data:

1) They usually give researcher a large number of points, increasing the degrees of freedom and reducing the collinearity amongst explanatory variables. This improves the efficiency of the economic estimates.

2) Controlling for individual heterogeneity: Panel data suggests that individuals, firms, states, countries are heterogeneous. Time-series and cross section data not accounting for this heterogeneity run the risk of giving biased results.

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[3] Countries like Germany, Yemen, Korea Dem Rep. etc are thus deleted from the study.

3) Panel data are better able to study the dynamics of adjustment.

4) They allow us to formulate and test more complicated models.

Besides these, panel data also resolves to some extent, the problem of omitted variables that are uncorrelated with the explanatory variables. By utilizing information on both the intertemporal dynamics and the individuals of the entities being investigated, one is better able to control in a more natural way for the missing of unobserved variables.

The power of panel data is its theoretical ability to isolate the effects of specific actions, treatments, and in general policies. This theoretical ability is based on the assumption that economic data are generated from controlled experiments in which the outcomes are random variables with a probability distribution that is a smooth function of the various variables describing the conditions of experiment. However, in real world data, the assumption that parameters are identical for all individuals across all times is not a realistic one. Therefore, a simple pooled estimator does not give the correct result.

The basic framework for our discussion will be the model of the form

$$Y_{it} = \alpha + \beta_1 X^1_{it} + \beta_2 X^2_{it} + \beta_3 X^3_{it} + \ldots\ldots + \beta_k X^k_{it} + \mu_i + V_{it} \qquad (2)$$

Where μ_i is constant over time and specific to the individual cross section unit and it is called the **individual effect**. There are two basic frameworks to generalize this model. The fixed effect approach takes μ_i to be a group-specific constant, whereas the random effect model takes μ_i to be group-specific disturbance term. V_{it}, in all cases is the idiosyncratic error. In common parlance it is called the random disturbance term.

Suppose we are drawing individuals from a large population. Even then the model of the above form is appropriate. The component μ_i is the random disturbance term characterizing the ith observation and is constant through time. Generalized least squares techniques are used to estimate this model.

Now there can arise a very important question regarding the selection of fixed effects or random effects model and the basis of such selection.

Fixed or Random Effect ? – The Hausman Test

The test is based on the idea that if it is a random effect model, then the two estimates (by random and fixed effects model) should not differ systematically. Therefore if we **cannot reject** the null hypothesis that there is no symmetric difference, **random effect** model is more **appropriate**.

In addition to model (2), we shall sometimes use country, year and income (slope) dummies as well. But country dummy can be used if we run random effects model. In case of fixed-effects model, the model implicitly assumes a country dummy in the form of μ_i and hence there is no necessity to introduce additional country dummies.

So the introduction of country and year dummies will modify model (2) to the following

$$Y_{it} = \alpha + ß_1X^1_{it} + ß_2X^2_{it} + ß_3X^3_{it} + \ldots\ldots\ldots + ß_kX^k_{it} + D_i + D_t + V_{it} \qquad (3)$$

Where D_i stands for the vector of country dummies and D_t stands for the vector of year dummies. In case of fixed effects model D_i has to be dropped.

The reason for the introduction of country and year dummies is imperative. There are some qualitative features that characterize the nature of each of the countries and that cannot be quantified. These qualitative features may come from climate, geographical location, available resource endowments, forests, rivers, land area etc that are entirely country-specific. Since these cannot be quantified, D_i will take care of these. Similarly, there are factors shared by all countries in a given period, but which may vary across time (e.g. technology and macroeconomic fluctuations). One important example is world energy prices, which exert influence on carbon fuel consumption and CO_2 emissions common to all countries. Hence we control for this feature of the data by the inclusion of year-specific intercepts (D_t) in equation (3).

One final aspect that needs to be discussed is the calculation of 'peak' and 're-linking' per capita income.

Suppose we are using the following model

$$Y = AX^3 + BX^2 + CX + D$$

where Y is total CO_2, BOD etc and X is per capita income.

Then at the 'peak' and 're-linking' income

$$\frac{\partial Y}{\partial X} = 0 \Rightarrow 3AX^2 + 2BX + C = 0 \Rightarrow X = \frac{-2B \pm \sqrt{4B^2 - 12AC}}{6A}$$

and

$$\frac{\partial^2 Y}{\partial X^2} = 6AX + 2B < 0 \, for \max i.e., for' peak' income$$
$$\frac{\partial^2 Y}{\partial X^2} = 6AX + 2B > 0 \, for \min i.e., for' re - linking' income$$

We are now in a position to run the regression.

(2) Regressions

I) Carbon-di-oxide (CO_2)

One of major concern of today's world is the phenomenon of 'global warming'. And as the name suggests; it's not a problem of any particular region or nation or continent, rather it's a problem of the entire globe that can affect human lifestyle to a significant extent. A huge consumption of energy by the developed nations is one of the prime reasons behind this. Although greenhouse gas (GHG) emissions results from the economic activities of individual countries, their level of concentration in the atmosphere affects the global temperature and the climatic condition of each and every sphere of the world. As carbon dioxide (CO_2) is the major GHG that mainly originates from energy use, an in-depth analysis of the relation shared by economic activities and the level of CO_2 emissions as flow over different phases of development needs to be carried out. Since the present time sees the inter-regional scenario of income and CO_2 emissions of the world to be characterized by a high degree of inequality in the distribution of these variables amongst the people of its different regions, any policy prescription with respect to the global reduction of CO_2 emission can generate severe conflict in the multilateral economic fora. We shall take care of this aspect in policy implication section at the end of this chapter. Now let us first investigate the relation.

We start out with total CO_2 emission by 42 countries for the period of 1980-1999 i.e., for 20 years. The CO_2 figures are in thousand metric tones and the per capita GDP is in PPP (95 US$).

Notations:

$t\_co_2\_em$ = total CO_2 emission

p_pcgdp = per capita GDP in PPP (95 US$)

sp_pcgdp = square of per capita GDP in PPP (95 US$)

cp_pcgdp = cube of per capita GDP in PPP (95 US$)

popln = total population of a country

cy_d = vector of country dummies

yr_d = vector of year dummies

$$Y_{it} = \alpha + \beta_1 X_{it} + \beta_2 X^2{}_{it} + \beta_3 X^3{}_{it} + \beta_4 Z_{it} + \mu_i + V_{it}$$

Y is CO_2, X is per capita income and Z is population.

We first run the random effects regression by taking a cubic polynomial in per capita GDP and population as shown above. The result of the random effects regression is shown in the following table. Then we perform the routine Hausman specification test.

Syntax : xtreg t_co$_2$_em p_pcgdp sp_pcgdp cp_pcgdp popln

Table 1 : Random-effects regression result on CO$_2$

t_co$_2$_em	coeff.	std. error	z	P>|z|	[95% Conf. Interval]	
p_pcgdp	125.2632	8.674967	14.440	0.000	108.2605	142.2658
sp_pcgdp	-.0091949	.0006116	-15.035	0.000	-.0103933	-.0079961
cp_pcgdp	2.18e-07	1.32e-08	16.539	0.000	1.92e-07	2.44e-07
popln	.0033943	.0001097	30.945	0.000	.0031793	.0036093
const	-361427.8	54843.81	-6.590	0.000	-468919.7	-253935.9

Note: $R^2 = 0.4007$

However Hausman specification test reveals that this should be a fixed-effects model.

Hence from now we run fixed effects model for this case. We run different types of regression one after another and very briefly mention them under different cases below and present them in a condensed tabular form. The entire regression, in each case, is produced in the appendix for chapter 3. Parts of the results are produced in table 2.

Case (a): **Simple fixed effects regression.**

Syntax : xtreg t_co$_2$_em p_pcgdp sp_pcgdp cp_pcgdp popln, fe

The entire regression is produced in appendix 3(I)1. Part of the result is shown in table 2.

The relevant Peak income = 10724 (PPP 95 US$), Re-linking income = 16734 (PPP 95 US$).

Seeing the table it becomes quite clear that all the explanatory variables are significant at even 1% level as seen in the table and also the relevant curve would have a shape of 'N'. This is in conformity with the Environmental Kuznets Curve.

Case (b): **Same regression with the insertion of year dummies.**

Syntax : xtreg t_co$_2$_em p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d20, fe

The entire result is given in appendix 3(I)2. Part of the result is shown in table 2.

Here most of the time dummies are coming out to be significant.

Case (c): **Robust variance regression with both country and year dummies.**

Syntax: `reg t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2- cy_d42 yr_d2- yr_d20, robust`

The entire regression is produced in appendix 3(I)3. Part of the result is shown in table 2.

In all the estimations involving year and country dummies starting from the present one, the first year dummy (yr_d1) and the first country dummy (cy_d1) are dropped to escape the dummy variable trap. This implies that the sign of the year and country coefficients are to be interpreted with respect to the first year dummy and first country dummy respectively. Most of the time dummies and country dummies are turning out to be significant. R^2 is very high because of the introduction of country and year dummies. They are capturing a significant part of the total variation in CO_2 emission.

Case (d): **GLS regression.**

Syntax: `xtgls t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2-cy_d42 yr_d2- yr_d20`

The entire result is given in 3(I)4. Part of the result is shown in table 2.

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares, **Panels: homoscedastic, Correlation: no autocorrelation**

The results and the coefficients are identically same as the previous case.

Case (e): **GLS regression with heteroscedasticity in the panels.**

Syntax : `xtgls t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2- cy_d42 yr_d2- yr_d20 , p(h)`

Entire regression is shown in appendix 3(I)5. Part of the result is shown in table 2.

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares, **Panels: heteroscedastic,** Correlation: no autocorrelation

We can infer that allowing for heteroscedasticity in the 'panel' i.e. across the cross-section unit doesn't alter the result.

Case (f): **We finally allow for first order autocorrelation for each panel.**

Syntax : xtgls t_co$_2$_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2- cy_d42 yr_d2- yr_d20 , corr(ar1) p(h)

Entire regression is shown in appendix 3(I)6. Part of the result is shown in table 2.

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares, **Panels: heteroscedastic, Correlation: common AR(1) coefficient for all panels (0.8451)**

We suspect that there is autocorrelation but that doesn't alter the result. So any two successive idiosyncratic or exogenous shocks in each panel are related to each other but they do not have any significant impact on the dependent variable.

Case (g): In the previous case the autocorrelation coefficient between two successive terms for each panel (cross section, i.e. each country) was assumed to be constant. That means the autocorrelation coefficient for countries, say, a, b, c etc was one and unique. We know relax that assumption. We now assume that the autocorrelation coefficient across for each panel varies across panels, which implies that autocorrelation coefficients for country, say a, b, c etc are different. This is a more general result of the previous case.

Syntax : xtgls t_co$_2$_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2- cy_d42 yr_d2- yr_d20 , corr (psar1) p(h)

Entire regression is shown in appendix 3(I)7. Part of the result is shown in table 2.

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares, Panels: heteroscedastic, **Correlation: panel-specific AR(1)**

Most of the country and year dummies are significant at 5% level. Also the sign of the coefficients remains the same.

Case (h): We allow the **panels to be correlated** along with panel specific first order autocorrelation. It can happen that the features of one country are affecting the features of another country in terms of economic decisions. So their actions may be correlated. This command takes care of that. This is the most general case in the present context.

Syntax: xtgls t_co$_2$_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2-cy_d42 yr_d2-yr_d20, panels(correlated) corr(psar1)

Entire regression is shown in appendix 3(I)8. Part of the result is shown in table 2.

Cross-sectional time-series FGLS regression

Coefficients: generalized least squares, **Panels: heteroscedastic with cross-sectional correlation,**

Correlation: panel-specific AR(1)

Most of the country and year dummies are significant at 5% level. Also the sign of the coefficients remains the same.

The relevant peak income =9977 PPP (1995 US$) and re-linking income=15073 PPP (1995 US$)

Case (i): Eventually we are interested in knowing that whether or not developed countries are more prone to emit CO_2. This suspicion is rising from the following fact. If we divide our sample of 42 countries with respect to income then **18 countries are falling in high or higher/middle income group and the rest 24 are falling in low or**

lower/middle income group.[4] Now if we calculate the mean yearly emission for the richer and the poorer group as a whole then the figures that emerge are 551605.8823 and 171724.2978 thousand metric tones respectively. These two figures are strikingly different. The figures give rise to the suspicion that developed countries do have more tendencies to emit CO_2 than their counterpart. Let us now try to check whether the developed richer nations by and large have higher inclination to emit CO_2 than the poor underdeveloped countries.

For this purpose we introduce slope dummy (slp_dum) as

Slp_dum = 1 × (per capita GDP) = per capita GDP, for richer group

and, = 0 × (per capita GDP) = 0, for poorer group

Accordingly we drop the country dummies to avoid autocorrelation between that and the slope dummies. So the model stands like this

$$Y_{it} = \alpha + \beta_1 X_{it} + \beta_2 X^2_{it} + \beta_3 X^3_{it} + \ldots\ldots\ldots + \beta_k X^k_{it} + D_s + D_t + V_{it}$$

Where D_s stands for the vector of the slope dummies. Now if this slope dummy turns out to be significant with a positive coefficient, we can say that the rich countries have a greater inclination to pollute.

Syntax: xtgls t_co₂_em p_pcgdp sp_pcgdp cp_pcgdp popln slp_dum yr_d2-yr_d20, panels (correlated) corr(psar1)

Entire regression is shown in appendix 3(I)9. Part of the result is shown in table 2.

Cross-sectional time-series FGLS regression

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[4] To stratify our set of countries into two groups with respect to per capita income, we have used the definition provided by "The World Bank" in their book "World Development Indicators 2001". They have classified the countries across the globe into 4 groups. 1) Low income ($ 755 or less), 2) lower-middle ($ 756-2995), 3) upper-middle ($ 2996-9265) and 4) high ($ 9266 or more). The '$' is the 'current US $'. The income figures correspond to Gross National Income per capita.
When we divided our set of countries into 2 groups, we considered the low and the lower-middle income groups as a single group and classified that as the 'poorer' group. Similarly, we considered the high and the higher-middle income groups as a single group and treated them as the 'richer' group.

Coefficients: generalized least squares, Panels: heteroscedastic with cross-sectional correlation,

Correlation: panel-specific AR(1)

We run the regression and the result shows that the richer countries are more prone to pollute in comparison to the poorer countries. We present all the above 9 cases of regression (case(a)-case(i)) in table 2.

So considering case (a) and case (h), we can specify a range for 'peak' and 're-linking' income. These are [9977, 10724] (PPP 95 US$) and [15073, 16734] (PPP 95 US$) respectively.

Table 2 : Regression results on CO_2 for the period of 1980-1999

Dependent variable = CO_2 emissions / **Independent Variable**	*case (a)*	*case (b)*	*case (c)*	*case (d)*	*case (e)*	*case (f)*	*case (g)*	*case (h)*	*case (i)*
Per capita GDP	107.6837	118.817	118.817	118.817	56.7156	26.7991	37.2837	64.9757	69.59107
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Square of per capita GDP	-0.0082378	-0.0085684	-0.0085684	-0.0085684	-0.004005	-0.0013106	-0.0026218	-0.0054112	-0.0072286
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0030)	(0.0000)	(0.0000)	(0.0000)
Cube of per capita GDP	2.00E-07	2.06E-07	2.06E-07	2.06E-07	1.02E-07	3.11E-08	7.14E-08	1.44e-07	2.62e-07
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0050)	(0.0000)	(0.0000)	(0.0000)
Population	0.0038	0.0041	0.0041	0.0041	0.0030	0.0022	0.0025	0.0043056	0.0028469
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Year dummies	-	1st year dummy was dropped	1st year dummy was dropped	1st year dummy was dropped	1st year dummy was dropped	1st year dummy was dropped	1st year dummy was dropped	1st year dummy was dropped	1st year dummy was dropped
Country dummies	-	-	1st country dummy was dropped	1st country dummy was dropped	1st country dummy was dropped	1st country dummy was dropped	1st country dummy was dropped	1st country dummy was dropped	-
Slope dummies	-	-	-	-	-	-	-	-	3.669712
									(0.0300)
R^2	0.3691	0.3892	0.9953	.	.	.	.	.	.

(The figures without parentheses signify the coefficient of the relevant independent variable and the figures in the parentheses correspond to the p-values i.e., the level

of significance at which the independent variable is significant. From now onwards the figures without and with parentheses in each table will carry the same meaning.)

From the above table it is quite clearly seen that EKC is relevant in each of the cases as reflected by the signs of the income related variables. The emission is positively related to the population implying that more populous countries emit more CO_2. So population's pressure on environment is felt in terms of a rise in total CO_2 emission.

Now we want to see whether wealth of a nation and time are playing any role in the results that have already emerged. For this purpose we divide our set of countries into two groups in each case.

First we divide the set of countries according to their per capita income. The richer group comprises 18 countries and the poorer group comprises 24 countries.

Second we divide the panel according to decades. The first panel comprises all the 42 countries for the period of 1980-1989. Similarly, the second panel the same number of countries for the period of 1990-1999.

Case (j): **Regression for the richer group**. Initially we run the random-effect model and then perform the Hausman specification test, which suggests that model would be a fixed–effects one.

Syntax : xtreg t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d20, fe

Entire regression is shown in appendix 3(I)10.

The result is shown in tabular form in table 3.

All the variables are turning out to be significant. And there is no change is sign.

Next we do the same exercise for the poorer group of countries.

Case (k): We run the random-effect model and then perform the Hausman specification test, which suggests that the model would again be a fixed–effects one.

Syntax : xtreg t_co$_2$_em p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d20, fe

The entire regression is shown in appendix 3(I)11.

The result is shown in tabular form in table 3.

Cube of per capita GDP is turning out to be marginally insignificant at 5% level of significance. However, it is significant at 6% level. But all other variables are significant with usual sign.

Table 3 : Regression results on CO_2 for 'richer' and 'poorer' group of nations for the period of 1980-1999

Dependent variable = CO_2 emissions	*Case (j)*	*Case (k)*
Independent Variable		
Per capita GDP	102.2715	320.2266
	(0.0000)	(0.0000)
Square of per capita GDP	-0.0070996	-0.0555153
	(0.0000)	(0.0060)
Cube of per capita GDP	1.70e-07	3.48e-06
	(0.0000)	(0.0600)
Population	0.0076088	0.0036662
	(0.0000)	(0.0000)
Year dummies	First year dummy dropped	First year dummy dropped
Country dummies	- -	- -
R^2	0.8090	0.8270

Now we perform the same regression for the two decades.

__Case (l):__ We run the random-effect model for the period of 1980-1989 and then perform the Hausman specification test, which suggests that the correct model specification would be a fixed-effects one.

Syntax : xtreg t_co$_2$_em p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d10, fe

Entire regression is shown in appendix 3(I)12.

Part of the result is shown in tabular form in table 4.

All the variables are turning out to be significant with the usual sign.

Case (m): We run the random-effect model for the period of 1990-1999 and then perform the Hausman specification test, which suggests that the correct specification would be a fixed–effects one.

Syntax : xtreg t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d10, fe

Entire regression is shown in appendix 3(I)13.

The result is shown in tabular form in table 4.

Here also all the variables are turning out to be significant with the usual sign.

Table 4 : Regression results on CO_2 for the decades of 80s and 90s

Dependent variable = CO_2 emissions **Independent Variable**	*Case (l)*	*Case (m)*
Per capita GDP	89.56677	119.3593
	(0.0000)	(0.0000)
Square of per capita GDP	-0.0075878	-0.0076716
	(0.0000)	(0.0000)
Cube of per capita GDP	1.99e-07	1.69e-07
	(0.0000)	(0.0000)
Population	0.0043046	0.0038396
	(0.0000)	(0.0000)
Year dummies	The first year dummy is dropped	The first year dummy is dropped
R^2	0.2647	0.4384

Considering all the above results one can infer that while the feature of initial rise and the subsequent fall in total CO_2 emissions can be explained in terms effects of changing structural pattern of an economy and the technological sophistication accompanying the developmental process on income, the reversal of the downward trend of aggregate CO_2 emissions beyond an income of 16734 (PPP 95 US$) per capita (case a) clearly indicates the re-linking of economic growth with the environmental base, particularly with carbon emissions and requires to be explained. In any given technological regime, the opportunities of cost-effective energy conservation and carbon emission reduction would define a limited set of technological options. After all, no large-scale production is likely to be possible with zero carbon emission in the fossil fuel age of industrial civilization. When all the cost effective opportunities of material and energy conservation have been exhausted for adoption, the technical coefficients of carbon emissions are likely to reach some lower bounds at a stage of development like 16734 (PPP 95 US$) per capita. Any further growth of the economy beyond such a stage would very likely lead to re-linking between per capita GDP growth and CO_2 emissions. On the demand side as well, the income elasticity of scenarios shows the trend for rising demand for services in advanced economies with increase in per capita income, and most of the services, including travel and tourism, involve the direct or indirect use of electricity as well as transport. While more detailed cross-country analysis of the sectoral behaviour of energy consumption at different stages of development is required, the fact remain that this sort of lifestyle of the people is characterized by the extensive use of electricity and transport and that these contribute to increasing CO_2 emissions. These observations are thus also in conformity with the hypothesis of the 'N'-shaped relation between per capita income and environmental stress as found out in our study. However, in the context of CO_2 emissions control in the developing countries, what is more important is the estimation of the time period at which marginal CO_2 emissions with respect to income become zero and the range of time over which it will remain negative, for policy purposes. This involves the analysis of the dynamic pattern of the behaviour of total flow of CO_2 emissions with the rise in per capita income and the size of population. For this purpose we take two of the most important countries from Asia in the form of India and China and calculate the relevant time range for them. First we calculate the growth rate of per capita income (in PPP 95 US$) for these two countries. Second we calculate the number of years China and India will take to reach the 'peak' per capita income (10724 PPP 95 US$). This will give us the time range during which China and India would be polluting.

To overcome the volatility, we take 3-year moving average of the per capita income for these two countries and then calculate the growth rate for the moving average series. We calculate the growth rate by using the following formula

$$Y_t = Y_0 (1 + g)^t \tag{1}$$

Where Y_t is the per capita income in period 't', Y_0 is the per capita income in the initial period, 'g' is the growth rate of per capita income and 't' represents time.

Using the above equation we can write

$$\ln Y_t = \alpha + \beta t \tag{2}$$

Where $\alpha = \ln Y_0$ and $\beta = \ln (1 + g)$

$$\text{So } g = e^{\beta} - 1 \tag{3}$$

Using the above formula we find that China's per capita income growth rate is 8.56 % over the period of 1980-1999 (with respect to PPP 95 US$). The same for India is 3.58 %. With this growth rate, China and India will respectively take nearly 14 and 45 more years to reach a per capita income of 10724 PPP 95 US$. So China and India before experiencing a decline in total CO_2 emissions will take another 14 and 45 years respectively, which are year 2013 and year 2044 respectively. We take this issue in the policy implication section at the end of this chapter.

With this we come to the conclusion of CO_2 analysis. We have found the evidence of "EKC" in all the cases without any reference to countries wealth and the time frame. This means that no individual group of countries is affecting the result. Similarly, the time dimension has no role to play with the outcome as the existence of EKC is found for both the decades.

II) Sulphur-di-oxide (SO_2)

SO_2 is one of the most commonly used environmental indicators (for pollution). Various studies have used this indicator as a measure of air pollution. For example Grossman and Krueger (1995) have used this indicator as a proxy of air pollution for various cities. SO_2 are found in huge quantities in many cities, particularly in densely populated cities. Its quantum is very high in those cities where the vehicle density (vehicle per person) is very high. Its disastrous effects on human health and on natural environment are of paramount importance for policy purpose.

But again, there is a severe paucity of data on this indicator, which restricts the scope for its analysis. We managed to download panel data on this indicator for 27 developed countries (mainly west European countries) for the same period, i.e., for 1980-1999, from the website **www.emep.int/emis_tables/tab1.html** as no other panel database was available. But the reliability of this data is not beyond any doubt and suspicion.

The unit of SO_2 is thousand tones. The per capita income is in PPP (95 US$).

Case (a): We run the **random effects model.**

Syntax : `xtreg so2 p_pcgdp sp_pcgdp cp_pcgdp popln`

Part of the result is shown in Table 5.

Entire regression is shown in appendix 3(II)1.

We observe that again there is an evidence of EKC. Population is positively related with emissions.

The relevant peak per capita GDP = 11946 PPP 95 US$ and re-linking income = 32557 PPP 95 US$

Case (b): We run the **GLS model.**

Syntax : `xtgls so2 p_pcgdp sp_pcgdp cp_pcgdp popln , corr(ar1) p(h)`

Part of the result is shown in Table 5.

Entire regression is shown in appendix 3(II)2.

We observe that again there is evidence of EKC.

The relevant peak income = 12707 PPP 95 US$ and re-linking income = 32625 PPP 95 US$

<u>*Case (c)*</u>**:** Lastly we run the **robust variance regression.**

Syntax : reg so_2 p_pcgdp sp_pcgdp cp_pcgdp popln, robust

Part of the result is shown in able 5 and the entire regression is shown in appendix 3(II)3.

The relevant peak income = 12691 PPP 95 US$ and re-linking income = 24787 PPP 95 US$

The outcome of the robust variance regression is similar to the previous ones.

Table 5 : Regression results on SO_2

Dependent variable = SO_2 emissions **Independent Variable**	*Case (a)*	*Case (b)*	*Case (c)*
Per capita GDP	0.4352331	0.0497517	0.1896989
	(0.0000)	(0.0010)	(0.0800)
Square of per capita GDP	-0.0000249	-2.72e-06	-0.0000113
	(0.0000)	(0.0010)	(0.0530)
Cube of per capita GDP	3.73e-10	4.00e-11	2.01e-10
	(0.0000)	(0.0060)	(0.0410)
Population	9.26e-06	.0000371	.0000752
	(0.0570)	(0.0000)	(0.0000)
R^2	0.3634	.	0.8935

Now if we consider all these three regressions simultaneously, then for this set of countries and for the period 1980-1999, we can specify a small range for the 'peak income' for SO_2 as [11946, 12707]. Similarly, the range for the 're-linking' income would be [24787, 32625].

III) Biological Oxygen Demand (BOD)

'Biological Oxygen Demand' is a very important indicator of the state of water quality and hence the environmental quality. Its impact is felt through the state of welfare of the aquatic life living in the water of a region. The aquatic life requires dissolved oxygen to metabolize organic carbon. Contamination of river water by human sewage or industrial discharges increases the concentration of organic carbon in forms usable by bacteria. The larger the number of bacteria, the greater is the demand for the dissolved oxygen, and hence the lesser is the availability of oxygen for fish and other higher forms of aquatic life. If the contamination reaches beyond the tolerance limit, the fish population starts dying. So one can directly monitor the level of dissolved oxygen in water body as an indicator of the state of oxygen regime in the same. One measure of this, called 'Biological Oxygen Demand (BOD)', is the amount of natural oxidation that occurs in a sample of water in a given period of time. While the quantum of dissolved oxygen in a water body is an indicator of environmental quality in broader sense, BOD is an inverse measure, revealing the presence of contamination in a water body that results in oxygen loss, which is harmful for the environment. We investigate the relation between BOD and per capita income in the same manner as we did in the earlier case.

In case of CO_2 analysis, we had 42 countries but here we have 36 countries. Actually a few more countries had to be dropped from the set on account of the non-availability of data. The unit of BOD is kg per day.

We start out by running random-effects regression which is succeeded by Hausman specification test. This test reveals that the correct model specification in this case will be a fixed-effects one. So we start presenting the cases with a fixed-effects model.

Case (a): We start by running a fixed-effects model with year dummies. Country dummies are not required since the model is a fixed-effects one.

Syntax : `xtreg  bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d20, fe`

The signs of the explanatory variables are turning in tune with the existence of EKC. Also population is positively related to BOD.

The entire regression is presented in appendix 3(III)1. Part of the result is produced in table 6. The relevant peak income = 15529 PPP 95US$ and re-linking income = 25625 PPP 95US$

Case (b): Robust variance regression with country and year dummies.

Syntax: `reg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d20 cy_d2- cy_d36, robust`

The entire regression is produced in appendix 3(III)2. Part of the result is shown in table 6. The variables are all significant and the coefficients have the usual sign as in the previous case.

The relevant peak income = 15529 PPP 95US$ and re-linking income = 25625 PPP 95US$, which is identical to the earlier case.

Case (c): GLS regression with country and year dummies but without allowing for heteroscedasticity and autocorrelation in the cross section units.

Syntax : `xtgls bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d20 cy_d2- cy_d36`

The entire regression is produced in appendix 3(III)3. Part of the result is shown in table 6. The variables are all significant and the coefficients have the usual sign.

The relevant peak income and re-linking income remain absolutely same.

Case (d): We now allow for heteroscedasticity and autocorrelation across the panels and run the GLS regression.

Syntax : `xtgls bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d20 cy_d2- cy_d36, corr(ar1) p(h)`

The entire regression is produced in appendix 3(III)4. Part of the result is shown in table 6. The variables are all significant and the coefficients have the usual sign.

The relevant peak income = 12654 PPP 95US$ and re-linking income = 26590 PPP 95US$

Case (e): Finally we allow the panels to be correlated with a panel specific first order auto correlation as the most general case.

Syntax : xtgls bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d20 cy_d2- cy_d36, panels (correlated) corr(psar1)

The entire regression is produced in appendix 3(III)5. Part of the result is shown in table 6. The variables are all significant and the coefficients have the usual sign.

The relevant peak income = 7585 PPP 95US$ and re-linking income = 27180 PPP 95US$

Table 6 : Regression results on Biological Oxygen Demand for the period of 1980-1999

Dependent variable = BOD					
Independent Variable	*Case (a)*	*Case (b)*	*Case (c)*	*Case (d)*	*Case (e)*
Per capita GDP	228.0317	228.0316	228.0316	42.7001	24.86604
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Square of per capita GDP	-0.011791	-0.011791	-0.011791	-0.0024901	-0.0020964
	(0.0000)	(0.0010)	(0.0000)	(0.0060)	(0.0000)
Cube of per capita GDP	1.91E-07	1.91E-07	1.91E-07	4.23E-08	4.02e-08
	(0.0010)	(0.0070)	(0.0010)	(0.0380)	(0.0000)
Population	0.0107397	0.0107397	0.0107397	0.0039907	0.0010591
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0010)
Year dummies	First year dummy was dropped	First year dummy was dropped	First year dummy was dropped	First year dummy was dropped	First year dummy was dropped
Country dummies	.	First country dummy was dropped	First country dummy was dropped	First country dummy was dropped	First country dummy was dropped
R^2	0.7497	0.9483	.	.	.

So considering all the countries for the period of 1980-1999, we found a strong evidence for the existence of EKC. To check the robustness of the result we split the panel with respect to per capita income of the countries and then with respect to two decades.

Now we have 17 countries in the richer category and 19 countries in the poorer category. We start with the richer category.

__Case (f):__ We run the random-effects model first and then perform the Hausman test, which suggests that the present case needs a random-effects analysis. We run the random effect regression with country and year dummies.

Syntax: xtreg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d20 cy_d2- cy_d17

The entire regression is shown in appendix 3(III)6. Part of the result is shown in table 7. The income related variables are all significant and the coefficients have the usual sign.

Next we perform the same exercise on the poorer group of nations.

__Case (g):__ We run the random-effects model first and then perform the Hausman test, which suggests that the present case needs a fixed-effects analysis. Hence we run the fixed-effects regression with year dummies.

Syntax: xtreg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d20, fe

The entire regression is shown in appendix 3(III)7. Part of the result is shown in table 7. Two of the income related variables are significant while the cube of per capita GDP is turning out to be insignificant but the coefficients have the usual sign. Population's effect on BOD is marginally positive.

Since the sign of per capita GDP and square of that are respectively positive and negative in both the cases, we can infer that EKC is true both for richer and poorer group of countries.

Table7 : Regression results on BOD for 'richer' and 'poorer' group of nations for the period of 1980-1999

Dependent variable = BOD **Independent Variable**	*case (f)*	*case (g)*
Per capita GDP	69.54178	1264.678
	(0.0000)	(0.0000)
Square of per capita GDP	-0.0047624	-0.1747041
	(0.0000)	(0.0570)
Cube of per capita GDP	9.42e-08	8.93E-06
	(0.0000)	(0.3260)
Population	0.0034698	0.008241
	(0.0000)	(0.0000)
Year dummies	First year dummy is dropped	First year dummy is dropped
Country dummies	First country dummy is dropped	-
R^2	0.9973	0.7291

We now perform the same analysis for each of the two decades. We start by running the regression for the first decade i.e., for 1980-1989.

Case (h): We run the random-effects model first and then perform the Hausman test, which suggests that the present case needs a fixed-effects analysis. Hence we run the fixed-effects regression with year dummies.

Syntax: xtreg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d10, fe

The entire regression is given in appendix 3(III)8. Part of the result is shown in table 8. Two of the income related variables are significant at 5% level of significance while the cube of per capita GDP is marginally insignificant at that level but significant at 6% level. However, the coefficients have the usual sign and population's effect on BOD is marginally positive.

Case (i): We do the same exercise for the decade of 90s. We run the random-effects model first and then perform the Hausman test, which suggests that the present case needs a fixed-effects analysis. We run the fixed-effects regression with year dummies.

Syntax: xtreg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2- yr_d10, fe

The entire regression is shown in appendix 3(III)9. Part of the result is shown in table 8. All the income related variables are significant at 5% level of significance The coefficients have the usual sign and population's effect on BOD is marginally positive.

Table 8 : Regression results on BOD for the decades of 80s and 90s

Dependent variable = BOD **Independent variable**	*Case (h)*	*Case (i)*
Per capita GDP	104.0539	298.5344
	(0.0010)	(0.0000)
Square of per capita GDP	-0.0059571	-0.0143756
	(0.0110)	(0.0010)
Cube of per capita GDP	9.88e-08	2.20e-07
	(0.0590)	(0.0090)
Population	0.0055888	0.0103413
	(0.0000)	(0.0000)
Year dummies	First year dummy is dropped	First year dummy is dropped
R^2	0.7577	0.7635

So we see that with a very few exceptions biological oxygen demand is also following an EKC with nation's development. For our sample of countries and for the years 1980-1999, it behaved in the same fashion like CO_2. Also the relevant R^2 are very high.

IV) Energy Intensity of GDP

The total CO_2 emission in an economy is perfectly equal to the product of the population, the per capita GDP, the energy intensity of GDP and the CO_2 intensity of energy. If energy intensity of GDP and CO_2 intensity of energy remain invariant over time, the total CO_2 emission would be directly proportional to the GDP. But in the process of development of an economy, both energy intensity of GDP and CO_2 intensity of energy change with the growth of per capita income. It is thus energy intensity of GDP becomes a very important indicator of environmental quality through it effect on CO_2 emission. If all other variables remain the same then a rise in energy intensity of GDP is likely to raise total CO_2 emission in an economy. The magnitude of energy intensity of GDP depends on various factors. The most important factors are the sectoral product composition of the economy, the rate of urbanization, the state of infrastructure, the composition of primary commercial energy resources and lastly the stage of technological development. With the inception of development, excluding the last factor, all other factors are very likely to affect energy intensity of GDP and hence in the initial phase of development energy intensity of GDP is very likely to rise. However during the later phase of development when the service sector becomes dominant in the overall economic scenario and the share of industry in final output declines, the development of physical infrastructure reaches its maximum, the process of urbanization is almost complete and the substitution of commercial fuels by non-commercial energy resources is almost complete, then energy intensity of GDP is likely to fall in an economy. This can be true for the developed nations of the west. We try to investigate the relation between energy intensity of GDP of a country with its per capita GDP, urbanization, openness and the value added in the industry as a percentage of GDP.

Notations

eng_gdp = Energy intensity per unit of GDP. Its unit is kg of oil equivalent per 1995, PPP US$

openness = Trade divided by GDP. This is equal to the ratio of (import plus export of goods and services) and GDP at factor cost[5]

urbnsn = Rate of urbanization. This is equal to the ratio of urban population and total population in a country.

ind_va = Value added in the industries as a % of GDP.

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[5] Though there are several other measures of openness of a nation, we select this measure because of the availability of data

We start with a linear model. Here we have 39 countries and a period of 1980-1999. Out of which 18 countries belong to the richer group and the 21 rest countries belong to the poorer group.

We first run a random effects model and then perform the Hausman specification test, which favours the fixed-effects model.

<u>Case (a)</u>: Fixed-effects model with year dummies.

Syntax : xtreg eng_gdp p_pcgdp openness urbnsn ind_va yr_d2- yr_d20, fe

The entire regression is presented in appendix 3(IV)1. Part of the result is produced in table 9.

<u>Case (b)</u>: GLS regression with both country and year dummies.

Syntax : xtgls eng_gdp p_pcgdp openness urbnsn ind_va yr_d2-yr_d20 cy_d2- cy_d39, corr(psar1) p(h)

The entire regression is given in appendix 3(IV)2. Part of the result is produced in table 9.

Table 9 : Regression results on Energy Intensity of GDP

Dependent variable = Energy Intensity of GDP	*Case (a)*	*Case (b)*
Independent Variable		
Per capita GDP	-4.02e-06	-3.61e-06
	(0.0130)	(0.0180)
Openness	.0002883	.000353
	(0.0160)	(0.0010)
Urbanization	-.0048606	-.0050779
	(0.0000)	(0.0000)
Value added in industry as a % of GDP	-.0015578	-.0011831
	(0.0010)	(0.0010)
Year dummies	First year dummy was dropped	First year dummy was dropped
Country dummies	-	First country dummy was dropped
R^2	0.1463	-

From the above table we quite clearly see that all the variables in both the cases are significant at 5% level. Only openness is positively related to energy intensity of GDP and all other explanatory variables are negatively related with the same. This is a bit surprising but this can be understood if we split the set of 39 countries into richer group (18 countries) and poorer group (21 countries). For these two groups we calculate the yearly average of energy intensity of GDP, yearly average per capita income, yearly average urbanization, yearly average openness and yearly average value added in the industries as a percentage of GDP. We see that energy intensity of GDP (expressed in the earlier mentioned unit) for the richer and the poorer groups of countries are respectively 0.2181 and 0.3084. These two figures are wide apart. The relevant figures for urbanization, openness and value added in the industries as a percentage of GDP are respectively (rich =76.25, poor =35.72), (rich =55%, poor =52%), (rich =34.34, poor =29.18).

Now one can feel interest in verifying whether the populations from where the sample of rich and poor countries are coming differ significantly with respect to their mean of energy intensity of GDP. We calculate the yearly average of energy intensity of GDP for the poorer and the richer countries. So we have a sample of 20 observations for each group of countries. Without loss of generality we can assume that the sample of richer countries is selected from the population of all richer countries across the globe. Similar is the case for the poorer countries. We assume that for both the populations, energy intensity of GDP follows normal distribution with parameters $N(\mu_1, \sigma_1^2)$ (for richer group) and $N(\mu_2, \sigma_2^2)$ (for poorer group) respectively. We want to test whether μ_1 and μ_2 differ significantly. So we can arrange the hypotheses as

Null hypothesis, H_O : $\mu_1 = \mu_2$

Alternative hypothesis, H_1 : $\mu_1 \neq \mu_2$

To test this hypothesis, we first need to check whether the population standard deviations are equal. The test shows that they are not equal (the result is given in appendix 3(IV)3).

Now we use the Welch correction for the level of significance for two different populations having unequal variance. The result is shown in appendix 3(IV)4. This test clearly shows that the second group of sample is coming from a population having higher population mean. So by and large low-income countries has a higher energy intensity of GDP as compared to their counterparts.

We can as well examine the dynamic behaviour of the energy use with respect to the increment in GDP per capita for both the richer and the poorer group of countries and for each decade. We start with the richer group of countries and the decade of 1980 and then we pass on to the next decade for the same group of countries. We proceed similarly for the poorer group of countries. We show the results in table 10. The relevant set of regressions are produced in appendix 3(IV)5(a), 3(IV)5(b), 3(IV)5(c) and 3(IV)5(d).

Table 10 : GDP elasticity of Energy for 'richer' and 'poorer' group of countries

Dependent variable = ln(energy)= ln_eng	**Richer group of countries**		**Dependent variable = ln(energy)= ln_eng**	**Poorer group of countries**	
Independent variable = ln(GDP)= ln_gdp	**1980-1989**	**1990-1999**	**Independent variable = ln(GDP)= ln_gdp**	**1980-1989**	**1990-1999**
Coefficient or GDP Elasticity of Energy	0.6498071	0.7609168	Coefficient or GDP Elasticity of Energy	0.421843	0.719803
	(0.0000)	(0.0000)		(0.0000)	(0.0000)

From the above table it is seen that for the richer group of countries the GDP elasticity of energy has increased from 0.6498071 to 0.7609168 from the period of 1980-1989 to 1990-1999 respectively. But this is not a very steep increase. On the other hand the GDP elasticity of energy for the poorer group of countries has increased considerably from 0.421843 to 0.719803 respectively from the period of 1980-1989 to 1990-1999.

So it's quite clear that more urbanized developed economies preserve their energy resource may be through a better technology. This is also evident from the fact that despite having a larger share of industries in GDP as compared to the poorer countries, the richer countries have lower energy intensity of GDP. This can happen if the technology is sophisticated so that it does not create an enormous stress on the natural resources that generate energy. It can be better understood if we consider the reciprocal of Energy Intensity of GDP, i.e., if we consider GDP per unit of energy used. The latter ratio signifies the contribution of one unit of energy in GDP. This ratio is greater in case of the developed nations. So the marginal contribution of energy in the production process in the developed nations is much higher than the same in the underdeveloped nations. This signifies the striking disparity between the state of technology used in developed and in underdeveloped world. In developed countries the technology used in production is sophisticated and hence its contribution to total output is more and the stress on natural resources are relatively less in those.

We now turn our attention to two relatively less important environmental indicators. These are NO_2 and total value of deforestation.

V) Nitrogen-di-oxide (NO_2)

Here also, like the case in SO_2, we have 27 countries. We test whether NO_2 also follows the dynamics of EKC.

First we run the random effects model and then perform the Hausman test, which suggests that the model is a fixed effect one. Hence we run the fixed effects model.

Case (a): We take per capita income and its square and its cube and population as the explanatory variables and run the fixed effects model.

Syntax: `xtreg no2 p_pcgdp sp_pcgdp cp_pcgdp popln, fe`

We show the result in appendix 3(V)1. Part of the result is shown in table 11.

Case (b): GLS regression with country and year dummies.

Syntax: xtgls no_2 p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2-cy_d27 yr_d2-yr_d20, panels(correlated) corr(psar1)

The whole result is in appendix 3(V)2. Part of the result is shown in table 11.

From table 11, it can quite clearly be seen that the dynamics of NO_2 is also of the EKC type. All the income related variables turned out to be significant. Population is also significant inserting a positive effect on NO_2 emissions.

Table 11 : Regression results on NO_2

Dependent variable = NO_2	*Case (a)*	*Case (b)*
Independent Variable		
Per capita GDP	0.1114915	0.0413518
	(0.0000)	(0.0000)
Square of per capita GDP	-5.99e-06	-9.12e-07
	(0.0000)	(0.0060)
Cube of per capita GDP	9.36e-11	8.79e-12
	(0.0000)	(0.0600)
Population	0.0000392	.0000368
	(0.0000)	(0.0000)
Year dummies	-	First year dummy is dropped
Country dummies	-	First country dummy is dropped
R^2	0.9218	-

VI) Deforestation

Forest plays an immensely important role in the conservation of biodiversity and ecosystem. It generates fresh oxygen for the living creatures. Deforestation of any sort not only generates CO_2 emissions and soil erosions, it could lead to result in an imbalance in the ecosystem. A country can experience deforestation because of many reasons. One of the main reasons of deforestation is urbanization. But the regression results might produce an ambiguous context. Let us explain this briefly. If we take a careful look at our dataset, we see that almost all the developed and massively urbanized countries register zero net amount of deforestation. So the regression results might show that urbanization mitigates deforestation. But that is not the true case. Deforestation mainly takes place in the developing nations that are gradually urbanizing. In the process of urbanization, people in these countries cut down their forests to arrange for shelter, food, business etc. Environmentalists talk about another important reason behind deforestation in the underdeveloped countries. According to them many underdeveloped nations deplete their forest or extract a huge amount of resources from forest or create stress on their natural resources just to reduce the burden of foreign debt through repayment. So in their opinion indebtedness is one of the principal factors behind deforestation. We try to see whether income, urbanization etc can explain the phenomenon of deforestation.

Before running for regression, we check the dataset for heteroscedasticity. We see that the panels are heteroscedastic. So we should apply GLS approach here. We see year dummies don't have any significance in explaining the variation in total deforestation. Hence we drop year dummies and finally run the regression with having the country dummies.

Syntax: xtgls dfrstn p_pcgdp sp_pcgdp cp_pcgdp urbnsn openness debt cy_d2-cy_d35, panels(correlated) corr(ar1)

Here defrstn = total value of deforestation

and debt = indebtedness, defined as the total debt service (% of exports of goods and services) to the IMF

We present part of the result in table 12. The whole regression is shown in 3(VI)1.

Table 12 : Regression results on Deforestation

Independent Variable	**Per capita GDP**	**Square of per capita GDP**	**Cube of per capita GDP**	**Urbanization**	**Openness**	**Indebtedness**	**Year dummies**
Dependent variable = Total Deforestation	0.0011513	-1.15e-07	2.46e-12	0.6100957	0.7297934	0.0037556	1st year dummy is dropped
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.1000)	

From the above table we see that total value of deforestation also has a tendency to exhibit the dynamics of EKC. It also shows that (amongst the developing nations) more urbanization is accompanied by more deforestation. Similarly in that stratum of countries, more openness implies more deforestation. Finally more indebted countries have a tendency to deplete their forest. Though debt, as an explanatory variable of deforestation, is rejected at 5% level of significance but it is significant at 10% level of significance.

B. Explanation for the existence of EKC

1) Change in the structure of the economy

At the very outset of development an underdeveloped country depends immensely on its agricultural sector in terms of subsistence farming and labour intensive technologies. With increase in income, gradually this thrust spills over to the industries and this results in the inception of industrialization. Heavy industries start occupying the largest share of the GDP and the traditional labor-intensive technologies get replaced by advanced capital-intensive technologies. These capital-intensive techniques depend heavily on the use of machines, which are more prone to pollution. In the next stage of development these heavy industries give way to the light consumer product industries and the thrust of the economy shifts from industry to the tertiary or service sector. This shift results in depletion in the quantum of pollution. In the ultimate stage of development the services sector starts playing the dominant role. This is particularly important for the 're-linking' phenomenon or the 'N' shape of the EKC. Most of the services sector, including information technology sector, telecommunication sector and the sector relating to travel and tourism consume huge amount of electricity that generate stress on energy, which generates CO_2 and other pollution. The accounts for the rise in pollution and as a result the 're-linking' phenomenon takes place.

2) Change in attitude and preference

In the initial stages of development of a country, people feel more concerned about food, employment and shelter. Thereafter as economy grows and gradually reaches to an advanced stage of development, people start recognizing the importance of the environment. Thus environment is basically a normal or sometimes a luxury good, as described in various theoretical models. With increment in income people attach more and more importance to environmental amenities. After a particular level of income is reached, people start spending more than proportionate increase in their income on environment. This is reflected in the formation of different organizations for environmental protection as well as people's willingness to donate for a cleaner environment in the later stage of development. This phenomenon is attributable to the prioritization of objectives both at individual and at national level. Maintaining a decent environmental standard for a sustainable development comes only when the initial anxiety for growth is overcome.

3) Change in policies

Market failures, ill-defined property rights for natural resources, lack of payment for the environmental externalities and severe policy distortions can be thought to play a vital role in the relative steepness of EKC during the first stage of development. But as soon as the economy reaches the second stage of development, the abolition of market distortion, establishment of property rights for natural resources and the inception of policies designed to internalize environmental externalities; emerge in the picture. All these are policy related changes. During the initial stage of development an LDC cannot afford to have strict environmental policy owing to its anxiety for economic growth. But in the second stage more stringent environmental policies, generation of public awareness, and protection of intellectual property rights start replacing the scenario of the earlier stage. This has happened in many developed countries in the west. Since environmental quality does not have any market, this upsurge in citizen's consciousness on environment starts getting reflected through public policies in the form of new norms and legislations on environment.

4) Technological innovation

Technological innovations, depending on its stress on natural resources, may benefit or harm the environment. In this direction the government in a developing country can play a vital role. The government may encourage the innovation of 'greener technology' creating lesser stress on natural resources. This concerns not only traditional technological aspects but also the state of production and the structure and design of products. The economic agents steadily get accustomed to 'green thinking' that may result in dematerialization of products and increased possibilities for recycling of waste products, with the potential to diminish environmental intensity of GDP.

5) **International relocation of industries**

Arrow et al. (1995), Stern et al. (1996), Eakins (1997) and Rothman (1998) have highlighted the linkage that works between consumption pattern, international trade and structural change in production. Their conjecture is based on the developed economies. According to them if the structure of consumption basket remain invariant to the change in the structure of production sphere of a developed economy, the EKC may simply record displacement of dirty industries to the less developed economies having lax environmental norms and regulations. An attractive feature of this 'displacement hypothesis' is that the reallocation of dirty industries can explain the inverted U curve effectively: decrease in pollution in developed and increase in developing countries, something we shall try to analyse in the later chapters of the present study. Not too many empirical studies support this argument as they were mainly carried out from the sphere of developed countries. However, a few economists have predicted this phenomenon through some interesting studies. One such study was carried out by Patrick Low and Alexander Yates (1992). They empirically analyzed the migration of dirty industries to the developing countries in terms of their conception of 'revealed comparative advantage'. Also Opschoor, Reijnders (1991) and Stern Common, Barbier (1994) have inferred that the observed U-shaped curve might be an outcome of the changes in the pattern of international specialization in trade and production in view of the differential pattern of the environmental regulation across the countries. According to them the poorer countries just cannot afford to have stringent environmental norms and regulations in view of achieving faster economic growth. In the process they might end up in attracting dirty, material and energy intensive industries on their soil while the developed nations would specialize in cleaner industries and hence would dematerialize their growth process without changing their pattern of consumption. Interestingly enough, with reference to a macro model of industrial metabolism, it has further been pointed out that such a tendency of de-linking economic growth from environmental base might not be persistent as some of the advanced industrialized economies have already entered a new phase of re-linking, particularly since the late 80s, which could explain even the 'N' shape of the EKC, something we have found in our analysis.

C. Policy Implication

Since a huge number of developing countries are passing through the income range where the total amount of CO_2, SO_2 emissions and the BOD are rising and also their energy intensity of GDP is higher than that of the developed countries, the existence and the features of the 'de-linked' phase of development have important consequence with reference to the choice of the future course of action in the developing countries for the climate control in the long run. Since any increment in these variables beyond the tolerance limit can damage human standard of living, can we afford to remain silent except trying to control the population? The Intergovernmental Panel on Climate Change (IPCC) has calculated the future GDP growth rate of different parts of the world. Using their calculation of income growth and also using the coefficients of the independent variables from our regression analysis, we can calculate the date of stabilization of CO_2, SO_2 emissions and also the quantum at which these would get stabilized (like we did in case of China and India). However, the aggregate global population that would be accompanied by the CO_2 emission stabilizing per capita income in the long run would be very high given the deliberation of the IPCC and the emission-stabilizing goal of the UN Framework Convention on Climate Change (UNFCCC). They have targeted to reduce the CO_2 emission to a fraction of its 1990 level by somewhere around the year 2015.

CO_2 and other greenhouse gases impact the climate system in two ways. First with their pre-existing stock and second with the amount of flow generated due to human activities. These factors determine the global CO_2 accumulation and concentration. So one should keep a watch at both of these. The possibility that by allowing a business-as-usual scenario, we end up with the global stabilization of flow of CO_2 emissions at too late a date and at too high a level of flow of CO_2 emission with linearly rising level of CO_2 concentration at a pace which might have quite an adverse impact on the climate system, cannot be ruled out. So the relevance of appropriate police measure that can cope with this issue can never be questioned from any viewpoint. So in such an eventuality, what should the design of policies be so that the CO_2 stabilizing per capita income level and the date of CO_2 stabilization are respectively lowered with a similar diminution in the 'peak' CO_2 emission level as well?

Given this austere scenario, let us now turn our attention to the feasible set of policies that can nullify the severity of the forthcoming situation. As the OECD countries approached the stabilization of the CO_2 emissions at high level, populous developing countries like China and India (14 and 45 years respectively to reach the 'peak' level of CO_2 emissions) would be largely contributing an increasing share of the total flow of CO_2 emissions in the near future. If this can be stopped for the major developing countries having huge demographic pressure, part of the problem of global warming would be solved. Modeling for the country or regional level is always easier than the same for the global level because of the latter's diversity. So the country-level modeling for the developing countries like China, India, Indonesia, Brazil etc is enormously important. The areas that deserve special attention of the researchers are the following:

a) The potential as well as the anticipation of CO_2 emissions for an assumed economic and demographic growth and the oil price scenario,

b) The policy options for the reduction of growth of CO_2 emissions to achieve a targeted global environmental quality for the purpose of climate control,

c) The supporting prerequisite through an international cooperation to share the costs of such CO_2 abatement, if necessary.

Climatic forecasting is always uncertain. But even then, at the very outset, we need to investigate about the exact nature through which CO_2 and other GHG concentrations impact the pattern of air circulation, ocean current, precipitation etc. Since this investigation is uncertain, the importance shifts to the critical level of concentration of CO_2 beyond which the risk of catastrophic changes in the earth's geography and climate becomes suddenly high, making adaptation to the changed environment very difficult, if any such threshold exists. Hence there is always a need to scientifically formulate the global air quality standard that can assure the safety of the global environment with its normal functioning. Once this is done, the distribution of responsibilities across countries comes into the picture. This distribution of responsibilities can be taken care of through a collective political process. The trend of the past, the present and the anticipation of the future CO_2 emissions may be widely different from the distribution of the economic opportunities of CO_2 across the nations. Similar is the case with the distribution of 'ability to pay' across countries. Some of the poorer developing countries may have some opportunity of reducing CO_2 emissions within a short span of time, but they may require the mobilization of large amount of capital for that. On the other hand availability and the costs of different options of CO_2 abatement, comprising among others, technological upgradation for energy conservation, fuel substitution in favour of relatively less carbon-intensive fuel (like natural gas, e.g., CNG), backstop technologies based on renewables like biomass, solar and wind resources, application of fuel cell, magneto hydrodynamics and hydrogen, CO_2 sequestration, and CO_2 removal and storage would vary from country to country. Now if we want to take a policy decision to set the standard for the individual countries, it should involve the consideration of global cost minimization for the climate control as well as that of equity with reference to the distribution of the burden of the global cost among the nations. The comparison among the schedules of the marginal cost of the alternative standards for GHG emissions of the different countries may point to the imposition of stringent standards for the developing countries like china or India in the interest of global cost minimization. However, given their ability to pay, such imposition would cause in a result leading to a trade-off between deceleration in the speed of development and the environmental quality, if there were no international cooperation regarding the flow of international finance or aid for the underdeveloped countries. While the climate change problem addresses the problem of intergenerational equity, the choice of policy options for resolving the problem would, thus inevitably lead us to the intragenerational issue.

Economic growth contributes not only to the accumulation of man-made capital but also to the quality of life of mankind. Thus human resource development would induce an effect towards the stabilization of the size of population and the innovative ability of the people to keep pace with the technical change of a society. Both of these would, in turn, contribute directly and indirectly to the stabilization or the setting in of a declining trend of CO_2 and other GHG emissions from human activities. Thus in the near future, the accumulation of man-made capital and human capital could gradually enable us to cope with any unfortunate catastrophic change that unpredictably occurs due to the combination of the problems of non-linearities of the relationships of climate variables and the uncertainties in this area of science. This is the reason why setting an ambitious GHG emissions targets for the developing countries or for the global level in the high abatement cost range by forgoing economic growth to a significant extent, would not be the best policy. What would be wiser as a strategy is to set a target of GHG emissions reduction over a certain time horizon and then go on revising it upwards with the passing of time in the long run. In this way we can approach the level that is needed to avert any high-risk situation of catastrophic climate change or high marginal damage cost due to non-linearities in the involved relationships. In other words, assuming risk aversion and climate stabilization to be laudable objectives in the interest of human well-being at the global level, climate control should be phased over time in a situation of high cost beyond a range of GHG emissions reduction. However, the process of stabilization of climate should have to be swift and fast since the cumulative emissions may be too high for any climate stabilization, and the crucial climate variables may threaten to reach their threshold levels. It may, therefore, be important for the global community to share the global cost of climate control not in proportion to the costs incurred within the national boundaries but by cooperating for the inception of a substantive international transfer of resources amongst the nations for the purpose. Besides, the industrialized countries may even be required optimally to make some sacrifice in the form of change in the lifestyle to make it more environment friendly and slow down their own pace of growth, if necessary, in order to avoid the 're-linking' of economic growth with the GHG emissions and allow the same of the poorer countries to grow for some time and yet enable the global community to reach a situation of climate stabilization. All of these would indicate the problems of international political economy and hence need to be resolved at the global political fora.

Chapter 4

4. Overall Environmental Index and Macroeconomy

The overall environmental condition of a country cannot be portrayed in terms of only one indicator. Rather the overall scenario of a nation depends on various (more than one) environmental indicators, each of which plays an important role in determining the overall quality of environment. In this chapter we shall try to see the overall environmental scenario of various nations through the formation of an indicator that will try to capture the wide variation prevailing in different environmental aspect. Then we shall try to see the impact of economic activities on that indictor.

The novelty of this lies in the following fact.

1) We have not come across any study that formulated a joint environmental index,
2) Different studies have considered the environmental aspects from various angles at local, city or state level. But there is a dearth of country level study,
3) An index of overall environmental quality can be useful for policy purpose.

A. Methodology

Our analysis is concerned with 35 countries across the globe having a population of more than 15 million in 1999 (with the exception of Hong Kong). This set of 35 countries is comprised of 2 groups of countries. The relatively poor group has 18 countries in the form of Algeria, China, Colombia, Egypt Arab Republic, Ethiopia, Ghana, India, Indonesia, Iran Islamic Republic, Kenya, Morocco, Mozambique, Nepal, Pakistan, Peru, Philippines, Sri Lanka, and Syrian Arab Republic. The richer group consists 17 countries. These include Argentina, Brazil, Canada, Chile, France, Hong Kong, Italy, Japan, Korea Republic, Malaysia, Mexico, Netherlands, South Africa, Spain, United Kingdom (UK), United States Of America (USA) and Venezuela, RB. We have considered 5 environmental indicators whose data were available. These are

1) Industrial CO_2 emission (kg) per unit of GDP,
2) BOD (kg per day) per unit of GDP,

3) Commercial energy use (kg of oil equivalent) per unit of GDP,

4) Value of Deforestation (net forest depletion) per unit of GDP and

5) Value of Mineral depletion per unit of GDP

The GDP is expressed in PPP 95 US$ to maintain the comparability amongst the countries.

There is a wide range of variation within this set of five environmental indicators. So in order to have a glimpse of overall environmental quality of a particular nation for a particular year, we need to form a composite index in such a manner that the index can capture a significant part of the total variation amongst these 5 indicators. Needless to say that this overall index shall have to be a function of these 5 indicators.

In order to do so, we construct a composite by using 'Principal Component Analysis (PCA)'. Despite having some limitations, it is a very scientific method. And in order to check the validity or robustness of PCA, we compared the outcome of PCA with the outcome of another indexation procedures, which we shall describe after we take a brief look at the nature of PCA.

A Resume of 'Principal Component Analysis (PCA)':

In this type of analysis the total variance of a set of 'n' points in 'p' dimensional space is described by a new set of 'p' orthogonal and uncorrelated variates. Taking normalized linear combinations of the original set so that the 'r^{th}' variate generated has the 'r^{th}' largest variance forms the new set.

Suppose the vector of observations $X' = (X_1, X_2, \ldots\ldots\ldots, X_p)$ has a variance-covariance matrix Σ. For mathematical convenience and without loss of generality, it is assumed that the mean of X_i is zero for all $i = 1, 2, \ldots\ldots, p$. To find the first principal component $Y_{(1)}$, a vector of coefficients $\gamma' = (\gamma_1, \gamma_2, \ldots\ldots\ldots, \gamma_p)$ are calculated such that the variance of $\gamma' X$ is a maximum over the class of all linear combinations of X subject to $\gamma'\gamma = 1$. This constraint prevents one from increasing the variance of $\gamma' X$ arbitrarily by making the components of γ large. For a given vector γ one canalways find another with a larger variance by choosing a vector having the same direction as γ but with a greater length. This amounts to multiplying γ by a constant, which does not alter the basic characteristics of $\gamma`X$. thus only the direction of γ shodld determine its suitability as a solution, and not its length. For the sake of convenience the length of γ is assumed to be unity, as it should be a constant and not enter into comparison. The problem thus reduces to

$$\text{Maximize } \gamma`\Sigma\gamma \text{ with respect to } \gamma$$

$$\text{Subject to } \gamma`\gamma = 1.$$

It can be shown that the γ coefficients must satisfy the p simultaneous linear equations

$$(\Sigma - \lambda_{(1)} I)\gamma_{(1)} = \mathbf{0}$$

Where the right hand side of the above equation is a (p x 1) null vector and $\lambda_{(1)}$ is the Lagrange multiplier. If the solution of these equations is to be non-null, the value of $\lambda_{(1)}$ must be chosen such that

$$| \Sigma - \lambda_{(1)} I | = \mathbf{0}$$

Thus we find that $\lambda_{(1)}$ is the largest eigen-value (root) of Σ and the required solution for γ is the corresponding eigen-vector, denoted by $\gamma_{(1)}$. Hence the first principal component can be written as $Y_{(1)} = \gamma`_{(1)} X$.

The next principal component is found by calculating a second normalized vector $\gamma_{(2)}$, orthogonal to $\gamma_{(1)}$, that will make $Y_{(2)} = \gamma`_{(2)} X$ have the second largest variance among all vectors satisfying the constraints $\gamma`_{(1)}\gamma_{(2)} = 0$ and $\gamma`_{(2)}\gamma_{(2)} = 1$. Following previous procedure, it can be shown that $\gamma_{(2)}$ is the eigen-vector corresponding to the second largest eigen-value of Σ, namely $\lambda_{(2)}$. The process continues until all ‘p’ eigen-vectors are generated where $\gamma_{(r)}$ is normalized and is orthogonal to $\gamma_{(1)}, \gamma_{(2)}, \ldots\ldots\ldots\ldots, \gamma_{(r-1)}$, $r = 2, 3, \ldots\ldots\ldots, p$.

The contribution of the i^{th} variable to the j^{th} principal component is given by the magnitude of coefficient $\gamma_{i(j)}$, with the algebraic sign indicating the direction of the effect. The covariance of the i^{th} response, $X_{(i)}$ with $Y_{(j)}$ is simply $\gamma_{i(j)}\lambda_{(j)}$.

The sample variance of the observations with respect to the j^{th} principal component is given by $\lambda_{(j)}$. The total variance of the p-variables is given by

$$\mathrm{Tr}(\Sigma) = \sum_{j=1}^{p} \Sigma_{jj}$$

It also holds that $\mathrm{Tr}(\Sigma) = \sum_{j=1}^{p} \lambda_{(j)}$

which shows that the sum of sample variances with respect to the derived coordinates is equal to the sum of the variances with respect to the original coordinates. Computing the component loadings often facilitates interpretation of principal components. These loadings give ordinary product-moment correlation of each variable and the respective component.

After getting the required eigen-values, differences, proportions, cumulative and factor loadings, up to that principal factors were retained for construction of the index, which can account for at least 75% of the total variance explained by the original variables for all the 20 years considered. The factor scores for each country corresponding to each factor for the years considered were calculated as follows.

$$F_{ki} = \sum_{j=i}^{n} (Z_j \cdot a_{jk})/\lambda_k \quad \text{...(1)}$$

Where, a_{jk} are the factor loadings. j = 1, 2, 3, ..., n and

Z_j is the standardized variable i.e., $Z_j = \{(X_{ij} - \overline{X}_j) / \sigma_j\}$, X_{ij} is the value of the j^{th} variable corresponding to the i^{th} country, $\overline{X}_j$ is the mean of the j^{th} variable and σ_j is its standard deviation, λ_k is the proportion of variance explained by the k^{th} factor. Actually λ_k is the corresponding eigen-value. In our study $i = 1, 2, \ldots\ldots\ldots, 35$ and $j = 1,2,3,4,5$ and $k = 1, 2, 3$ (as the first 3 principal components explained more than 75% of the total variation in the variables in each year, which is shown in the appendix). Standardized values of the variables have been taken since the variables are expressed in different units. Since PCA is not scale invariant this transformation makes the results more general than they otherwise would have been.

Another point that deserves special mention is the fact 'Principal Component Index' cannot be generated in 'panel form' instantaneously. Since the variables (both the 5 environmental indicators, i.e., the dependent variables and the economic and demographic variables, i.e., the independent variables), are essentially in panel form, we must need to generate a panel of 'Principal Component Index'. Hence we pick up each of the 20 years, one by one and run the PCA separately for each year. This gives us a value for each country for a given year. In other words, given a year, the procedure gives a column vector signifying one value for one country. In this way we generate a panel of 'Principal Component Index'. The calculation of 'Principal Component Index' for each year is shown in appendix 4(A). It's worth mentioning that this entire process is really very rigorous and time consuming too.

We shall consider the 'Principal Component Index' as the dependent variable (a proxy for the overall environmental condition of each country and for each year). At some later stage of the analysis we shall need to **'Rank'** the countries with respect its overall environmental condition. Hence we shall consider the summation of all the 20-year's principal component indexes for each country as that country's **'final environmental index'**. Since the principal component index is actually an index of pollution, the lower is its value for a country the better is that country's environmental standard. Accordingly, the lower is a country's 'final environmental index' the better is its performance in the environmental scenario for the whole 20 years. The country having the lowest 'final environmental index' is the best country and hence will have a rank of 1. Similarly, the country getting the highest 'final environmental index' is the worst country and hence it will get a rank of 35.

A pertinent question may arise at this juncture regarding the validity or the effectiveness of the 'final environmental index'. One might say that since each country has a differential preference pattern with respect to time, the relevant summation across the years cannot be a revelation of a country's performance. To be honest, this argument is partly valid. But at the same time we need to consider two points. First, starting from principal component index for each country and for each year, there cannot be any other way through which we can arrive at a 'final environmental index'. Second, an individual year might see some shocks and fluctuations, but when we are summing over 20 years to arrive at a final figure, these shocks and fluctuations are considerably reduced and thus we get a figure that reflects the comprehensive performance of the economy over a significant duration of time.

The other indexation procedure that we shall use is borrowed from 'Human Development Index (HDI)' developed by 'United Nations' in their yearly publication of 'Human Development Report'. To construct an index for the 'well being' for each nation, they use 3 indicators, 1) log of GDP per capita, 2) literacy rate and 3) life expectancy. With these 3 welfare indicators they arrive at an overall index for each country in their yearly publication. This is done as follows.

Suppose **for a particular year,** a_{ij} represents the value of j^{th} indicator for the i^{th} country. In case of HDI, j = 1,2 and 3 as the UN considers only 3 indicators. Now for a given year they find out the maximum and minimum value of a_{ij} for each j. These are respectively called a_{ij}^{max} and a_{ij}^{min}. Now the relative position of the i^{th} country in j^{th} indicator is determined by using the following formula.

$$I_{ij} = (a_{ij}^{max} - a_{ij}) / (a_{ij}^{max} - a_{ij}^{min}) \quad \ldots\ldots\ldots\ldots(2)$$

Thus the UN calculate 3 welfare indicators for each nation. These are I_{i1}, I_{i2} and I_{i3}. Equation (2) has the following interpretations.

a) Going by this formula the country for which a_{ij} is maximum has an index of 0,

b) The country for which a_{ij} is minimum is getting an index of 1. So the index lies between 0 and 1 and

c) For a given country the denominator of the fraction (right hand side of equation (2)) is fixed. So a country's relative position is determined by the magnitude of the numerator. Clearly the higher is the numerator (i.e., the higher is the deviation from the maximum value), the worse is its condition. Similarly, the lesser is the numerator; the better is the country's relative position.

Thus UN calculate I_{i1}, I_{i2} and I_{i3} for each 'i' that is for each country. Then they take the unweighted arithmetic mean of these 3 indicators. This arithmetic mean, quite understandably, represents how worse a country's relative position is. Hence UN finally arrive at the 'Human Development Index' by subtracting the arithmetic mean from 1. That is

$$HDI = 1 - (I_{i1} + I_{i2} + I_{i3}) / 3$$

This time the country that has the highest HDI is in the best 'welfare-state', according to UN's terminology. The rank to the country is accordingly given.

However, in our study, we have taken the help of this index only partly. In our study

$i = 1, 2, 3, \ldots\ldots\ldots, 35$

$j = 1, 2, 3, 4, 5.$

Since in our case, a_{ij} is a value representing a certain amount of pollution, the higher is right hand side of equation (2), the better is the country's environmental condition. This is just opposite to the HDI. So to arrive at a single figure for each country (for a particular year), we take the arithmetic mean of the three a_{ij}. We do not need to subtract this arithmetic-mean from 1. We do this analysis for each of the 20 years. Finally to arrive at a single figure, we take the sum of this arithmetic mean over the 20 years period. Here again, the rank is accordingly given.

B. Econometric analysis

We want to see the behaviour of a country's overall index of environmental quality with respect to its openness, per capita income, urbanization, indebtedness, value added in its industries as a percentage of GDP etc. In other words we try to investigate about how the economy affects the 'overall environmental index'. To do so, we start out by regressing the index of environmental quality with respect to these variables. We shall use the following notations.

index = overall index of environmental quality of a country (principal component index), the dependent variable

The independent variables are

p_pcgdp = per capita GDP in PPP 95 US$

openness = export plus import of goods and services divided by GDP at factor cost

urbnsn = urbanization, defined simply as the urban population divided by the total population

debt = indebtedness, defined as the total debt service (% of exports of goods and services) to the IMF

ind_va = value added in the industries as a percentage of GDP.

cy_d = vector of country dummies = D_i

yr_d = vector of year dummies = D_t

We use the same model of panel-data analysis that we have used in chapter 2.

$$Y_{it} = \alpha + \beta_1 X^1_{it} + \beta_2 X^2_{it} + \beta_3 X^3_{it} + \ldots\ldots\ldots + \beta_k X^k_{it} + D_i + D_t + V_{it}$$

Before running the regression we check out for the autocorrelation and heteroscedasticity, if any, in the dataset. By running a test for heteroscedasticity, we find that the dataset suffers from the problem of heteroscedasticity. Hence we run the 'Generalized Least Square' regression as that can take care of the problem of heteroscedasticity and autocorrelation. OLS estimator, in this case, would have given biased result.

Case (a): We start out by regressing the index with respect to openness and country and year dummies only. We also assumed heteroscedasticity in the panels.

Syntax : xtgls index openness cy_d2- cy_d35 yr_d2- yr_d20, p(h)

We see that the dependent variable index is negatively related to openness, which turned out to be significant. The entire regression is produced in appendix 4(B)(a). Part of the result is produced in table 1.

Case (b): We now introduce another important variable in the form of per capita GDP and then run the regression. This time we make adjustment for autocorrelation too.

Syntax: xtgls index openness p_pcgdp cy_d2- cy_d35 yr_d2- yr_d20, corr(ar1) p(h)

We notice that the variable per capita income is also significant and negatively related to the index. The entire regression is produced in appendix 4(B)(b). Part of the result is produced in table 1.

Case (c): This time we introduce another important variable in the form of urbanization.

Syntax: xtgls index openness p_pcgdp urbnsn cy_d2-cy_d35 yr_d2-yr_d20, corr(ar1) p(h)

The insertion of urbanization as an independent variable in the present model does not invalidate the significance of openness and per capita income. Hence these two variables are really important. We observe that the dependent variable 'index' is negatively related to urbanization, which came to be significant. The entire regression is produced in appendix 4(B)(c). Part of the result is produced in table 1.

Case (d): We introduce debt in the model to see whether debt plays any role in the determination of index.

Syntax: xtgls index openness p_pcgdp urbnsn debt cy_d2-cy_d35 yr_d2-yr_d20, panels(correlated) corr(psar1)

We observe that debt is negatively related to index. This needs a careful interpretation. All other variables remain significant. We show the entire regression in appendix 4(B)(d). We produce part of the result in table 1.

Case (e): Finally we seek to see whether the quantum of value added in the industries plays any role in the determination of index.

Syntax: xtgls index openness p_pcgdp urbnsn debt ind_va cy_d2-cy_d35 yr_d2-yr_d20, panels(correlated) corr(psar1)

We see that value added in the industries does not have any major role to play in the determination of index, as it emerged insignificant. But all other variables remained significant with their earlier signs. This means that the variables openness, per capita income, urbanization and debt are the important variables that influence the value of index for a country. We show the entire regression in appendix 4(B)(e). We produce part of the result in table 1.

Table 1 : Regression results on Principal Component Index

Dept. var = index	*case (a)*	*case (b)*	*case (c)*	*case (d)*	*case (e)*
Indept. var					
Openness	-0.8616867	-0.6245696	-0.6837044	-0.8219902	-0.8721818
	(0.0000)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Per capita GDP	.	-0.0000449	-0.0000357	-0.0000463	-0.0000388
	.	(0.0000)	(0.0060)	(0.0060)	(0.0040)
Urbanization	.	.	0.0228269	0.0437294	0.0440255
	.	.	(0.0170)	(0.0000)	(0.0000)
Debt	.	.	.	-0.0082767	-0.009035
	.	.	.	(0.0000)	(0.0000)
Value added in industry as a % of GDP	.	.	.	.	-0.0019136
	.	.	.	.	(0.2790)
Pr > chi2	0.0000	0.0000	0.0000	0.0000	0.0000

Before going in for the explanation we must remember that the independent variables in all the above regressions was an index of pollution. So the less is the value of the index for any country, the better is the country's environmental quality. Now we have seen that the index is negatively related to the openness of a nation. This mathematically means that as countries become more and more open their environmental standard gets better and better, i.e., their environmental quality improves with the opening up of the domestic market. What does this imply? Does it men that if the developing nations start increasingly opening their market to foreign nations, their environmental quality would improve?

The answer to the second question is no. Rather it means that the developed nations that are already very open are enjoying a very high standard of environmental quality. In fact, when we rank the countries with respect to the total PCI score, we see that most of the west European developed nations and USA are at the top of the ranking. This means these 'very open' developed nations have a very high standard of environmental quality. On the other hand, the less open developing nations are more or less concentrated at the lower half of the ranking. So one explanation for this phenomenon can be the fact that these developed nations are getting more and more open with the passing of time and are exporting pollution to the developing nations as well. But to claim this at the macro level, one needs to have a sectoral level study, which is beyond the scope of present analysis. However, if we consider all these 35 countries simultaneously and compute the figure for overall openness[1] and further if we consider the group of 17 rich countries of our sample as a single unit and compute their overall figure of export to GDP ratio[2], the picture might be clearer. This is shown in table 2.

---

[1] The overall figure of openness for each year is derived as follows. First we take the figure of each country's export plus import for a particular year and then compute sum of the same over all the countries. Similarly, we take the GDP figure for each country for a particular year and then sum over all the countries. Finally we divide the former sum by the latter sum to arrive at the overall figure of openness.

[2] We take the export figure of these 17 rich countries for a particular year and then take the sum of these. Similarly, we take their GDP figures and compute the sum of GDP. Then we divide the former total by the latter total.

Table 2 : Trend of Openness and Export/GDP Ratio

Year	Overall openness	Rich country's export by GDP ratio
1980	0.262295	0.1143
1981	0.266431	0.1168
1982	0.261137	0.1161
1983	0.264434	0.1178
1984	0.276737	0.1231
1985	0.272990	0.1238
1986	0.268944	0.1236
1987	0.274761	0.1279
1988	0.286184	0.1342
1989	0.297883	0.1394
1990	0.306938	0.1452
1991	0.319437	0.1506
1992	0.335233	0.1573
1993	0.346255	0.1630
1994	0.367068	0.1735
1995	0.389099	0.1885
1996	0.400102	0.1954
1997	0.426933	0.2079
1998	0.429392	0.2123
1999	0.438856	0.2179

From the above table we see that both overall openness of these 35 nations and the export by GDP ratio of the rich nations as a whole have considerably and steadily increased after 1986. Although not shown in the table, but we have computed the export by GDP ratio and the import by GDP ratio for the poor countries as a whole for the period of 1980-1999. The dynamics of these two time series reveal that export, as a percentage of GDP has not picked up in these developing nations while their import, as a percentage of GDP has significantly gone up. So it can happen that these developed nations are exporting 'dirty' industries to the developing nations or the developing nations are partially specializing in 'dirty' goods. But this is only a possibility. To justify or counter this prediction, an in-depth industry-wise sectoral study is needed. We now turn to a very related issue, which can further induce us to think in this manner. This time we try to address the question of what is happening to the difference in environmental standard between the developed and developing nations with the increase in overall openness? We try to investigate the answer in the following manner.

First we take the two groups of developed (17 nations) and developing (18 nations) countries. Then we consider their PCI scores. Initially we take the developing nations. For each year we take the sum of individual country score. Then we divide the sum by 18. This gives us the average level of pollution in these developing countries (as a whole) for a particular year. We do this exercise for all the 20 years, starting from 1980 to 1999 and thus generate a time-series. Similarly, we compute the same time series for the developed nations. **We now compute the yearly differences in these two averages. We regress this difference with respect to the overall openness of these 35 nations. We do this time-series regression in E-Views. We fit the following model. This is the general moving average (MA(2)) model having the usual notations.**

$$Y_t = \alpha_0 + \alpha_1 t + \alpha_2 x_t + \varepsilon_t$$

where $$\varepsilon_t = \theta_0 + \theta_1 \eta_{t-2} + \eta_t$$

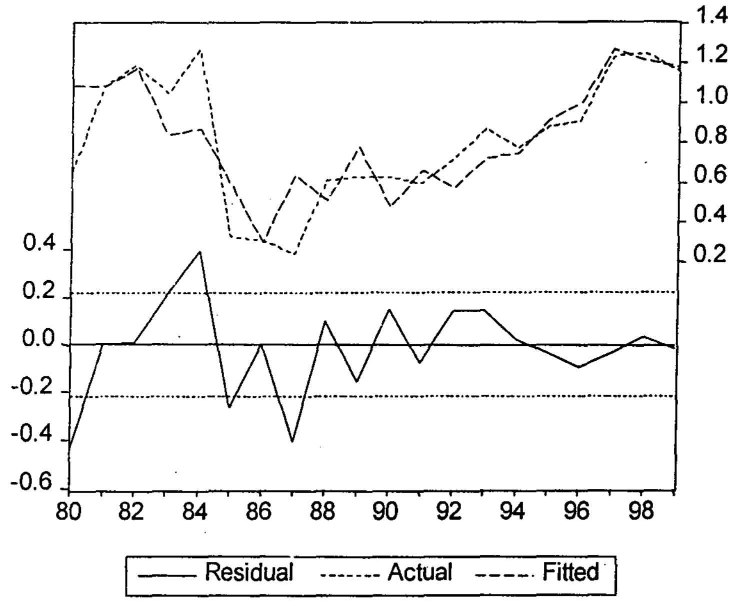
Here Y_t is the difference in environmental standard and t and x_t are time and overall openness respectively. We depict the E-Views output on the next page. The table shows the regression results. **In the graph, we horizontally measure overall openness and vertically measure differences in environmental standard.**

Table 3 : E-Views Regression result

Dependent Variable: difference in environmental standard
Method: Least Squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-2.112404	0.434205	-4.864997	0.0002
TIME	-0.121982	0.022505	-5.420332	0.0001
OVERALL OPENNESS	13.01017	2.059157	6.318203	0.0000
MA(2)	-0.588284	0.195736	-3.005501	0.0084
R-squared	0.631964	F-statistic		9.157987
Adjusted R-squared	0.562957	Prob (F-statistic)		0.000921

Graph 1



From the above table we see that overall openness is significant in explaining the differences in environmental standard and its coefficient is positive as well. So with the passing of time, the phenomenon of increasing openness is seen to be correlated with an increasing difference in environmental standard. In fact, if we consider the individual time series of environmental standard for both the groups (not shown), we find that the developed nations are becoming better and better with respect to their environmental standard where as in case of the developing nations the picture is just the reverse. The developing country's environment is deteriorating. So as an obvious outcome, the differences in environmental standard are getting wider with the passing of time and with the increase in openness.

The graph tells us the same story. It reveals that since 1988, there emerged an incessant increase (with very little amount of fluctuations) in the differences of environmental standard.

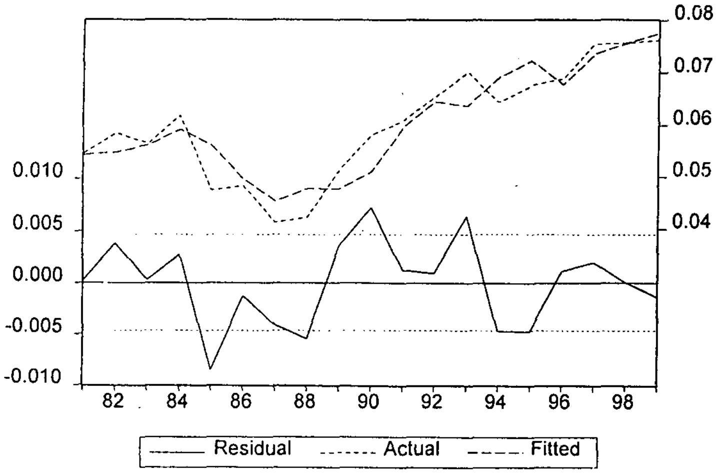
In the earlier regression the dependent variable i.e., differences in environmental standard was unweighted. Now we run the same regression by giving a weight to the index of environmental quality for each country before they are summed for the poorer and the richer group; the weight being equal to the proportion of a country's GDP with respect to the total GDP (sum of the GDP of all countries). The economic logic behind this as follows. If we do not give weights to the index, it means all countries are treated with equal importance. But as economy affects ecology, one needs to use the relative importance of an economy to find out the relative importance of its environmental performance with respect to all the countries. To run the regression we use the same equation but this time we fit an **(ar(1)MA(2))** model. The E-Views output is shown below. It shows the same story despite the introduction of the weight.

Table 4 : E-Views Regression result for weighted index

Dependent Variable: weighted difference in environmental standard
Method: Least Squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.016941	0.027338	-0.619671	0.5454
@TREND	-0.001825	0.001490	-1.224531	0.2410
OVERALL OPENNESS	0.291995	0.125038	2.335245	0.0349
AR(1)	0.404905	0.228663	1.770746	0.0984
MA(2)	0.489672	0.244491	2.002826	0.0650
R-squared	0.857215	F-statistic		21.01237
Adjusted R-squared	0.816419	Prob (F-statistic)		0.000008

Graph 2



We see that there is a break in the first graph. In fact there might be a structural change since 1988, after which the trend got reversed. We conduct a Chow test to prove this.

[Chow's Breakpoint Test

The idea of the Chow breakpoint test is to fit the equation separately for each subsample and to see whether there are significant differences in the estimated equations. A significant difference indicates a structural change in the relationship. For example, we can use this test to examine whether the demand function for energy was the same before and after the oil shock. The test may be used with least squares and two-stage least squares regressions.

To carry out the test, we partition the data into two or more subsamples. Each subsample must contain more observations than the number of coefficients in the equation so that the equation can be estimated using each subsample. The Chow breakpoint test is based on a comparison of the sum of squared residuals obtained by fitting a single equation to the entire sample with the sum of squared residuals obtained when separate equations are fit to each subsample of the data.

E-Views reports two test statistics for the Chow breakpoint test. The F-statistic is based on the comparison of the restricted and unrestricted sum of squared residuals. The F-statistic has an exact finite sample F-distribution if the errors are independent and identically distributed normal random variables.

The log likelihood ratio statistic is based on the comparison of the restricted and unrestricted maximum of the (Gaussian) log likelihood function. The LR test statistic has an asymptotic chi-square distribution with degrees of freedom equal to (m-1)k under the null hypothesis of no structural change, where m is the number of subsamples.]

Chow Breakpoint Test: 1988

F-statistic	5.229758	Probability	0.0112
Log likelihood ratio	20.18289	Probability	0.0005

From the last column of the above table we see that the null hypothesis is rejected at 5% level of significance as shown by F-statistic and Log likelihood ratio. So there is a structural break in the year 1988. There is a structural break in the second too. We again use the Chow test to see the structural break. We see that the trend got reversed after 1987.

Chow Breakpoint Test: 1987

F-statistic	7.565074	Probability	0.0048
Log likelihood ratio	31.33481	Probability	0.0000

This difference in environmental standard can be attributed to many reasons. But openness can be one of the important explaining factors. Openness increases competition and the market size. To survive in a very competitive structure the firms need to cost-efficient and also they need to optimally use sophisticated technology to conserve energy resources etc. The cost-inefficient firms might have to leave the industry. So the inefficient firms might flock in the developing nations taking advantage of their increased openness and also their weaker environmental norms and regulations. This might increase pollution in the developing nations. This phenomenon can be termed as the flight of foreign capital and investment. But there can be a totally different phenomenon other than this. Openness increases the market for the developing nations too. Now these developing nations might specialize in dirty goods depending on their comparative advantage. The developing nations might inherit a tendency in doing so owing to their weaker environmental laws.

Table 1 also reveals that the index of pollution is negatively related to per capita income. This is a pretty straightforward phenomenon. High-income countries have very strong environmental norms and regulation. Since environmental quality is a normal good, as income grows up beyond a certain 'threshold' level, people start demanding for a better and cleaner environment. But since environmental quality does not have any market, this demand in turn gets reflected in formation of stringent environmental laws and regulations. Let us take the example of deforestation. In our sample of rich countries, barring only two nations, the amount of relevant 'net deforestation' in all other rich countries is zero. Actually these nations attach an immense value to the conservation of their forests and hence any unauthorized cutting down of forests is a cognizable offense there. Similar is the case with 'net mineral depletion'. Unlike the developing nations, the developed nations do not create stress on their mineral as a source of energy. Rather they believe in the conservation of the same and they incur huge expenditure in research and development to find out alternative and non-conventional source of energy. So from all front the developed nations care for their environment and natural resources. Hence it is quite expected that rich countries will have a cleaner environment. On the contrary, most of the developing nations are passing through the process of industrialization. And industries have greater proclivity to pollute than agriculture. So the transformation of the emphasis from agriculture to industries is generally accompanied by more pollution. Moreover these nations are passing through the initial phase of development and hence are very likely to pollute because of the reasons described in the explanation of the shape of 'Environmental Kuznets Curve'. But one striking feature of table 1 is that it shows openness has a greater coefficient than per capita income in all cases. This means that openness emerges as a stronger variable in explaining the index.

The next explaining factor is urbanization. The regression reveals that as urbanization grows the overall environmental standard of the surrounding area deteriorates. This can be explained very easily. The size of urban population vis-à-vis total population in any country is an important factor behind its development and the environmental condition as well. Urbanization means gathering or concentration of people in a locality providing economic opportunities and a relatively sophisticated living standard as compared to the rural areas. In an urban area people depend more on machines than on labour intensive techniques. They depend on vehicles and energy intensive commodities. The production process there, in general, is also energy intensive. Vehicles emit SO_2 and other pollutants, energy intensive production generates CO_2. These gases pollute the air in urban areas. On the other hand, to sustain life in a relatively small area, food and other markets have to operate all day long. This creates wastes and garbage. To keep the environment clean, a proper management of this wastes and garbage is absolutely necessary. But the developing countries show laxity in this regard. This can generate both air and water pollution and as a result of that the overall environmental standard gets deteriorated with the intensity of urbanization.

The 4th independent variable in table 1 is debt. Actually we wanted to capture how far foreign indebtedness impacts the overall environmental standard by the means of say, deforestation or mineral extraction. Now indebtedness in the present case is defined as the total debt service (% of exports of goods and services) to the IMF. For the developing countries we could have taken total foreign debt as a % of GNP. Now for the developing nations this figure would have been positive. But for the developed countries this figure could have turned negative, as they are net donor of debt. But it is very difficult to find out this figure for the developed countries as an analogue of the net debt receipt by the developing countries, as an appropriate data is not available. Hence, we took IMF loan as debt in the sense that IMF does provide loans to many nations, especially the developing nations, but IMF does not owe to any nation. In our regression it is found that debt is significant and it benefits the environment. But this is totally ambiguous. The fact that can explain this is the developing nations that are having relatively better environmental standard have got more IMF loan in comparison to their poorer counterpart.

Value added in the industries as a percent of GDP does not come out to be significant in explaining the overall environmental scenario.

Now to check the robustness or validity of the rank (which we have already calculated) of the countries generated by the principal component analysis, we calculate the ranking of the countries by the second method i.e., the human development index method. The objective is to compare the two rankings. Since 'human development index' method is well known and accepted, if we see that the rank generated by 'principal component analysis' has a close association with the former, we can assume that the 'principal component ranking' is fairly satisfactory. The process of calculation is described in the methodology section. We produce the two rankings below.

Table 5 : Environmental Rank

Country	Rank by HDI method (Relative Rank)	Rank by PCI method (Score Rank)	Difference in the Two Ranks	Square of Differe-nce		
Italy	1	1	0	0	Total of Square of Difference	486
Hong Kong, China	2	2	0	0		
Colombia	3	3	0	0	6 x (Total of Square of Difference)	2916
Argentina	4	4	0	0		
Japan	5	5	0	0		
France	6	7	-1	1	Rank Correlation	$1 - \{ 2916 / (35^3 - 35) \}$
Spain	7	8	-1	1		
Mexico	8	6	2	4		
Brazil	9	16	-7	49		
Morocco	10	15	-5	25		
Netherlands	11	9	2	4	Rank Correlation	1- 2916/42840
Philippines	12	18	-6	36		
United Kingdom	13	10	3	9	Rank Correlation	0.931932773
Peru	14	23	-9	81		
Algeria	15	13	2	4		
Ghana	16	19	-3	9		
Pakistan	17	14	3	9		
Sri Lanka	18	21	-3	9		
Korea, Rep.	19	17	2	4		
Iran, Islamic Rep.	20	12	8	64		
United States	21	11	10	100		
Indonesia	22	24	-2	4		
Canada	23	20	3	9		
Egypt, Arab Rep.	24	26	-2	4		
Malaysia	25	25	0	0		
India	26	27	-1	1		
Syrian Arab Republic	27	22	5	25		
Venezuela, RB	28	28	0	0		
South Africa	29	31	-2	4		
Chile	30	34	-4	16		
Ethiopia	31	29	2	4		
Mozambique	32	32	0	0		
Nepal	33	30	3	9		
Kenya	34	33	1	1		
China	35	35	0	0		

We see that the two rankings are very close to each other. We calculate the Spearman's product-moment rank correlation between the two rankings. The rank correlation comes to be as high as 0.9319. So each of the rankings can be assumed to be more or less satisfactory.

Now if we consider the extreme poor and extreme rich countries of our sample (following the World Bank definition) we get the following table.

Table 6 : Environmental Rank of the Extreme Countries

Extreme poor countries	Rank	Extreme rich countries	Rank
Ethiopia	29	Canada	20
Ghana	19	France	7
India	27	Hong Kong, China	2
Indonesia	24	Italy	1
Kenya	33	Japan	5
Mozambique	32	Netherlands	9
Nepal	30	Spain	8
Pakistan	14	United Kingdom	10
		United States	11
Total rank	208	Total rank	73
Average rank	26	Average rank	8.11

From the second column of the above table we see that barring Pakistan and Ghana the best rank from the extremely poor section is 24 out of total 35 countries. This is a dismal performance. Moreover China, which has the worst performance by both the rankings, is marginally excluded from the group of extreme poor countries, as its per capita income is slightly higher than the level set for the extreme poor group by the World Bank. On the other hand for the extremely rich group of countries barring Canada, the next worst performance is 11 by USA. This is really a very good performance from the developed nations. Very expectedly the average rank for the poor and the rich are strikingly different and are respectively 26 and 8.11. So income plays really a very vital role in determining the environmental standard of a nation.

Finally to see whether human development does have any connection with the overall index of environmental quality, we calculate the human development index for all the 35 nations by HDI method and compute the rank correlation between that index and environmental index by PCI method. We found the rank correlation to be 0.8115. This reflects that human development has a very close association with environmental standard of a nation-----an issue we shall discuss in the concluding chapter.

From the above analysis we have seen that global economic order is moving in a direction that widens the gap in the environmental standards of the developed and the developing nations. From the graphs we saw that the situation before 1987-1988 was just the opposite of this. Before that period the globe was moving to a direction of equitable environmental standards as the difference between the environmental standard of the developed and the developing nations was decreasing. But after 1987-1988 the trend got reversed. The globe, in present days, is moving away from equity. Hence to ensure a sustainable development from the global perspective, the developed and developing countries should cooperate to minimize the gap. Nothing, other than the cooperation at the global level can be more fruitful to take care of this problem, something we have talked about in the policy implication part of chapter 3. Although cooperation at the global level is of paramount importance, but that cannot help reduce the pollution problem alone. The exigency should come from within the geographical boundary of countries as well. For the underdeveloped nations there is a severe need of cooperation at the societal, institutional and individual level to minimize the problem of pollution and this cooperation can prove to be vital from the perspective of sustainable development strategy-----another issue we shall take up in conclusion.

Chapter 5

5. Conclusion

The study of the interaction between environment and macroeconomy aims at formulating strategies for sustainable development. Although the priorities of a country or even a small economy differ depending upon the phase of development it is in, but its ultimate goal is to 'sustain' the overall improvement in the living standard of its people that it achieves in course of development. We have seen earlier that for an underdeveloped nation, environmental quality deteriorates during the initial stages of development. During this period the underdeveloped nation generally emphasizes on meeting economic goals like poverty eradication, increase in output and employment generation. They cannot afford to attach highest priority with environment and instead they sacrifice environmental quality up to a certain extent to achieve economic goals during these days. In the process environmental degradation gradually reaches a bottom. Then environmental concerns among citizens' starts growing juxtaposed with the increment in their income with further development. Since environmental quality does not have any market, this concern of citizens' starts getting reflected in the public policies. The nation now starts taking care of its environment through environmental norms and legislations. As a result of that environmental quality starts improving with further development. It is the period when the emphasis of the nation can shift to the designing of policies that can 'sustain' the welfare-gains achieved by the improvement in environmental quality.

As Sen pointed out sustainable development enlarges the choice set of options for a community, it also stresses on transformation in order to improve economic, ecological and social conditions of all people, at all places, and all the times. In other words sustainable development is a phenomenon where a nation meets the needs of present without compromising the ability of future generations to meet their own needs. Sustainable development not only cares for human lifestyle but it encompasses other living beings of the planet too. Thus it recognizes the worth of natural system supporting life on earth. Since human activities and standard of living are intrinsically related to the conditions of environment, the importance of researches on the human causes and impacts of environmental change to recognize the fact that local and regional scales are important for human dimensions of sustainable development is not worth mentioning. Environmental scenario is subject to variations with human activities. If we pollute air; our health would suffer, if we degrade land by soil erosion and excessive use of chemicals; agriculture would be affected, if we pollute the water of river and sea; raw material production would be hampered. Hence the human activities that account for such variations, and their implications to sustainable development are gaining more and more importance these days. This is promoting capacity building, especially in terms of human resources and networking chains and policy support activities. Thus most of the social disciplines are focusing on the integrated involvement of human dimension research and the relevant public policy measures. Resource management policy should be chosen in such a manner that it could address the issue of environmental protection, as a component of sustainable development that is consistent with poverty eradication. Therefore, the human dimension has to be incorporated into planning with an emphasis on sustainable development. These issues should be synchronized with scientific approaches, socio-economic traditions, lifestyles, culture and productive system.

A development process cannot be termed as 'sustainable' if it does not promise an 'at least as good as' lifestyle for the future generations in comparison to the present generation. Thus "....we can summarize the necessary conditions for sustainable development as constancy of the natural capital stock; more strictly, the requirement for non-negative changes in the stock of natural resources, such as soil and soil quality, ground and surface water and their quality, land biomass, water biomass, and the waste assimilation capacity of the receiving environments" (Pearce, Barbier and Markandya, 1988, p.6).[1] In view of this "World Commission on Environment and Development (1987)" defined sustainable development as an overall improvement that requires a boundary condition to be satisfied to take care of the considerations of intergenerational equity in resource use. Hence emphasis is given on uses (as well as policies) of natural resources that would enable the future generations to experience at least the present

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[1] Partha Dasgupta and Karl-Goran Maler in "Poverty, Institutions, and the Environmental Resource-Base", in 'Handbook of Development Economics' Volume III, Edited by J Behrman and T N Srinivasan, chapter 39; page 2393, Elsevier Science B. V., 1995

generation's level of standard of living. But to ensure such a phenomenon, apt set of policies and the development of science and technologies are of absolute necessity. This sophistication of technology can enhance the biophysical limits on economic processes and create space for sustainable upward movement of economic well-being index in the face of growing human population. Since the planet's resource is scarce and there is a limit to the ecology-economy relationship, technological upgradation must address the important issues like:

a) dematerialization of economic process,

b) decarbonization of energy,

c) increasing substitution of nonrenewable resources by renewables,

d) recycling of waste by converting it into a manmade resource,

e) enhancement of primary productivity of biospheric space in ecosystems,

One of the principal aims of a sustainable development strategy should be the minimization of the stress on environment imposed by the economy. This aim can be met with the help of technological upgradation. Technology transforms the resources that are extracted from the nature into final output. So given any state of technology, the more the extraction the more will be the final output. Hence in course of achieving a sustainable growth path, technological development should be such that it tries to minimize the flow or the extraction of environmental resources into the economy (without leading to any substantial depletion in the quantum of production) and also the flow of material waste that goes to the environment, as the latter is the sink for any economy. Energy as a factor of production, like the natural resources, is also in dearth in supply. So its preservation is equally important. "While energy conservation through higher efficiency of use is of paramount importance, the decarbonization of energy needs to be targeted to circumvent the problems of pollution and exhaustibility of fossil fuels and to reduce the pressure on land created by the use of plant biomass for energy by a growing population."[2]

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[2] Ramprased Sengupta in "Ecology and Economics- an Approach to Sustainable Development", Oxford University Press

Because of the multiplicity of conditions that are needed to be satisfied as prerequisites of any sustainable development strategy, the development of science and technology and the role of social institutions are of paramount importance. A society needs to understand that technological progress is not 'exogenous' (as described by many growth models) in reality; rather its sophistication depends on the society's efforts. If a society succeeds in doing this, any economic or public policy can be ideally complemented by equivalent progress in science and technology that, in turn, will take care of the objectives set out by the policy. To generate such a congenial atmosphere for sustainable development that can keep pace with an ever-growing demand, investment in research and development activities is desired. Even if the fact that this investment can prove to be a failure from the viewpoint of cost-benefit analysis for an individual project, but for an economy this can result in a rise in its overall productivity concomitant to sustainable development. If utility gains form investment in research and development expenditure is assured to a bare minimum extent, technology can be envisaged as a reproducible item. The reproduction of technology can be achieved following a path very similar to the transformation of capital to surplus to profit and to capital again. The surplus that accrues from the exploitation of natural resource base in any economy can be mobilized and reinvested to the formation of new resources and technology. Better technology can be utilized to achieve the aim of lessening stress on scarce environmental resources through the substitution of the non-renewable factors of production by renewable factors, which will remain as a principal motive of sustainable development for centuries.

The geneses of new and newer technologies make people ambitious about the sustainability of the developmental process that is taking place in due course. However, barring the genesis of sophisticated technology, the genesis of human values, knowledge and consciousness (or in other words human capital) regarding the aspiration of societal transformation, had always played the most important role in the development of a small community or even a very large country; in the past and it will continue to play the same role in the far future as well. The demographic problems like population control cannot be single-handedly tackled by technological improvements. This needs elementary education on the vulnerability of population explosion and its resultant outcome on environment and development. Thus there is a need for investment in human capital formation that will help take care of population control. Human capital formation enhances the power of knowledge and informational base. Therefore, in the process, people can get to conceive about the impact of a change in their preference pattern on the ecosystem and on the lifestyle of the society. And if all the people start realizing the notion of societal well-being from the viewpoint of sustainability by making small compromises in their individual lives; at times and for short run, the process will become everlasting as knowledge acquired in course of development cannot get reverted in the backward direction.

As we have mentioned in the fourth chapter, the correlation between the human development index and the overall environmental index is fairly high, there is the opportunity to comprehend the fact that countries having high human development index are doing well in the environmental front too. So there must be a link between these two. In fact the relation is a two-way one. Both indexes can affect the other. Let us briefly explain this. Human development index takes into account the per capita income, the literacy rate and the life expectancy rate for each country. Now, more income means more willingness on the part of people to spend on environment, which leads to a higher environmental quality. Similarly, the higher the literacy rate in a country, the wider is its educational base. More education is accompanied by more knowledge and consciousness on every societal aspect including the environment. This leads to the formation of environmental norms and regulations from the public or macro sphere as well as individual care and protection for the environment from the micro sphere. As a result the process of maintaining a decent environmental standard becomes smooth. Thus a high human development index implies a high environmental index. On the other hand, high environmental index points to a better environmental standard. Now environmental quality has positive effects on human productivity and human health. Higher productivity generates higher output and hence income, and the positive impacts on human health leads to higher life expectancy rate. Thus a cumulative chain of causation runs from environmental index to human development index as well. Actually environment is an 'enabler', it influences the well being of a nation from various angles. Therefore, researchers can take interest in constructing a broader index of well being for a nation with the help of interdisciplinary issues. This index can reflect the state of well being of the human society and the well being of nature as well. Eventually it will help in formulating strategies for sustainable development that will take care of the well being of both human society and nature.

The supporters of free trade and the free market economists can argue against any sacrifice in output for environmental cause by saying that environment does not have a direct impact on the economic well being of people. Apparently their argument may seem to be logical. But if anyone goes into deep, this argument will turn out to be fallacious. Actually, sometimes the state of development of a nation remains implicit in the sense that it might not get reflected in its performance for a short span of time. But that does not truly mean that the nation is lacking in developmental front. Rather what is more important is what the nation is capable of performing or what it could have achieved (but has remained unsuccessful because of exogenous shock or say due to the operation of business cycle) from a long-term perspective. This scenario can emerge from various other ways. Going by the model of intertemporal choice for two periods, if a nation chooses not to deplete its resources for future needs, a situation of the above sort might emerge. Thus the role of environmental resources on the overall well being of a nation might not always be felt in the short run. Rather their utilities can be perceived if proper long-term sustainable development strategies are formulated. On the contrary, a nation, in a jiffy, might emphasize on extracting resources for growth in the present period. Ultimately it might end up exhausting its natural resource base. Hence the growth achieved for a small span of time would become unsustainable. Therefore, the route to sustainable development partly depends on the society's preference.

Once the sustainable path for development is identified, the next objective arises in the form of managing the economy and its environmental resources to ensure its smooth movement along the sustainable path. The management of environmental resources can partly be taken care of by addressing the issue of market failure, if any. The feature of non-excludability of common public resources can give birth to the problem of 'free riding' and also can contribute to environmental externality as the private cost of using the resources is short of its social cost. This feature might result in an over-exploitation of natural resources further leading to environmental degradation. This issue can be addressed in mainly three ways. First government intervention, second privatization and third by undertaking local level common property management activities. But government intervention is very likely to become abortive in an underdeveloped nation owing to the inefficiency and corruption in bureaucratic level. Privatization, on the other hand might result in profit making behaviour through restricting the supply of the resource to the common public. The third option that talks of cooperation on common property resources with well-defined property rights at community level, may be able to resolve the problems of conflicts and disputes regarding the purpose and manner of resource utilization and enable systems to attain a cooperative solution, which is Pareto optimal from the point of view of resource allocation or at least definitely superior to the non-cooperative equilibrium generated by other policy measures. Moreover local people have more knowledge on local resources than the outsiders. The conditions of feasibility and the chances of success of such cooperation have been formulated by game theoretic models. It appears that a competitive sharing of the natural resources might often become destructive and it might not lead to an optimal outcome. On the contrary, cooperation at the organizational level of planning for local resources could lead to a Pareto optimal solution where the society as well as individuals, benefit from a long-term perspective. Therefore the formation of local level institutions or governing bodies that would take care of the local resources is immensely important. However this sort of a formulation does not rule out the role of ".... market transaction for matching demand and supply of commodities and services which would induce the forces of competitive efficiency to influence decision-making at all stages including the local community. In terms of institutional arrangements what is thus important for interdependent ecological and social sustainability of development process is the definition of property rights and obligations relating to the use of natural and environmental resources without necessarily meaning their privatization, and a rightly balanced role of local community organization and market to combine efficiency and equity in both ecological and economic sense."[3]

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[3] Ramprased Sengupta in "Ecology and Economics- an Approach to Sustainable Development", Oxford University Press

The apparent conflict between ecology and economy is not a new phenomenon; it dates back to the age of inception of human civilization. But the nature of the conflict changed substantially with the passing of time. However, what remains invariant to time, is the role of cooperation at local, regional, community, state or even at country level in solving the conflict. Cooperation ranging from individual level (say, in local resource management problem) to global political level (in solving problems like 'global warming') is the quintessence of solving such a conflict. If cooperation is assured through mandatory regulations imposed by institutions at all levels, the role of science and technology emerges in supplementing the economic and social norms and regulations. The rapid advancement in knowledge based theoretical and practical research in other disciplines of study can, as well, play a very important role to solve such a conflict. With the changing needs of time, there is emerging ample opportunity to accommodate the need of interdisciplinary approach and admit the importance of technology and environment not only on the supply side laws of economic system but also on the demand side and on the institutional rules of the game to ensure a matching of demand and supply. Only this reorientation of the traditional approach can uphold the slogan of sustainable development for all people across all corners of the globe in the 21st century.

Appendices

Appendix to chapter 3

- *3(I)Carbon-di-oxide (CO2)*

3(I)1

```
. xtreg t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln, fe

Fixed-effects (within) regression               Number of obs      =       840
Group variable (i) : cocode                     Number of groups   =        42

R-sq:  within  = 0.7691                         Obs per group: min =        20
       between = 0.3625                                        avg =      20.0
       overall = 0.3691                                        max =        20

                                                F(4,794)           =    661.03
corr(u_i, Xb)  = -0.3953                        Prob > F           =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   107.6837   8.260811     13.035   0.000       91.46814    123.8994
sp_pcgdp |  -.0082378   .0005703    -14.444   0.000      -.0093574   -.0071183
cp_pcgdp |   2.00e-07   1.22e-08     16.415   0.000       1.76e-07    2.24e-07
   popln |   .0038016   .0001128     33.709   0.000       .0035803     .004023
   _cons |  -337085.8   23412.17    -14.398   0.000      -383042.8   -291128.7
------------------------------------------------------------------------------
 sigma_u |  724958.95
 sigma_e |  60697.938
     rho |  .99303875   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(41,794) =  1060.88            Prob > F = 0.0000
```

3(I)2

```
. xtreg t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2-yr_d20, fe

Fixed-effects (within) regression               Number of obs      =       840
Group variable (i) : cocode                     Number of groups   =        42

R-sq:  within  = 0.7852                         Obs per group: min =        20
       between = 0.3830                                        avg =      20.0
       overall = 0.3892                                        max =        20

                                                F(23,775)          =    123.21
corr(u_i, Xb)  = -0.4494                        Prob > F           =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |    118.817   8.325958     14.271   0.000       102.4729    135.1611
sp_pcgdp |  -.0085684   .0005644    -15.182   0.000      -.0096763   -.0074605
cp_pcgdp |   2.06e-07   1.20e-08     17.144   0.000       1.83e-07    2.30e-07
   popln |   .0040602   .0001179     34.433   0.000       .0038287    .0042917
   yr_d2 |  -13685.13   12929.83     -1.058   0.290      -39066.77    11696.51
```

```
    yr_d3 |  -22318.65   12932.55     -1.726   0.085      -47705.64    3068.331
    yr_d4 |  -26483.02   12941.47     -2.046   0.041       -51887.5   -1078.532
    yr_d5 |  -25596.76   12958.65     -1.975   0.049      -51034.96   -158.5509
    yr_d6 |  -27588.26   12977.27     -2.126   0.034      -53063.02   -2113.503
    yr_d7 |  -33890.57   13008.92     -2.605   0.009      -59427.47   -8353.674
    yr_d8 |  -34860.47      13059     -2.669   0.008      -60495.68   -9225.262
    yr_d9 |  -32030.72   13122.74     -2.441   0.015      -57791.05   -6270.385
   yr_d10 |  -34888.89   13177.73     -2.648   0.008      -60757.16   -9020.628
   yr_d11 |     -40220   13232.26     -3.040   0.002      -66195.33   -14244.68
   yr_d12 |  -39523.94   13292.11     -2.973   0.003      -65616.75   -13431.14
   yr_d13 |     -41217   13365.96     -3.084   0.002      -67454.77   -14979.24
   yr_d14 |  -41337.63      13434     -3.077   0.002      -67708.96   -14966.29
   yr_d15 |  -42303.32   13557.99     -3.120   0.002      -68918.06   -15688.58
   yr_d16 |  -45214.29   13671.35     -3.307   0.001      -72051.55   -18377.02
   yr_d17 |  -46127.93   13816.77     -3.339   0.001      -73250.67   -19005.19
   yr_d18 |  -58315.55   13982.46     -4.171   0.000      -85763.53   -30867.58
   yr_d19 |  -73630.01   14028.92     -5.248   0.000      -101169.2   -46090.83
   yr_d20 |  -93135.77   14160.19     -6.577   0.000      -120932.6   -65338.89
    _cons |  -383035.2   26622.68    -14.388   0.000      -435296.3   -330774.1
-------------------------------------------------------------------------------
  sigma_u |  733585.81
  sigma_e |  59245.149
      rho |  .99351992   (fraction of variance due to u_i)
-------------------------------------------------------------------------------
F test that all u_i=0:     F(41,775) =  1063.65            Prob > F = 0.0000
```

3(I)3

```
. reg t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2-cy_d42 yr_d2-yr_d20, robust

Regression with robust standard errors                 Number of obs =     840
                                                       F( 63,   775) =  812.33
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.9953
                                                       Root MSE      =   59245

-------------------------------------------------------------------------------
         |               Robust
t_co2_em |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+---------------------------------------------------------------------
 p_pcgdp |    118.817    11.0276     10.775   0.000       97.16949    140.4645
sp_pcgdp |  -.0085684   .0008751     -9.791   0.000      -.0102864   -.0068505
cp_pcgdp |   2.06e-07   2.13e-08      9.674   0.000       1.64e-07    2.48e-07
   popln |   .0040602   .0004493      9.037   0.000       .0031782    .0049422
   cy_d2 |  -116868.3   19933.37     -5.863   0.000      -155998.1   -77738.53
   cy_d3 |    25587.8   32306.27      0.792   0.429      -37830.37    89005.96
   cy_d4 |  -113353.2   48167.16     -2.353   0.019      -207906.8   -18799.68
   cy_d5 |  -397629.9   56120.35     -7.085   0.000      -507795.8     -287464
   cy_d6 |   71332.65   37331.06      1.911   0.056      -1949.327    144614.6
   cy_d7 |   -16630.5    13512.9     -1.231   0.219      -43156.73    9895.719
   cy_d8 |   -1900674   496078.4     -3.831   0.000       -2874490     -926857
   cy_d9 |  -66942.16   10515.27     -6.366   0.000      -87583.94   -46300.37
  cy_d10 |   214868.8   25420.26      8.453   0.000         164968    264769.5
  cy_d11 |   47247.17   21009.73      2.249   0.025       6004.449    88489.89
  cy_d12 |   169499.6   35688.18      4.749   0.000       99442.67    239556.6
  cy_d13 |  -68.32099   42974.09     -0.002   0.999      -84427.72    84291.08
  cy_d14 |   207538.4   24992.69      8.304   0.000         158477    256599.8
```

```
     cy_d15 |  -147233.3   28186.75      -5.223   0.000      -202564.8   -91901.88
     cy_d16 |   -2452987   373411.5      -6.569   0.000       -3186004    -1719969
     cy_d17 |  -336667.1   72066.82      -4.672   0.000      -478136.4   -195197.8
     cy_d18 |   27000.93   18077.52       1.494   0.136       -8485.78    62487.64
     cy_d19 |   13057.86   40380.19       0.323   0.746      -66209.64    92325.37
     cy_d20 |   318625.7   64053.31       4.974   0.000       192887.1    444364.2
     cy_d21 |   234689.6   29469.96       7.964   0.000       176839.3      292540
     cy_d22 |   14250.02   22294.42       0.639   0.523      -29514.59    58014.63
     cy_d23 |   289205.6   31449.29       9.196   0.000       227469.7    350941.5
     cy_d24 |   1007.715   9894.858       0.102   0.919      -18416.19    20431.61
     cy_d25 |  -85736.93   30191.65      -2.840   0.005        -145004   -26469.84
     cy_d26 |   68753.82   14767.23       4.656   0.000       39765.32    97742.33
     cy_d27 |     305375   33383.61       9.147   0.000       239841.9      370908
     cy_d28 |     249181   29770.34       8.370   0.000       190740.9      307621
     cy_d29 |  -43459.76   31971.02      -1.359   0.174      -106219.8     19300.3
     cy_d30 |   36232.37   45698.91       0.793   0.428      -53475.94    125940.7
     cy_d31 |  -97518.56   45980.94      -2.121   0.034      -187780.5   -7256.604
     cy_d32 |  -2795.452   11713.98      -0.239   0.811      -25790.34    20199.44
     cy_d33 |  -91724.66   19978.88      -4.591   0.000      -130943.8   -52505.52
     cy_d34 |   61870.87   20055.21       3.085   0.002       22501.89    101239.8
     cy_d35 |  -46707.89   28934.34      -1.614   0.107      -103506.9    10091.08
     cy_d36 |   138790.1   20188.15       6.875   0.000       99160.14      178420
     cy_d37 |   146430.3   17462.02       8.386   0.000       112151.8    180708.8
     cy_d38 |  -37526.17   18047.57      -2.079   0.038      -72954.08   -2098.259
     cy_d39 |   271227.9   31052.55       8.734   0.000       210270.8    332184.9
     cy_d40 |   198376.2   39567.77       5.014   0.000       120703.5    276048.9
     cy_d41 |    3376324   124121.2      27.202   0.000        3132671     3619978
     cy_d42 |   33754.73    13079.5       2.581   0.010       8079.295    59430.17
      yr_d2 |  -13685.13   18283.95      -0.748   0.454      -49577.07    22206.81
      yr_d3 |  -22318.66      18023      -1.238   0.216      -57698.35    13061.03
      yr_d4 |  -26483.02   17502.26      -1.513   0.131      -60840.47    7874.427
      yr_d5 |  -25596.76   15439.35      -1.658   0.098      -55904.67    4711.138
      yr_d6 |  -27588.26   14533.25      -1.898   0.058      -56117.45     940.934
      yr_d7 |  -33890.57   14446.86      -2.346   0.019      -62250.18   -5530.967
      yr_d8 |  -34860.47   13422.71      -2.597   0.010      -61209.65   -8511.288
      yr_d9 |  -32030.71    13253.4      -2.417   0.016      -58047.53   -6013.891
     yr_d10 |  -34888.88   13196.73      -2.644   0.008      -60794.47   -8983.303
     yr_d11 |     -40220      13412      -2.999   0.003      -66548.15   -13891.85
     yr_d12 |  -39523.94   13682.24      -2.889   0.004      -66382.58   -12665.29
     yr_d13 |     -41217   14124.99      -2.918   0.004      -68944.79   -13489.22
     yr_d14 |  -41337.63   15246.81      -2.711   0.007      -71267.56    -11407.7
     yr_d15 |  -42303.32    16431.5      -2.575   0.010      -74558.83   -10047.81
     yr_d16 |  -45214.28   17060.56      -2.650   0.008      -78704.66    -11723.9
     yr_d17 |  -46127.93   17505.99      -2.635   0.009      -80492.71   -11763.14
     yr_d18 |  -58315.56    17278.1      -3.375   0.001      -92232.98   -24398.13
     yr_d19 |  -73630.02   17295.46      -4.257   0.000      -107581.5   -39678.52
     yr_d20 |  -93135.77   18482.87      -5.039   0.000      -129418.2   -56853.35
      _cons |  -396504.4   40205.23      -9.862   0.000      -475428.5   -317580.3
------------------------------------------------------------------------------
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3(I)4

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. xtgls t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2-cy_d42 yr_d2-yr_d20

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        homoscedastic
Correlation:   no autocorrelation

Estimated covariances      =         1          Number of obs      =       840
Estimated autocorrelations =         0          Number of groups   =        42
Estimated coefficients     =        65          No. of time periods=        20
                                                Wald chi2(64)      = 178585.18
Log likelihood             = -10389.21          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |    118.817   7.997337     14.857   0.000       103.1425    134.4915
sp_pcgdp |  -.0085684   .0005421    -15.806   0.000      -.0096309   -.0075059
cp_pcgdp |   2.06e-07   1.15e-08     17.848   0.000       1.83e-07    2.29e-07
   popln |   .0040602   .0001133     35.848   0.000       .0038382    .0042822
   cy_d2 |  -116868.3   22984.95     -5.085   0.000        -161918   -71818.65
   cy_d3 |    25587.8   33577.97      0.762   0.446      -40223.81     91399.4
   cy_d4 |  -113353.2   31437.56     -3.606   0.000      -174969.7   -51736.76
   cy_d5 |  -397629.9   22449.85    -17.712   0.000      -441630.8     -353629
   cy_d6 |   71332.65   36261.04      1.967   0.049       262.3256      142403
   cy_d7 |   -16630.5   18180.42     -0.915   0.360      -52263.47    19002.46
   cy_d8 |   -1900674   131529.8    -14.451   0.000       -2158467    -1642880
   cy_d9 |  -66942.16   18031.49     -3.713   0.000      -102283.2   -31601.08
  cy_d10 |   214868.8   24668.62      8.710   0.000       166519.2    263218.4
  cy_d11 |   47247.17   22211.91      2.127   0.033       3712.622    90781.72
  cy_d12 |   169499.6    31883.3      5.316   0.000       107009.5    231989.7
  cy_d13 |  -68.32099   34260.34     -0.002   0.998      -67217.34     67080.7
  cy_d14 |   207538.4   25305.66      8.201   0.000       157940.2    257136.6
  cy_d15 |  -147233.3    30940.9     -4.759   0.000      -207876.4   -86590.26
  cy_d16 |   -2452987     101094    -24.264   0.000       -2651127    -2254846
  cy_d17 |  -336667.1   31461.23    -10.701   0.000        -398330   -275004.2
  cy_d18 |   27000.93   18388.33      1.468   0.142      -9039.541     63041.4
  cy_d19 |   13057.86   33567.74      0.389   0.697      -52733.69    78849.42
  cy_d20 |   318625.7   37285.22      8.546   0.000         245548    391703.4
  cy_d21 |   234689.6   28454.77      8.248   0.000       178919.3      290460
  cy_d22 |   14250.02   21399.13      0.666   0.505      -27691.51    56191.54
  cy_d23 |   289205.6   28894.09     10.009   0.000       232574.2      345837
  cy_d24 |   1007.715   18082.56      0.056   0.956      -34433.45    36448.87
  cy_d25 |  -85736.93   20081.25     -4.270   0.000      -125095.5   -46378.42
  cy_d26 |   68753.82   20315.08      3.384   0.001          28937    108570.6
  cy_d27 |     305375   30422.37     10.038   0.000       245748.2    365001.7
  cy_d28 |     249181   28448.47      8.759   0.000         193423      304939
  cy_d29 |  -43459.76   33347.56     -1.303   0.192      -108819.8    21900.26
  cy_d30 |   36232.37   32556.34      1.113   0.266      -27576.88    100041.6
  cy_d31 |  -97518.56   29463.71     -3.310   0.001      -155266.4   -39770.75
  cy_d32 |  -2795.452   18282.51     -0.153   0.878      -38628.52    33037.61
  cy_d33 |  -91724.66   20061.49     -4.572   0.000      -131044.5   -52404.85
  cy_d34 |   61870.87   21473.84      2.881   0.004       19782.91    103958.8
  cy_d35 |  -46707.89   27101.29     -1.723   0.085      -99825.44    6409.654
  cy_d36 |   138790.1   22488.59      6.172   0.000       94713.24    182866.9
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    cy_d37 |   146430.3   20760.13      7.053   0.000       105741.2    187119.4
    cy_d38 |  -37526.17   19073.89     -1.967   0.049      -74910.31    -142.027
    cy_d39 |   271227.9   29120.63      9.314   0.000       214152.5    328303.2
    cy_d40 |   198376.2   32380.01      6.127   0.000       134912.5    261839.9
    cy_d41 |    3376324   48028.29     70.299   0.000        3282190     3470458
    cy_d42 |   33754.73   18252.39      1.849   0.064      -2019.295    69528.76
     yr_d2 |  -13685.13    12419.5     -1.102   0.271      -38026.89    10656.64
     yr_d3 |  -22318.66   12422.11     -1.797   0.072      -46665.56    2028.231
     yr_d4 |  -26483.02   12430.68     -2.130   0.033       -50846.7   -2119.345
     yr_d5 |  -25596.76   12447.18     -2.056   0.040      -49992.78   -1200.748
     yr_d6 |  -27588.26   12465.06     -2.213   0.027      -52019.33   -3157.189
     yr_d7 |  -33890.57   12495.47     -2.712   0.007      -58381.24   -9399.909
     yr_d8 |  -34860.47   12543.57     -2.779   0.005      -59445.42   -10275.52
     yr_d9 |  -32030.71    12604.8     -2.541   0.011      -56735.66   -7325.765
    yr_d10 |  -34888.88   12657.61     -2.756   0.006      -59697.34   -10080.43
    yr_d11 |     -40220   12709.99     -3.164   0.002      -65131.13   -15308.87
    yr_d12 |  -39523.94   12767.48     -3.096   0.002      -64547.73   -14500.14
    yr_d13 |     -41217   12838.41     -3.210   0.001      -66379.83   -16054.18
    yr_d14 |  -41337.63   12903.76     -3.204   0.001      -66628.54   -16046.72
    yr_d15 |  -42303.32   13022.86     -3.248   0.001      -67827.66   -16778.97
    yr_d16 |  -45214.28   13131.75     -3.443   0.001      -70952.04   -19476.53
    yr_d17 |  -46127.93   13271.43     -3.476   0.001      -72139.46   -20116.39
    yr_d18 |  -58315.56   13430.58     -4.342   0.000         -84639   -31992.11
    yr_d19 |  -73630.02    13475.2     -5.464   0.000      -100040.9    -47219.1
    yr_d20 |  -93135.77    13601.3     -6.848   0.000      -119793.8   -66477.72
     _cons |  -396504.4   32260.74    -12.291   0.000      -459734.3   -333274.5
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3(I)5

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. xtgls t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2-cy_d42 yr_d2-yr_d20, p(h)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic
Correlation:   no autocorrelation

Estimated covariances      =        42          Number of obs      =       840
Estimated autocorrelations =         0          Number of groups   =        42
Estimated coefficients     =        65          No. of time periods=        20
                                                Wald chi2(63)      =  44956.71
Log likelihood             = -9431.185          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   56.71559   4.708633     12.045   0.000       47.48684    65.94434
sp_pcgdp |   -.004005   .0003873    -10.340   0.000      -.0047641   -.0032459
cp_pcgdp |   1.02e-07   9.57e-09     10.660   0.000       8.32e-08    1.21e-07
   popln |   .0030343   .0001911     15.874   0.000       .0026596    .0034089
   cy_d2 |   -55397.9   12320.73     -4.496   0.000      -79546.08   -31249.72
   cy_d3 |   60174.38   18541.55      3.245   0.001       23833.61    96515.15
   cy_d4 |  -177168.3   23730.03     -7.466   0.000      -223678.3   -130658.3
   cy_d5 |  -250362.1   25157.33     -9.952   0.000      -299669.5   -201054.6
   cy_d6 |   136388.6   22392.22      6.091   0.000       92500.61    180276.5
   cy_d7 |  -20395.47   12230.02     -1.668   0.095      -44365.88    3574.936
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       cy_d8 |  -892434.8   216516.5    -4.122   0.000     -1316799   -468070.3
       cy_d9 |  -55893.08   9290.001    -6.016   0.000    -74101.15   -37685.02
      cy_d10 |   82933.22   14274.44     5.810   0.000     54955.84    110910.6
      cy_d11 |  -3709.851   12172.17    -0.305   0.761    -27566.87    20147.17
      cy_d12 |   15225.63   17165.28     0.887   0.375    -18417.69    48868.95
      cy_d13 |   71183.69   23376.39     3.045   0.002      25366.8    117000.6
      cy_d14 |   72317.44   13028.17     5.551   0.000      46782.7    97852.18
      cy_d15 |  -120377.8    18431.8    -6.531   0.000    -156503.4   -84252.11
      cy_d16 |   -1744179   160841.4   -10.844   0.000     -2059422    -1428935
      cy_d17 |  -281150.8   33490.92    -8.395   0.000    -346791.8   -215509.8
      cy_d18 |   46739.16   13562.03     3.446   0.001     20158.06    73320.25
      cy_d19 |   83751.95   20333.17     4.119   0.000     43899.68    123604.2
      cy_d20 |     479972   29098.64    16.495   0.000     422939.7    537004.3
      cy_d21 |   77769.02   14593.02     5.329   0.000     49167.22    106370.8
      cy_d22 |   68409.56   19170.51     3.568   0.000     30836.05    105983.1
      cy_d23 |   113497.9   15643.54     7.255   0.000     82837.12    144158.7
      cy_d24 |   175.8327   9179.947     0.019   0.985    -17816.53     18168.2
      cy_d25 |   12034.12   15226.06     0.790   0.429    -17808.41    41876.64
      cy_d26 |   5915.239   9933.761     0.595   0.552    -13554.57    25385.05
      cy_d27 |   118346.8   16009.71     7.392   0.000     86968.31    149725.2
      cy_d28 |    86712.3    14668.4     5.912   0.000     57962.77    115461.8
      cy_d29 |  -12713.85   18604.57    -0.683   0.494    -49178.14    23750.44
      cy_d30 |  -57267.58   22624.85    -2.531   0.011    -101611.5   -12923.68
      cy_d31 |  -142672.7   23141.34    -6.165   0.000    -188028.9   -97316.55
      cy_d32 |  -26770.84   10522.71    -2.544   0.011    -47394.97   -6146.713
      cy_d33 |  -98459.96   11512.99    -8.552   0.000      -121025   -75894.92
      cy_d34 |   123627.5    14550.3     8.497   0.000     95109.43    152145.6
      cy_d35 |   13733.08   17507.08     0.784   0.433    -20580.17    48046.32
      cy_d36 |   38133.76   12012.53     3.174   0.002     14589.63    61677.89
      cy_d37 |    62988.4   11029.13     5.711   0.000      41371.7     84605.1
      cy_d38 |  -36955.63   12222.71    -3.024   0.002     -60911.7   -12999.56
      cy_d39 |   99387.66   15133.48     6.567   0.000     69726.58    129048.7
      cy_d40 |     269585   20306.71    13.276   0.000     229784.6    309385.4
      cy_d41 |    3780208   59478.88    63.555   0.000      3663632     3896785
      cy_d42 |   44641.26    12152.8     3.673   0.000     20822.21    68460.31
       yr_d2 |  -3794.743   4333.246    -0.876   0.381    -12287.75    4698.263
       yr_d3 |  -6459.936   4337.586    -1.489   0.136    -14961.45    2041.576
       yr_d4 |  -9436.228   4348.493    -2.170   0.030    -17959.12   -913.3391
       yr_d5 |  -10082.78   4366.191    -2.309   0.021    -18640.35   -1525.199
       yr_d6 |  -10567.94   4389.686    -2.407   0.016    -19171.56    -1964.31
       yr_d7 |  -14050.46   4416.015    -3.182   0.001    -22705.69   -5395.226
       yr_d8 |  -14625.47   4451.183    -3.286   0.001    -23349.63   -5901.309
       yr_d9 |  -16789.42   4491.258    -3.738   0.000    -25592.12   -7986.711
      yr_d10 |  -16627.28       4535    -3.666   0.000    -25515.72   -7738.842
      yr_d11 |  -17060.93   4580.884    -3.724   0.000     -26039.3   -8082.564
      yr_d12 |  -18150.53   4635.138    -3.916   0.000    -27235.23   -9065.823
      yr_d13 |  -18197.05   4693.834    -3.877   0.000    -27396.79     -8997.3
      yr_d14 |  -21145.07   4740.699    -4.460   0.000    -30436.67   -11853.48
      yr_d15 |  -24523.13    4827.81    -5.080   0.000    -33985.46    -15060.8
      yr_d16 |  -25181.98   4909.554    -5.129   0.000    -34804.53   -15559.43
      yr_d17 |  -28247.39   5012.515    -5.635   0.000    -38071.74   -18423.04
      yr_d18 |  -31550.64   5121.106    -6.161   0.000    -41587.83   -21513.46
      yr_d19 |  -33945.68   5197.662    -6.531   0.000    -44132.91   -23758.45
      yr_d20 |  -37403.39   5293.254    -7.066   0.000    -47777.97    -27028.8
       _cons |  -177458.3   18394.85    -9.647   0.000    -213511.6   -141405.1
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3(I)6

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. xtgls t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2-cy_d42 yr_d2-yr_d20,
corr(ar1) p(h)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic
Correlation:   common AR(1) coefficient for all panels  (0.8451)

Estimated covariances      =        42      Number of obs      =       840
Estimated autocorrelations =         1      Number of groups   =        42
Estimated coefficients     =        65      No. of time periods=        20
                                            Wald chi2(64)      =   7726.32
Log likelihood             = -8706.451      Pr > chi2          =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   26.79907   4.957604      5.406   0.000       17.08235    36.5158
sp_pcgdp |  -.0013106   .0004386     -2.988   0.003      -.0021702   -.000451
cp_pcgdp |   3.11e-08   1.10e-08      2.827   0.005       9.54e-09   5.27e-08
   popln |   .0022326   .0002251      9.917   0.000       .0017914   .0026739
   cy_d2 |  -49783.38   16244.61     -3.065   0.002      -81622.24  -17944.52
   cy_d3 |    49583.4   24325.44      2.038   0.042       1906.408   97260.39
   cy_d4 |  -176072.5   28595.41     -6.157   0.000      -232118.4  -120026.5
   cy_d5 |  -139959.4   31538.73     -4.438   0.000      -201774.2  -78144.63
   cy_d6 |   154156.6   37526.38      4.108   0.000       80606.24   227706.9
   cy_d7 |  -32174.43   16434.03     -1.958   0.050      -64384.53   35.67275
   cy_d8 |    -132892   275503.1     -0.482   0.630      -672868.2   407084.2
   cy_d9 |  -52212.52   14572.72     -3.583   0.000      -80774.52  -23650.51
  cy_d10 |    17969.6   19040.91      0.944   0.345      -19349.89    55289.1
  cy_d11 |  -18072.18   16018.96     -1.128   0.259      -49468.77   13324.41
  cy_d12 |  -46032.59   20556.21     -2.239   0.025      -86322.02  -5743.166
  cy_d13 |   111196.7   36103.76      3.080   0.002        40434.6   181958.8
  cy_d14 |   7633.271   16983.69      0.449   0.653      -25654.14   40920.68
  cy_d15 |  -132773.8   29342.48     -4.525   0.000        -190284  -75263.59
  cy_d16 |   -1136470     190246     -5.974   0.000       -1509345  -763594.2
  cy_d17 |  -207847.5   41762.48     -4.977   0.000      -289700.5  -125994.6
  cy_d18 |    65320.8   25056.58      2.607   0.009       16210.81   114430.8
  cy_d19 |   104512.3   25755.68      4.058   0.000       54032.09   154992.5
  cy_d20 |   578624.2   44870.94     12.895   0.000       490678.8   666569.6
  cy_d21 |   8748.517   17838.51      0.490   0.624      -26214.33   43711.36
  cy_d22 |   70985.69   29748.38      2.386   0.017       12679.93   129291.4
  cy_d23 |   29873.27   18492.51      1.615   0.106       -6371.38   66117.92
  cy_d24 |  -8421.235   14298.47     -0.589   0.556      -36445.73   19603.26
  cy_d25 |   67995.65   27454.01      2.477   0.013       14186.78   121804.5
  cy_d26 |  -21806.91   16066.46     -1.357   0.175      -53296.59   9682.779
  cy_d27 |   30056.96   18690.46      1.608   0.108      -6575.666   66689.59
  cy_d28 |   12374.67    17708.1      0.699   0.485      -22332.56    47081.9
  cy_d29 |  -25949.33   24958.57     -1.040   0.298      -74867.23   22968.57
  cy_d30 |  -78362.24   29420.69     -2.664   0.008      -136025.7  -20698.75
  cy_d31 |  -133748.7   27928.19     -4.789   0.000      -188486.9  -79010.46
  cy_d32 |  -42595.96   15796.27     -2.697   0.007      -73556.09  -11635.83
  cy_d33 |   -88874.4   15569.73     -5.708   0.000      -119390.5  -58358.29
  cy_d34 |   134583.9   23858.88      5.641   0.000       87821.38   181346.5
  cy_d35 |   19422.18   22852.86      0.850   0.395       -25368.6   64212.97
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    cy_d36 |  -9335.025   15042.33      -0.621   0.535      -38817.45     20147.4
    cy_d37 |   20209.75   16414.08       1.231   0.218      -11961.26    52380.76
    cy_d38 |  -26294.75    15517.1      -1.695   0.090      -56707.71    4118.205
    cy_d39 |   18848.57   18059.51       1.044   0.297      -16547.41    54244.56
    cy_d40 |   285435.6   29851.89       9.562   0.000         226927    343944.2
    cy_d41 |    4146613   131399.3      31.557   0.000        3889075     4404151
    cy_d42 |   40529.65   22737.85       1.782   0.075      -4035.712    85095.01
     yr_d2 |  -2824.026   1539.647      -1.834   0.067       -5841.68     193.627
     yr_d3 |  -4239.402   2104.372      -2.015   0.044      -8363.895   -114.9095
     yr_d4 |  -5555.055    2495.22      -2.226   0.026       -10445.6   -664.5138
     yr_d5 |  -6363.774   2798.886      -2.274   0.023      -11849.49   -878.0578
     yr_d6 |  -6815.099   3046.209      -2.237   0.025      -12785.56   -844.6394
     yr_d7 |  -8512.053   3258.578      -2.612   0.009      -14898.75   -2125.359
     yr_d8 |  -8578.506   3449.658      -2.487   0.013      -15339.71     -1817.3
     yr_d9 |  -8988.853   3624.151      -2.480   0.013      -16092.06   -1885.647
    yr_d10 |  -8557.755   3783.507      -2.262   0.024      -15973.29   -1142.218
    yr_d11 |  -7885.891   3933.068      -2.005   0.045      -15594.56   -177.2189
    yr_d12 |  -8056.636   4083.982      -1.973   0.049      -16061.09   -52.17754
    yr_d13 |  -7425.328   4236.464      -1.753   0.080      -15728.64    877.9887
    yr_d14 |  -8045.615   4371.491      -1.840   0.066      -16613.58    522.3509
    yr_d15 |  -8900.251   4546.875      -1.957   0.050      -17811.96    11.45959
    yr_d16 |  -7544.942   4714.108      -1.601   0.109      -16784.42     1694.54
    yr_d17 |   -7078.71   4897.301      -1.445   0.148      -16677.24    2519.823
    yr_d18 |  -7917.221    5084.49      -1.557   0.119      -17882.64    2048.195
    yr_d19 |   -9873.56   5208.955      -1.895   0.058      -20082.92    335.8037
    yr_d20 |  -12440.43   5369.465      -2.317   0.021      -22964.39   -1916.472
     _cons |  -71687.56   19636.26      -3.651   0.000      -110173.9   -33201.21
------------------------------------------------------------------------------
```

3(I)7

```
. xtgls t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2-cy_d42 yr_d2-yr_d20,
corr(psar1) p(h)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic
Correlation:   panel-specific AR(1)

Estimated covariances      =        42          Number of obs      =       840
Estimated autocorrelations =        42          Number of groups   =        42
Estimated coefficients     =        65          No. of time periods=        20
                                                Wald chi2(64)      =  32027.27
Log likelihood             = -8726.429          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.        z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   37.28373   5.170561      7.211   0.000       27.14962    47.41785
sp_pcgdp |  -.0026218   .0004535     -5.781   0.000      -.0035107   -.0017329
cp_pcgdp |   7.14e-08   1.13e-08      6.308   0.000       4.92e-08    9.36e-08
   popln |   .0024751   .0002685      9.219   0.000       .0019489    .0030013
   cy_d2 |   6594.776    35379.2      0.186   0.852      -62747.18    75936.73
   cy_d3 |   103251.8   36591.33      2.822   0.005       31534.12    174969.5
   cy_d4 |  -136881.3   48302.26     -2.834   0.005        -231552   -42210.65
   cy_d5 |  -109646.1   60216.64     -1.821   0.069      -227668.5      8376.4
```

```
      cy_d6 |   255670.3   47218.11      5.415   0.000      163124.5    348216.1
      cy_d7 |   18314.81   35874.52      0.511   0.610     -51997.95    88627.57
      cy_d8 |  -352484.8   323505.3     -1.090   0.276     -986543.6      281574
      cy_d9 |  -10028.75   31437.36     -0.319   0.750     -71644.84    51587.35
     cy_d10 |   75477.27    33748.3      2.236   0.025      9331.813    141622.7
     cy_d11 |   24827.09   33147.93      0.749   0.454     -40141.67    89795.85
     cy_d12 |    11061.8   36127.83      0.306   0.759     -59747.44    81871.05
     cy_d13 |   156506.8    42077.6      3.719   0.000      74036.24    238977.4
     cy_d14 |      66552   31807.53      2.092   0.036      4210.394    128893.6
     cy_d15 |  -72299.88   38955.14     -1.856   0.063     -148650.5    4050.792
     cy_d16 |   -1270359   241708.5     -5.256   0.000      -1744099   -796619.4
     cy_d17 |  -195080.5    63505.6     -3.072   0.002     -319549.2   -70611.79
     cy_d18 |   105582.6   47613.68      2.217   0.027      12261.47    198903.6
     cy_d19 |   156233.8   36045.29      4.334   0.000      85586.37    226881.3
     cy_d20 |   593902.3   45409.95     13.079   0.000      504900.5    682904.2
     cy_d21 |   70604.73   46701.51      1.512   0.131     -20928.55      162138
     cy_d22 |   115061.7   79014.43      1.456   0.145      -39803.7    269927.2
     cy_d23 |   93691.12   33856.33      2.767   0.006      27333.93    160048.3
     cy_d24 |   39445.35   30516.62      1.293   0.196     -20366.14    99256.83
     cy_d25 |   99859.52   35334.75      2.826   0.005      30604.69    169114.4
     cy_d26 |   26008.03   30222.79      0.861   0.389     -33227.55    85243.62
     cy_d27 |   96168.57   33448.49      2.875   0.004      30610.74    161726.4
     cy_d28 |   73775.33   33380.71      2.210   0.027      8350.336    139200.3
     cy_d29 |    97634.5    45108.3      2.164   0.030      9223.863    186045.1
     cy_d30 |  -42053.49   130701.4     -0.322   0.748     -298223.5    214116.5
     cy_d31 |  -97451.94   47306.66     -2.060   0.039     -190171.3   -4732.585
     cy_d32 |   3711.918   30501.37      0.122   0.903     -56069.68    63493.51
     cy_d33 |  -51618.56   31551.71     -1.636   0.102     -113458.8    10221.64
     cy_d34 |   184192.5   43706.77      4.214   0.000       98528.8    269856.2
     cy_d35 |    40461.9   50830.75      0.796   0.426     -59164.54    140088.3
     cy_d36 |   43562.14    35030.9      1.244   0.214     -25097.16    112221.4
     cy_d37 |   72691.69   31032.56      2.342   0.019      11868.99    133514.4
     cy_d38 |   14761.51   32653.91      0.452   0.651     -49238.97       78762
     cy_d39 |   81956.06   33297.32      2.461   0.014      16694.51    147217.6
     cy_d40 |   341160.3    37453.9      9.109   0.000        267752    414568.5
     cy_d41 |    4014363   94433.33     42.510   0.000       3829278     4199449
     cy_d42 |   86816.18   36102.06      2.405   0.016      16057.44    157574.9
      yr_d2 |   -3643.32    1553.86     -2.345   0.019      -6688.83   -597.8106
      yr_d3 |  -5716.481   2115.086     -2.703   0.007     -9861.972   -1570.989
      yr_d4 |  -7011.136   2497.663     -2.807   0.005     -11906.47   -2115.806
      yr_d5 |  -7873.155   2788.451     -2.823   0.005     -13338.42   -2407.891
      yr_d6 |  -8777.679     3018.8     -2.908   0.004     -14694.42    -2860.94
      yr_d7 |  -10699.35   3216.115     -3.327   0.001     -17002.82   -4395.878
      yr_d8 |  -10980.91   3389.733     -3.239   0.001     -17624.66   -4337.153
      yr_d9 |   -11687.8    3542.07     -3.300   0.001     -18630.13   -4745.468
     yr_d10 |  -11625.38   3682.401     -3.157   0.002     -18842.75   -4408.008
     yr_d11 |  -11262.51   3813.187     -2.954   0.003     -18736.21   -3788.798
     yr_d12 |  -11544.61   3946.998     -2.925   0.003     -19280.59   -3808.639
     yr_d13 |  -11170.55   4084.597     -2.735   0.006     -19176.21   -3164.886
     yr_d14 |  -11973.04   4196.274     -2.853   0.004     -20197.59   -3748.497
     yr_d15 |  -13374.33   4355.847     -3.070   0.002     -21911.63   -4837.025
     yr_d16 |  -12849.31   4516.283     -2.845   0.004     -21701.06   -3997.556
     yr_d17 |  -12796.62   4699.336     -2.723   0.006     -22007.15   -3586.091
     yr_d18 |  -14560.01   4904.656     -2.969   0.003     -24172.96   -4947.063
     yr_d19 |  -17672.83   5072.558     -3.484   0.000     -27614.87   -7730.804
     yr_d20 |  -21505.15   5294.642     -4.062   0.000     -31882.46   -11127.84
      _cons |  -143038.4   34688.43     -4.124   0.000     -211026.5   -75050.33
------------------------------------------------------------------------------
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3(I)8

```
. xtgls t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2-cy_d42 yr_d2-yr_d20,
panels(correlated) corr(psar1)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   panel-specific AR(1)

Estimated covariances      =       903          Number of obs      =       840
Estimated autocorrelations =        42          Number of groups   =        42
Estimated coefficients     =        65          No. of time periods=        20
                                                Wald chi2(40)      = 112530.50
Log likelihood             =         .          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |    64.9757   3.009041     21.593   0.000       59.07809    70.87332
sp_pcgdp |  -.0054112   .0002358    -22.946   0.000      -.0058734    -.004949
cp_pcgdp |   1.44e-07   5.66e-09     25.364   0.000       1.33e-07    1.55e-07
   popln |   .0043056   .0001752     24.569   0.000       .0039621    .0046491
   cy_d2 |  (dropped)
   cy_d3 |   4947.212   46238.38      0.107   0.915      -85678.35    95572.77
   cy_d4 |  (dropped)
   cy_d5 |  -566624.9   38987.56    -14.533   0.000      -643039.1   -490210.7
   cy_d6 |   146812.9   44249.68      3.318   0.001       60085.13    233540.7
   cy_d7 |  (dropped)
   cy_d8 |   -2499328   196737.4    -12.704   0.000       -2884926    -2113729
   cy_d9 |  (dropped)
  cy_d10 |  -27311.32   39975.95     -0.683   0.494      -105662.7    51040.12
  cy_d11 |  (dropped)
  cy_d12 |  (dropped)
  cy_d13 |   -28650.9   48091.32     -0.596   0.551      -122908.2    65606.35
  cy_d14 |  (dropped)
  cy_d15 |  -163314.4   50957.65     -3.205   0.001      -263189.5   -63439.19
  cy_d16 |   -3088818   133965.1    -23.057   0.000       -3351385    -2826251
  cy_d17 |  -635309.4   48090.77    -13.211   0.000      -729565.6   -541053.2
  cy_d18 |   -57570.7   46907.92     -1.227   0.220      -149508.5    34367.14
  cy_d19 |  (dropped)
  cy_d20 |   290444.6   42836.41      6.780   0.000       206486.8    374402.5
  cy_d21 |  (dropped)
  cy_d22 |  (dropped)
  cy_d23 |  (dropped)
  cy_d24 |  (dropped)
  cy_d25 |  -177877.5    40722.3     -4.368   0.000      -257691.7   -98063.23
  cy_d26 |  (dropped)
  cy_d27 |  (dropped)
  cy_d28 |  (dropped)
  cy_d29 |  (dropped)
  cy_d30 |  (dropped)
  cy_d31 |  (dropped)
  cy_d32 |  -158882.2   40003.84     -3.972   0.000      -237288.3   -80476.09
  cy_d33 |  (dropped)
  cy_d34 |   46660.68   38357.31      1.216   0.224      -28518.27    121839.6
  cy_d35 |  -179724.6   44630.12     -4.027   0.000        -267198   -92251.15
```

```
   cy_d36 |  (dropped)
   cy_d37 |  (dropped)
   cy_d38 |  (dropped)
   cy_d39 |  (dropped)
   cy_d40 |   158281.1   45475.92      3.481   0.001      69149.96   247412.3
   cy_d41 |    3333332   60798.89     54.826   0.000       3214169    3452496
   cy_d42 |  -56065.27   41797.89     -1.341   0.180     -137987.6   25857.08
    yr_d2 |  -12343.38   970.6799    -12.716   0.000     -14245.88  -10440.88
    yr_d3 |  -21308.71   1419.105    -15.016   0.000     -24090.11  -18527.32
    yr_d4 |   -24993.7   1871.341    -13.356   0.000     -28661.46  -21325.94
    yr_d5 |  -24886.87   2312.189    -10.763   0.000     -29418.67  -20355.06
    yr_d6 |  -27131.76   2703.778    -10.035   0.000     -32431.07  -21832.45
    yr_d7 |  -32532.28   3073.691    -10.584   0.000      -38556.6  -26507.95
    yr_d8 |  -30224.22   3469.254     -8.712   0.000     -37023.84  -23424.61
    yr_d9 |  -24784.42   3882.403     -6.384   0.000     -32393.78  -17175.05
   yr_d10 |   -25641.7   4245.037     -6.040   0.000     -33961.82  -17321.59
   yr_d11 |  -27651.48   4508.996     -6.133   0.000     -36488.94  -18814.01
   yr_d12 |  -24309.64   4702.219     -5.170   0.000     -33525.82  -15093.46
   yr_d13 |  -23408.58   4989.495     -4.692   0.000     -33187.82  -13629.35
   yr_d14 |  -22136.89   5272.407     -4.199   0.000     -32470.62  -11803.16
   yr_d15 |  -19672.32   5631.733     -3.493   0.000     -30710.31  -8634.326
   yr_d16 |  -19517.17   5951.609     -3.279   0.001     -31182.11  -7852.227
   yr_d17 |  -15621.93     6227.1     -2.509   0.012     -27826.82  -3417.033
   yr_d18 |  -25902.87   6600.123     -3.925   0.000     -38838.87  -12966.87
   yr_d19 |  -39917.97   7050.622     -5.662   0.000     -53736.93     -26099
   yr_d20 |  -57382.33   7532.253     -7.618   0.000     -72145.27  -42619.38
    _cons |  -77356.57   39392.12     -1.964   0.050     -154563.7  -149.4333
------------------------------------------------------------------------------
Note: You estimated at least as many quantities as you have observations.
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3(I)9

```
. xtgls t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln slp_dum yr_d2-yr_d20,
panels(correlated) corr(psar1)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   panel-specific AR(1)

Estimated covariances      =       903          Number of obs      =       840
Estimated autocorrelations =        42          Number of groups   =        42
Estimated coefficients     =        25          No. of time periods=        20
                                                Wald chi2(24)      =   7706.78
Log likelihood             =         .          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   69.59107    3.82762     18.181   0.000      62.08907    77.09307
sp_pcgdp |  -.0072286    .000329    -21.970   0.000     -.0078734   -.0065837
cp_pcgdp |   2.62e-07   9.44e-09     27.709   0.000      2.43e-07    2.80e-07
   popln |   .0028469   .0000452     62.973   0.000      .0027583    .0029356
 slp_dum |   3.669712   1.689011      2.173   0.030       .359311    6.980112
   yr_d2 |  -11298.31   702.2752    -16.088   0.000     -12674.74   -9921.871
   yr_d3 |  -15622.01   1012.262    -15.433   0.000     -17606.01   -13638.02
```

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     yr_d4 |  -23473.28   1307.252    -17.956   0.000       -26035.45   -20911.12
     yr_d5 |  -25778.85   1468.856    -17.550   0.000       -28657.75   -22899.94
     yr_d6 |  -32918.76   1683.108    -19.558   0.000       -36217.59   -29619.93
     yr_d7 |   -43293.3   1931.122    -22.419   0.000       -47078.23   -39508.37
     yr_d8 |   -50028.9   2251.115    -22.224   0.000       -54441.01    -45616.8
     yr_d9 |  -55945.73   2681.594    -20.863   0.000       -61201.55    -50689.9
    yr_d10 |  -62404.86   3187.272    -19.579   0.000        -68651.8   -56157.92
    yr_d11 |  -67316.22   3731.673    -18.039   0.000       -74630.16   -60002.28
    yr_d12 |  -61148.99    4291.72    -14.248   0.000       -69560.61   -52737.37
    yr_d13 |  -63158.64       4991    -12.655   0.000       -72940.82   -53376.46
    yr_d14 |  -64020.06   5706.979    -11.218   0.000       -75205.53   -52834.58
    yr_d15 |  -69178.27   6690.931    -10.339   0.000       -82292.25   -56064.28
    yr_d16 |  -74004.83   7818.488     -9.465   0.000       -89328.78   -58680.87
    yr_d17 |  -76311.36   9151.397     -8.339   0.000       -94247.77   -58374.95
    yr_d18 |   -93919.9   10729.63     -8.753   0.000       -114949.6   -72890.21
    yr_d19 |  -106968.9   12518.97     -8.545   0.000       -131505.6   -82432.15
    yr_d20 |    -129959   14655.37     -8.868   0.000         -158683     -101235
     _cons |  -149022.4   9999.219    -14.903   0.000       -168620.5   -129424.3
------------------------------------------------------------------------------
Note: You estimated at least as many quantities as you have observations.
```

3(I)10

```
. xtreg  t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln  yr_d2- yr_d20, fe

Fixed-effects (within) regression               Number of obs      =       360
Group variable (i) : cocode                     Number of groups   =        18

R-sq:  within  = 0.8063                         Obs per group: min =        20
       between = 0.8140                                        avg =      20.0
       overall = 0.8090                                        max =        20

                                                F(23,319)          =     57.72
corr(u_i, Xb)  = 0.6800                         Prob > F           =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   102.2715    9.58195     10.673   0.000        83.41968    121.1233
sp_pcgdp |  -.0070996   .0006672    -10.641   0.000       -.0084122   -.0057869
cp_pcgdp |   1.70e-07   1.41e-08     12.040   0.000        1.42e-07    1.98e-07
   popln |   .0076088    .000791      9.619   0.000        .0060526     .009165
   yr_d2 |  -22056.48   16185.83     -1.363   0.174       -53900.95    9787.992
   yr_d3 |  -40021.86   16203.97     -2.470   0.014          -71902   -8141.714
   yr_d4 |  -50029.87   16266.91     -3.076   0.002       -82033.85   -18025.88
   yr_d5 |  -49807.58   16400.27     -3.037   0.003       -82073.93   -17541.22
   yr_d6 |  -54713.38   16529.45     -3.310   0.001       -87233.89   -22192.87
   yr_d7 |   -66741.5   16766.22     -3.981   0.000       -99727.84   -33755.16
   yr_d8 |  -66537.61   17118.49     -3.887   0.000         -100217    -32858.2
   yr_d9 |  -58485.65   17535.92     -3.335   0.001       -92986.33   -23984.98
  yr_d10 |  -59226.91   17874.12     -3.314   0.001       -94392.95   -24060.87
  yr_d11 |  -65834.62   18205.37     -3.616   0.000       -101652.4   -30016.85
  yr_d12 |  -62123.48   18574.13     -3.345   0.001       -98666.76    -25580.2
  yr_d13 |   -68680.4   18980.96     -3.618   0.000       -106024.1   -31336.71
  yr_d14 |  -66636.34   19345.63     -3.445   0.001       -104697.5   -28575.21
  yr_d15 |  -67852.43   19918.93     -3.406   0.001       -107041.5   -28663.37
  yr_d16 |  -76154.91   20412.98     -3.731   0.000         -116316   -35993.84
```

```
   yr_d17 |  -77926.25   20964.56      -3.717   0.000      -119172.5   -36679.98
   yr_d18 |  -91533.86    21591.1      -4.239   0.000      -134012.8   -49054.92
   yr_d19 |  -105421.4   21752.26      -4.846   0.000      -148217.4   -62625.43
   yr_d20 |  -126555.4   22171.71      -5.708   0.000      -170176.6    -82934.1
    _cons |  -348636.9    60485.8      -5.764   0.000      -467638.4   -229635.5
------------------------------------------------------------------------------
  sigma_u |  666733.18
  sigma_e |  48520.329
      rho |  .99473196   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(17,319) =  1577.36             Prob > F = 0.0000
```

3(I)11

```
. xtreg  t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln  yr_d2- yr_d20, fe

Fixed-effects (within) regression               Number of obs      =       480
Group variable (i) : cocode                     Number of groups   =        24

R-sq:  within  = 0.7932                         Obs per group: min =        20
       between = 0.8473                                        avg =      20.0
       overall = 0.8270                                        max =        20
                                                F(23,433)          =     72.21
corr(u_i, Xb)  = -0.9332                        Prob > F           =    0.0000
------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.        t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   320.2266   68.95591      4.644   0.000       184.6967    455.7566
sp_pcgdp |  -.0555153   .0202899     -2.736   0.006      -.0953943   -.0156364
cp_pcgdp |   3.48e-06   1.84e-06      1.888   0.060      -1.44e-07    7.10e-06
   popln |   .0036662   .0001688     21.722   0.000       .0033345    .0039979
   yr_d2 |  -8688.059   18706.89     -0.464   0.643      -45455.65    28079.54
   yr_d3 |  -10519.77   18719.27     -0.562   0.574      -47311.71    26272.17
   yr_d4 |  -11242.07   18737.39     -0.600   0.549      -48069.62    25585.47
   yr_d5 |  -11360.78   18753.17     -0.606   0.545      -48219.34    25497.78
   yr_d6 |  -12655.83    18769.3     -0.674   0.500       -49546.1    24234.44
   yr_d7 |  -16868.55      18786     -0.898   0.370      -53791.64    20054.54
   yr_d8 |  -20869.73   18808.99     -1.110   0.268      -57838.02    16098.55
   yr_d9 |  -25725.71   18834.24     -1.366   0.173       -62743.6    11292.19
  yr_d10 |  -31861.93   18871.64     -1.688   0.092      -68953.35     5229.48
  yr_d11 |  -38007.06   18917.61     -2.009   0.045      -75188.82   -825.2994
  yr_d12 |  -40601.77   18969.04     -2.140   0.033      -77884.62   -3318.934
  yr_d13 |   -39293.8   19023.78     -2.066   0.039      -76684.24   -1903.355
  yr_d14 |  -43167.13    19083.3     -2.262   0.024      -80674.56   -5659.708
  yr_d15 |  -44974.18   19181.21     -2.345   0.019      -82674.04   -7274.327
  yr_d16 |   -45426.4   19298.92     -2.354   0.019       -83357.6   -7495.196
  yr_d17 |  -47187.53   19454.33     -2.426   0.016       -85424.2   -8950.864
  yr_d18 |  -58615.18   19556.44     -2.997   0.003      -97052.53   -20177.83
  yr_d19 |  -75561.66   19603.61     -3.854   0.000      -114091.7   -37031.59
  yr_d20 |  -93872.45   19710.42     -4.763   0.000      -132612.4   -55132.45
   _cons |  -672757.7    54743.4    -12.289   0.000      -780353.5   -565161.8
------------------------------------------------------------------------------
 sigma_u |  570255.62
 sigma_e |  64795.139
     rho |  .98725398   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(23,433) =   188.20             Prob > F = 0.0000
```

3(I)12

```
. xtreg  t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln  yr_d2- yr_d10, fe

Fixed-effects (within) regression               Number of obs      =       420
Group variable (i) : cocode                     Number of groups   =        42

R-sq:  within  = 0.6510                         Obs per group: min =        10
       between = 0.2632                                        avg =      10.0
       overall = 0.2647                                        max =        10

                                                F(13,365)          =     52.38
corr(u_i, Xb)  = -0.5491                        Prob > F           =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   89.56677   14.83473      6.038   0.000        60.3945    118.739
sp_pcgdp |  -.0075878   .0010804     -7.023   0.000      -.0097124  -.0054632
cp_pcgdp |   1.99e-07   2.47e-08      8.058   0.000       1.50e-07   2.47e-07
   popln |   .0043046   .0002231     19.296   0.000       .0038659   .0047433
   yr_d2 |  -13691.64   8841.376     -1.549   0.122      -31078.07   3694.789
   yr_d3 |   -22901.6   8856.753     -2.586   0.010      -40318.27   -5484.93
   yr_d4 |  -27707.18   8899.347     -3.113   0.002      -45207.61  -10206.75
   yr_d5 |  -26327.12   8974.613     -2.934   0.004      -43975.56  -8678.686
   yr_d6 |  -28618.83   9059.297     -3.159   0.002       -46433.8  -10803.86
   yr_d7 |  -34368.28    9193.52     -3.738   0.000       -52447.2  -16289.37
   yr_d8 |  -34598.97    9396.04     -3.682   0.000      -53076.14  -16121.81
   yr_d9 |   -31195.9   9653.916     -3.231   0.001      -50180.18  -12211.63
  yr_d10 |  -34291.84   9885.353     -3.469   0.001      -53731.23  -14852.45
   _cons |  -284168.1   43583.35     -6.520   0.000      -369874.1  -198462.1
------------------------------------------------------------------------------
 sigma_u |  779139.11
 sigma_e |   40483.59
     rho |  .99730749   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(41,365) =   887.45            Prob > F = 0.0000
```

3(I)13

```
. xtreg  t_co2_em p_pcgdp sp_pcgdp cp_pcgdp popln  yr_d2- yr_d10, fe

Fixed-effects (within) regression               Number of obs      =       420
Group variable (i) : cocode                     Number of groups   =        42

R-sq:  within  = 0.6764                         Obs per group: min =        10
       between = 0.4375                                        avg =      10.0
       overall = 0.4384                                        max =        10

                                                F(13,365)          =     58.68
corr(u_i, Xb)  = -0.3662                        Prob > F           =    0.0000

------------------------------------------------------------------------------
t_co2_em |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   119.3593   14.82446      8.052   0.000       90.20727    148.5114
sp_pcgdp |  -.0076716   .0009211     -8.329   0.000       -.009483   -.0058603
cp_pcgdp |   1.69e-07   1.80e-08      9.378   0.000       1.33e-07    2.04e-07
   popln |   .0038396   .0002459     15.614   0.000        .003356    .0043231
   yr_d2 |   334.3854   8912.713      0.038   0.970      -17192.33     17861.1
   yr_d3 |   -737.619   8984.567     -0.082   0.935      -18405.63    16930.39
   yr_d4 |  -296.2985   9086.073     -0.033   0.974      -18163.92    17571.32
   yr_d5 |   184.6007   9323.773      0.020   0.984      -18150.45    18519.66
   yr_d6 |  -1543.817   9581.609     -0.161   0.872       -20385.9    17298.27
   yr_d7 |  -870.5807   9955.643     -0.087   0.930       -20448.2    18707.04
   yr_d8 |  -10750.15   10389.06     -1.035   0.301      -31180.08    9679.778
   yr_d9 |  -24077.34   10463.06     -2.301   0.022      -44652.78   -3501.894
  yr_d10 |  -40552.59   10774.21     -3.764   0.000      -61739.91   -19365.28
   _cons |  -426142.3   50686.26     -8.407   0.000      -525816.1   -326468.6
------------------------------------------------------------------------------
 sigma_u |  734580.62
 sigma_e |  40729.518
     rho |  .99693517   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(41,365) =   811.40             Prob > F = 0.0000
```

• *3(II) Sulphur-di-oxide (SO2)*

3(II)1

```
. xtreg so2 p_pcgdp sp_pcgdp cp_pcgdp popln

Random-effects GLS regression                   Number of obs      =       540
Group variable (i) : cocode                     Number of groups   =        27

R-sq:  within  = 0.1440                         Obs per group: min =        20
       between = 0.4167                                        avg =      20.0
       overall = 0.3634                                        max =        20

Random effects u_i ~ Gaussian                   Wald chi2(4)       =     88.36
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
     so2 |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   .4352331   .0822686      5.290   0.000        .2739896   .5964767
sp_pcgdp |  -.0000249   4.29e-06     -5.820   0.000       -.0000333  -.0000165
cp_pcgdp |   3.73e-10   7.03e-11      5.302   0.000        2.35e-10   5.10e-10
   popln |   9.26e-06   4.87e-06      1.900   0.057       -2.91e-07   .0000188
   _cons |  -509.7669   583.7453     -0.873   0.383       -1653.887   634.3528
---------+--------------------------------------------------------------------
 sigma_u |  1114.6889
 sigma_e |  367.50602
     rho |  .90195888   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

3(II)2

```
. xtgls so2 p_pcgdp sp_pcgdp cp_pcgdp popln, corr(ar1) p(h)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic
Correlation:   common AR(1) coefficient for all panels  (0.9771)

Estimated covariances      =        27          Number of obs      =       540
Estimated autocorrelations =         1          Number of groups   =        27
Estimated coefficients     =         5          No. of time periods=        20
                                                Wald chi2(3)       =     74.18
Log likelihood             = -2874.671          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
     so2 |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   .0497517   .0147976      3.362   0.001         .020749   .0787544
sp_pcgdp |  -2.72e-06   8.34e-07     -3.263   0.001       -4.36e-06  -1.09e-06
cp_pcgdp |   4.00e-11   1.47e-11      2.731   0.006        1.13e-11   6.87e-11
   popln |   .0000371   4.67e-06      7.940   0.000        .0000279   .0000462
   _cons |  -218.1708   88.11423     -2.476   0.013       -390.8715  -45.47008
------------------------------------------------------------------------------
```

3(II)3

```
. reg so2 p_pcgdp sp_pcgdp cp_pcgdp popln, robust

Regression with robust standard errors                 Number of obs =     540
                                                       F(  3,    535) =  254.50
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.8935
                                                       Root MSE      =  1249.4

------------------------------------------------------------------------------
         |               Robust
     so2 |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   .1896989   .1082333      1.753   0.080       -.0229153    .4023132
sp_pcgdp |  -.0000113   5.81e-06     -1.940   0.053       -.0000227    1.41e-07
cp_pcgdp |   2.01e-10   9.81e-11      2.046   0.041        8.04e-12    3.93e-10
   popln |   .0000752   2.74e-06     27.460   0.000        .0000698    .0000805
   _cons |  -1293.234   614.2713     -2.105   0.036       -2499.913   -86.55443
------------------------------------------------------------------------------
```

- *3(III)Biological Oxygen Demand (BOD)*

3(III)1

```
. xtreg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2-yr_d20, fe

Fixed-effects (within) regression               Number of obs      =       720
Group variable (i) : cocode                     Number of groups   =        36

R-sq:  within  = 0.4824                         Obs per group: min =        20
       between = 0.7971                                        avg =      20.0
       overall = 0.7497                                        max =        20

                                                F(23,661)          =     26.79
corr(u_i, Xb)  = -0.9340                        Prob > F           =    0.0000

------------------------------------------------------------------------------
     bod |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   228.0317   43.06805      5.295   0.000       143.4651    312.5984
sp_pcgdp |   -.011791   .0028453     -4.144   0.000      -.0173778   -.0062041
cp_pcgdp |   1.91e-07   5.92e-08      3.224   0.001       7.46e-08    3.07e-07
   popln |   .0107397   .0005564     19.302   0.000       .0096472    .0118322
   yr_d2 |  -19231.71   64282.43     -0.299   0.765      -145454.1    106990.6
   yr_d3 |  -33463.13   64295.41     -0.520   0.603        -159711    92784.72
   yr_d4 |  -51619.68   64339.11     -0.802   0.423      -177953.3    74713.98
   yr_d5 |  -67209.45   64421.62     -1.043   0.297      -193705.1    59286.22
   yr_d6 |  -73735.03   64511.62     -1.143   0.253      -200407.4    52937.37
   yr_d7 |  -89739.08   64672.05     -1.388   0.166      -216726.5    37248.32
   yr_d8 |  -99411.59   64920.89     -1.531   0.126      -226887.6    28064.43
   yr_d9 |  -113137.3   65249.16     -1.734   0.083        -241258    14983.26
  yr_d10 |  -126195.5   65527.68     -1.926   0.055        -254863     2471.96
  yr_d11 |  -89352.22   65819.49     -1.358   0.175      -218592.7    39888.26
  yr_d12 |  -108112.7   66120.16     -1.635   0.103      -237943.6    21718.14
  yr_d13 |  -126894.1   66472.48     -1.909   0.057      -257416.8    3628.542
  yr_d14 |  -156548.4    66774.5     -2.344   0.019      -287664.1   -25432.73
  yr_d15 |  -176541.7   67377.85     -2.620   0.009      -308842.1   -44241.32
  yr_d16 |  -192385.3   67904.91     -2.833   0.005      -325720.6      -59050
  yr_d17 |  -226765.8   68622.94     -3.305   0.001        -361511   -92020.58
  yr_d18 |  -222329.9   69483.64     -3.200   0.001      -358765.2   -85894.68
  yr_d19 |    -207722   69715.83     -2.980   0.003      -344613.1   -70830.81
  yr_d20 |    -188164   70333.07     -2.675   0.008      -326267.2   -50060.84
   _cons |   -1330840   142567.1     -9.335   0.000       -1610779    -1050901
------------------------------------------------------------------------------
 sigma_u |  1454102.2
 sigma_e |  272697.93
     rho |  .96602479   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(35,661) =     64.53             Prob > F = 0.0000
```

3(III)2

```
. reg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2-yr_d20 cy_d2-cy_d36, robust

Regression with robust standard errors                 Number of obs =     720
                                                       F( 58,   661) =  461.34
                                                       Prob > F      =  0.0000
                                                       R-squared     =  0.9483
                                                       Root MSE      =  2.7e+05

------------------------------------------------------------------------------
         |               Robust
     bod |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   228.0316   60.64421      3.760   0.000        108.9531   347.1101
sp_pcgdp |   -.011791   .0036288     -3.249   0.001       -.0189164  -.0046656
cp_pcgdp |   1.91e-07   7.07e-08      2.699   0.007        5.20e-08   3.30e-07
   popln |   .0107397   .0025291      4.247   0.000        .0057737   .0157056
   yr_d2 |  -19231.71   82314.96     -0.234   0.815         -180862   142398.6
   yr_d3 |  -33463.12   78222.42     -0.428   0.669       -187057.5   120131.2
   yr_d4 |  -51619.68   73303.92     -0.704   0.482       -195556.3   92316.91
   yr_d5 |  -67209.44   71954.88     -0.934   0.351       -208497.1   74078.23
   yr_d6 |  -73735.03   67334.06     -1.095   0.274       -205949.5   58479.39
   yr_d7 |  -89739.07   65375.68     -1.373   0.170       -218108.1   38629.96
   yr_d8 |  -99411.61   64684.27     -1.537   0.125         -226423    27599.8
   yr_d9 |  -113137.4    64561.6     -1.752   0.080       -239907.9   13633.18
  yr_d10 |  -126195.5    66971.9     -1.884   0.060       -257698.8   5307.755
  yr_d11 |  -89352.21   64623.96     -1.383   0.167       -216245.2   37540.78
  yr_d12 |  -108112.7   68725.15     -1.573   0.116       -243058.6    26833.2
  yr_d13 |  -126894.1   70529.99     -1.799   0.072       -265383.9    11595.7
  yr_d14 |  -156548.4    71131.8     -2.201   0.028       -296219.9  -16876.89
  yr_d15 |  -176541.7   74761.97     -2.361   0.018       -323341.3  -29742.14
  yr_d16 |  -192385.3   77438.62     -2.484   0.013       -344440.6  -40329.99
  yr_d17 |  -226765.8   81037.03     -2.798   0.005       -385886.8  -67644.78
  yr_d18 |  -222329.9   85933.07     -2.587   0.010       -391064.6  -53595.25
  yr_d19 |  -207721.9      87744     -2.367   0.018       -380012.5  -35431.38
  yr_d20 |    -188164   83316.47     -2.258   0.024       -351760.8  -24567.14
   cy_d2 |  -385921.5   110224.1     -3.501   0.000       -602353.1  -169489.8
   cy_d3 |  -763496.7   318733.8     -2.395   0.017        -1389349  -137643.9
   cy_d4 |  -265541.9   140351.8     -1.892   0.059         -541131   10047.29
   cy_d5 |   26859.56   42295.16      0.635   0.526        -56189.5   109908.6
   cy_d6 |   -5175678    2708188     -1.911   0.056       -1.05e+07     142010
   cy_d7 |  -111178.2   33078.53     -3.361   0.001       -176129.9  -46226.56
   cy_d8 |   581176.1     144974      4.009   0.000        296511.1     865841
   cy_d9 |     180955   109015.1      1.660   0.097       -33102.66   395012.6
  cy_d10 |   419993.2   201255.5      2.087   0.037        24815.96   815170.4
  cy_d11 |  -274977.1   192517.8     -1.428   0.154       -652997.1     103043
  cy_d12 |   579258.3   147791.7      3.919   0.000        289060.6     869456
  cy_d13 |  -291744.8   112694.2     -2.589   0.010       -513026.4   -70463.1
  cy_d14 |   -6810389    2076391     -3.280   0.001       -1.09e+07   -2733272
  cy_d15 |  -801736.5   388452.6     -2.064   0.039        -1564486  -38986.79
  cy_d16 |  -256337.5   73032.76     -3.510   0.000       -399741.7  -112933.4
  cy_d17 |  -548890.3   193040.9     -2.843   0.005       -927937.5    -169843
  cy_d18 |  -132569.9   341767.7     -0.388   0.698       -803651.1   538511.3
  cy_d19 |   633832.1   173676.7      3.649   0.000        292807.6   974856.6
  cy_d20 |  -273076.3   111537.4     -2.448   0.015       -492086.6  -54065.92
  cy_d21 |   40833.25   32043.47      1.274   0.203       -22085.99   103752.5
  cy_d22 |  -791680.3   170815.9     -4.635   0.000        -1127087  -456273.1
```

```
     cy_d23 |   261802.9   76986.93      3.401   0.001       110634.5    412971.3
     cy_d24 |   780172.3   198994.1      3.921   0.000       389435.5     1170909
     cy_d25 |   667611.7   176444.1      3.784   0.000       321153.3     1014070
     cy_d26 |  -338522.8   124856.6     -2.711   0.007        -583686   -93359.49
     cy_d27 |  -302204.3   242658.7     -1.245   0.213        -778679    174270.5
     cy_d28 |   94235.88      39799      2.368   0.018       16088.18    172383.6
     cy_d29 |  -103357.8   100348.4     -1.030   0.303      -300397.8    93682.29
     cy_d30 |  -312671.6   98957.92     -3.160   0.002      -506981.3   -118361.8
     cy_d31 |  -410913.6   143443.9     -2.865   0.004      -692574.3   -129252.9
     cy_d32 |   468608.7   113145.2      4.142   0.000       246441.4    690776.1
     cy_d33 |   391993.4   95646.34      4.098   0.000       204186.2    579800.7
     cy_d34 |  -222649.5   192197.5     -1.158   0.247      -600040.8    154741.8
     cy_d35 |  -404827.1   646701.6     -0.626   0.532       -1674664    865009.9
     cy_d36 |  -37966.68   33037.84     -1.149   0.251      -102838.4    26905.07
      _cons |  -945034.2   232460.4     -4.065   0.000       -1401484   -488584.4
------------------------------------------------------------------------------
```

3(III)3

```
. xtgls bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2-yr_d20 cy_d2-cy_d36

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        homoscedastic
Correlation:   no autocorrelation

Estimated covariances      =         1          Number of obs      =       720
Estimated autocorrelations =         0          Number of groups   =        36
Estimated coefficients     =        59          No. of time periods=        20
                                                Wald chi2(58)      =  13218.86
Log likelihood             = -10002.46          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
        bod |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
    p_pcgdp |   228.0316   41.26574      5.526   0.000       147.1522    308.9109
   sp_pcgdp |   -.011791   .0027262     -4.325   0.000      -.0171342   -.0064477
   cp_pcgdp |   1.91e-07   5.67e-08      3.365   0.001       7.97e-08    3.02e-07
      popln |   .0107397   .0005331     20.145   0.000       .0096948    .0117846
      yr_d2 |  -19231.71   61592.35     -0.312   0.755      -139950.5    101487.1
      yr_d3 |  -33463.12   61604.78     -0.543   0.587      -154206.3    87280.04
      yr_d4 |  -51619.68   61646.66     -0.837   0.402      -172444.9    69205.55
      yr_d5 |  -67209.44   61725.71     -1.089   0.276      -188189.6    53770.74
      yr_d6 |  -73735.03   61811.95     -1.193   0.233      -194884.2    47414.17
      yr_d7 |  -89739.07   61965.67     -1.448   0.148      -211189.5     31711.4
      yr_d8 |  -99411.61   62204.09     -1.598   0.110      -221329.4    22506.17
      yr_d9 |  -113137.4   62518.63     -1.810   0.070      -235671.6      9396.9
     yr_d10 |  -126195.5   62785.49     -2.010   0.044      -249252.8   -3138.239
     yr_d11 |  -89352.21   63065.09     -1.417   0.157      -212957.5     34253.1
     yr_d12 |  -108112.7   63353.17     -1.707   0.088      -232282.7    16057.23
     yr_d13 |  -126894.1   63690.75     -1.992   0.046      -251725.7   -2062.536
     yr_d14 |  -156548.4   63980.13     -2.447   0.014      -281947.2   -31149.65
     yr_d15 |  -176541.7   64558.23     -2.735   0.006      -303073.5    -50009.9
     yr_d16 |  -192385.3   65063.24     -2.957   0.003      -319906.9   -64863.71
     yr_d17 |  -226765.8   65751.22     -3.449   0.001      -355635.8   -97895.77
     yr_d18 |  -222329.9    66575.9     -3.339   0.001      -352816.3   -91843.56
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     yr_d19 |  -207721.9   66798.37     -3.110   0.002      -338644.3   -76799.53
     yr_d20 |    -188164   67389.79     -2.792   0.005      -320245.5   -56082.42
      cy_d2 |  -385921.5   109217.2     -3.534   0.000      -599983.2   -171859.8
      cy_d3 |  -763496.7   103428.6     -7.382   0.000        -966213   -560780.4
      cy_d4 |  -265541.9   171783.3     -1.546   0.122        -602231    71147.28
      cy_d5 |   26859.56   83646.52      0.321   0.748      -137084.6    190803.7
      cy_d6 |   -5175678   625890.2     -8.269   0.000       -6402400    -3948956
      cy_d7 |  -111178.2   82797.08     -1.343   0.179      -273457.5    51101.09
      cy_d8 |   581176.1   120131.7      4.838   0.000       345722.3    816629.9
      cy_d9 |     180955   106569.6      1.698   0.090      -27917.64    389827.6
     cy_d10 |   419993.2   159430.2      2.634   0.008       107515.8    732470.5
     cy_d11 |  -274977.1   161594.1     -1.702   0.089      -591695.7    41741.56
     cy_d12 |   579258.3   123669.5      4.684   0.000       336870.5    821646.2
     cy_d13 |  -291744.8   146863.3     -1.987   0.047      -579591.5   -3898.012
     cy_d14 |   -6810389   483449.6    -14.087   0.000       -7757933    -5862846
     cy_d15 |  -801736.5   153315.1     -5.229   0.000       -1102229   -501244.5
     cy_d16 |  -256337.5   84668.13     -3.028   0.002        -422284   -90391.03
     cy_d17 |  -548890.3   158319.6     -3.467   0.001        -859191   -238589.5
     cy_d18 |  -132569.9   175392.1     -0.756   0.450      -476332.1    211192.3
     cy_d19 |   633832.1   140910.8      4.498   0.000       357651.9    910012.2
     cy_d20 |  -273076.3   100262.9     -2.724   0.006      -469587.9    -76564.7
     cy_d21 |   40833.25   83109.82      0.491   0.623        -122059    203725.5
     cy_d22 |  -791680.3   92984.99     -8.514   0.000      -973927.5     -609433
     cy_d23 |   261802.9   95939.49      2.729   0.006       73764.99    449840.9
     cy_d24 |   780172.3   151458.6      5.151   0.000       483318.9     1077026
     cy_d25 |   667611.7   140841.5      4.740   0.000       391567.5    943655.9
     cy_d26 |  -338522.8   157931.6     -2.143   0.032      -648062.9   -28982.56
     cy_d27 |  -302204.3   145428.7     -2.078   0.038      -587239.3   -17169.22
     cy_d28 |   94235.88   84277.42      1.118   0.263      -70944.83    259416.6
     cy_d29 |  -103357.8   94237.08     -1.097   0.273      -288059.1    81343.49
     cy_d30 |  -312671.6   101505.1     -3.080   0.002        -511618   -113725.2
     cy_d31 |  -410913.6   128666.8     -3.194   0.001      -663095.8   -158731.3
     cy_d32 |   468608.7   108112.5      4.334   0.000       256712.1    680505.4
     cy_d33 |   391993.4   98348.66      3.986   0.000       199233.6    584753.3
     cy_d34 |  -222649.5   152748.4     -1.458   0.145      -522030.8    76731.75
     cy_d35 |  -404827.1   226370.1     -1.788   0.074      -848504.4     38850.2
     cy_d36 |  -37966.68   84107.77     -0.451   0.652      -202814.9    126881.5
      _cons |  -945034.2   164067.2     -5.760   0.000       -1266600   -623468.3
------------------------------------------------------------------------------
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3(III)4

```
. xtgls bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2-yr_d20 cy_d2-cy_d36, corr(ar1)
p(h)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic
Correlation:   common AR(1) coefficient for all panels  (0.8428)

Estimated covariances      =        36          Number of obs      =       720
Estimated autocorrelations =         1          Number of groups   =        36
Estimated coefficients     =        59          No. of time periods=        20
                                                Wald chi2(58)      =   4723.64
Log likelihood             = -7723.617          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
     bod |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |    42.7001   12.24224      3.488   0.000       18.70574    66.69446
sp_pcgdp |  -.0024901   .0008986     -2.771   0.006      -.0042513    -.000729
cp_pcgdp |   4.23e-08   2.04e-08      2.080   0.038       2.44e-09    8.22e-08
   popln |   .0039907   .0009553      4.178   0.000       .0021184     .005863
   yr_d2 |  -7285.864   4101.581     -1.776   0.076      -15324.81    753.0872
   yr_d3 |   -11741.5   5619.433     -2.089   0.037      -22755.38   -727.6104
   yr_d4 |   -17378.2   6720.385     -2.586   0.010      -30549.91   -4206.487
   yr_d5 |  -19172.26   7633.111     -2.512   0.012      -34132.88   -4211.638
   yr_d6 |  -21350.03   8368.094     -2.551   0.011       -37751.2    -4948.87
   yr_d7 |  -23626.99    9084.89     -2.601   0.009      -41433.04    -5820.93
   yr_d8 |  -23499.39   9793.812     -2.399   0.016      -42694.91   -4303.871
   yr_d9 |   -24168.7   10495.71     -2.303   0.021      -44739.91    -3597.49
  yr_d10 |  -24486.86   11130.74     -2.200   0.028       -46302.7    -2671.02
  yr_d11 |  -24140.11   11721.06     -2.060   0.039      -47112.96   -1167.263
  yr_d12 |  -27277.47   12276.36     -2.222   0.026      -51338.69    -3216.24
  yr_d13 |  -33042.35    12848.1     -2.572   0.010      -58224.16   -7860.539
  yr_d14 |  -37459.44    13270.4     -2.823   0.005      -63468.94   -11449.94
  yr_d15 |  -43092.85   13905.19     -3.099   0.002      -70346.52   -15839.17
  yr_d16 |  -44521.06   14488.66     -3.073   0.002      -72918.32    -16123.8
  yr_d17 |  -49234.62   15105.23     -3.259   0.001      -78840.33    -19628.9
  yr_d18 |  -52508.86   15780.27     -3.327   0.001      -83437.63   -21580.09
  yr_d19 |  -55769.97   16236.36     -3.435   0.001      -87592.64   -23947.29
  yr_d20 |  -58340.77   16810.24     -3.471   0.001      -91288.23   -25393.32
   cy_d2 |   29672.01    45024.6      0.659   0.510      -58574.58    117918.6
   cy_d3 |   164331.7   136806.6      1.201   0.230      -103804.4    432467.8
   cy_d4 |   183465.1   59188.64      3.100   0.002       67457.45    299472.7
   cy_d5 |   1808.651   41715.76      0.043   0.965      -79952.73    83570.03
   cy_d6 |    2178912    1274146      1.710   0.087      -318367.7     4676192
   cy_d7 |  -31736.74   34012.81     -0.933   0.351      -98400.61    34927.14
   cy_d8 |   61618.08   46450.38      1.327   0.185      -29422.99    152659.1
   cy_d9 |   73723.03   47610.34      1.548   0.122      -19591.51    167037.6
  cy_d10 |  -37519.86    59674.4     -0.629   0.530      -154479.5    79439.81
  cy_d11 |   387089.1   64335.82      6.017   0.000       260993.2      513185
  cy_d12 |   58052.44   44344.54      1.309   0.190      -28861.27    144966.1
  cy_d13 |   11617.41   49295.66      0.236   0.814       -85000.3    108235.1
  cy_d14 |   -1730186   852893.8     -2.029   0.042       -3401827    -58544.6
  cy_d15 |  -156266.4   158756.7     -0.984   0.325      -467423.8    154891.1
  cy_d16 |  -105060.9   51641.66     -2.034   0.042      -206276.7   -3845.075
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   cy_d17 |   123727.9   67127.19      1.843   0.065       -7838.925    255294.8
   cy_d18 |     941350   119355.4      7.887   0.000        707417.7     1175282
   cy_d19 |   73947.81   46608.44      1.587   0.113       -17403.05    165298.7
   cy_d20 |   110613.9   55582.45      1.990   0.047        1674.313    219553.5
   cy_d21 |   41193.63   36626.22      1.125   0.261       -30592.45    112979.7
   cy_d22 |  -206027.2   70471.98     -2.924   0.003       -344149.8   -67904.68
   cy_d23 |   19549.63   41769.44      0.468   0.640       -62316.97    101416.2
   cy_d24 |   90418.04   52030.29      1.738   0.082       -11559.45    192395.5
   cy_d25 |   72960.76   46621.21      1.565   0.118       -18415.14    164336.7
   cy_d26 |   47153.51   53613.09      0.880   0.379       -57926.21    152233.2
   cy_d27 |  -210421.9   102991.6     -2.043   0.041       -412281.8   -8562.115
   cy_d28 |  -10335.39   45973.27     -0.225   0.822       -100441.3    79770.56
   cy_d29 |  -29412.51   52674.88     -0.558   0.577       -132653.4    73828.35
   cy_d30 |   57329.26   40625.57      1.411   0.158       -22295.41    136953.9
   cy_d31 |   133237.8   50035.05      2.663   0.008        35170.91    231304.7
   cy_d32 |   69557.99   42493.55      1.637   0.102       -13727.84    152843.8
   cy_d33 |   38331.74   42708.28      0.898   0.369       -45374.96    122038.4
   cy_d34 |   473818.3   69151.28      6.852   0.000        338284.3    609352.3
   cy_d35 |    1575284     244216      6.450   0.000         1096630     2053939
   cy_d36 |   4888.135   44298.13      0.110   0.912       -81934.61    91710.88
    _cons |  -137527.5   52025.02     -2.643   0.008       -239494.6   -35560.29
------------------------------------------------------------------------------
```

3(III)5

```
. xtgls bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2-yr_d20 cy_d2-cy_d36,
panels(correlated) corr(psar1)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   panel-specific AR(1)

Estimated covariances      =       666          Number of obs      =       720
Estimated autocorrelations =        36          Number of groups   =        36
Estimated coefficients     =        59          No. of time periods=        20
                                                Wald chi2(40)      =  38368.76
Log likelihood             = -61473.97          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
     bod |      Coef.   Std. Err.        z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   24.86604   3.270496      7.603   0.000       18.45598    31.27609
sp_pcgdp |  -.0020964   .0001841    -11.389   0.000      -.0024572   -.0017356
cp_pcgdp |   4.02e-08   3.64e-09     11.069   0.000       3.31e-08    4.74e-08
   popln |   .0010591    .000333      3.180   0.001       .0004064    .0017117
   yr_d2 |  -8926.047   1651.611     -5.404   0.000      -12163.15   -5688.948
   yr_d3 |  -14886.19    2450.88     -6.074   0.000      -19689.82   -10082.55
   yr_d4 |  -28285.55   3098.878     -9.128   0.000      -34359.24   -22211.86
   yr_d5 |  -29634.15   3472.936     -8.533   0.000      -36440.98   -22827.32
   yr_d6 |  -26883.39   3895.107     -6.902   0.000      -34517.66   -19249.12
   yr_d7 |  -31709.67   3936.515     -8.055   0.000      -39425.09   -23994.24
   yr_d8 |  -28387.85    3918.51     -7.245   0.000      -36067.99   -20707.71
   yr_d9 |  -27871.86   4017.807     -6.937   0.000      -35746.61    -19997.1
  yr_d10 |  -37987.88    4124.69     -9.210   0.000      -46072.12   -29903.63
  yr_d11 |   16973.14     4175.5      4.065   0.000       8789.312    25156.97
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     yr_d12 |   9417.058    4253.56      2.214   0.027      1080.235    17753.88
     yr_d13 |  -510.0816   4306.048     -0.118   0.906      -8949.78    7929.617
     yr_d14 |  -27071.91    4362.87     -6.205   0.000     -35622.97   -18520.84
     yr_d15 |  -32622.05   4385.795     -7.438   0.000     -41218.05   -24026.05
     yr_d16 |  -42005.76   4464.376     -9.409   0.000     -50755.78   -33255.75
     yr_d17 |  -67739.09   4510.365    -15.019   0.000     -76579.24   -58898.94
     yr_d18 |  -49823.68   4656.965    -10.699   0.000     -58951.16   -40696.19
     yr_d19 |  -32005.89   4918.182     -6.508   0.000     -41645.35   -22366.43
     yr_d20 |  -8910.953   5301.777     -1.681   0.093     -19302.25     1480.34
      cy_d2 |  (dropped)
      cy_d3 |    2551503     593168      4.301   0.000       1388915     3714091
      cy_d4 |    1542041   498643.5      3.092   0.002      564717.2     2519364
      cy_d5 |  (dropped)
      cy_d6 |  (dropped)
      cy_d7 |  (dropped)
      cy_d8 |  (dropped)
      cy_d9 |    1375855   494441.7      2.783   0.005      406767.1     2344943
     cy_d10 |  (dropped)
     cy_d11 |  (dropped)
     cy_d12 |  (dropped)
     cy_d13 |    1301369   498733.9      2.609   0.009        323869     2278870
     cy_d14 |    1896475   518623.5      3.657   0.000      879991.7     2912959
     cy_d15 |    1602007   475667.4      3.368   0.001      669716.3     2534298
     cy_d16 |  (dropped)
     cy_d17 |    1553857   497056.8      3.126   0.002      579643.5     2528070
     cy_d18 |    2557003   490790.6      5.210   0.000       1595071     3518935
     cy_d19 |  (dropped)
     cy_d20 |    1427348     487048      2.931   0.003      472751.7     2381945
     cy_d21 |  (dropped)
     cy_d22 |    1088493     558225      1.950   0.051     -5608.049     2182594
     cy_d23 |    1218241   496135.5      2.455   0.014        245833     2190648
     cy_d24 |    1205539   493195.4      2.444   0.015      238893.3     2172184
     cy_d25 |  (dropped)
     cy_d26 |    1420403   497574.6      2.855   0.004        445175     2395632
     cy_d27 |  (dropped)
     cy_d28 |  (dropped)
     cy_d29 |    1263429   493847.1      2.558   0.011      295506.3     2231351
     cy_d30 |  (dropped)
     cy_d31 |    1629797   497809.2      3.274   0.001      654108.8     2605485
     cy_d32 |    1239892   496610.8      2.497   0.013      266553.1     2213232
     cy_d33 |  (dropped)
     cy_d34 |    1860489     496865      3.744   0.000      886651.2     2834326
     cy_d35 |    3517647   490100.5      7.177   0.000       2557067     4478226
     cy_d36 |  (dropped)
      _cons |   -1208068     494295     -2.444   0.015      -2176869   -239267.7
------------------------------------------------------------------------------
Note: You estimated at least as many quantities as you have observations.
```

3(III)6

```
. xtreg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2-yr_d20 cy_d2-cy_d17

Random-effects GLS regression                   Number of obs      =       340
Group variable (i) : cocode                     Number of groups   =        17

R-sq:  within  = 0.3882                         Obs per group: min =        20
       between = 1.0000                                        avg =      20.0
       overall = 0.9973                                        max =        20

Random effects u_i ~ Gaussian                   Wald chi2(39)      = 109500.66
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000
------------------------------------------------------------------------------
     bod |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   69.54178   6.858549     10.139   0.000       56.09927    82.98428
sp_pcgdp |  -.0047624   .0004767     -9.989   0.000      -.0056968   -.003828
cp_pcgdp |   9.42e-08   1.01e-08      9.336   0.000       7.44e-08    1.14e-07
   popln |   .0034698   .0005671     -6.119   0.000       .0029813   -.0038583
   yr_d2 |  -12424.72   11861.54     -1.047   0.295       -35672.9    10823.47
   yr_d3 |  -24546.52   11877.32     -2.067   0.039      -47825.64     -1267.4
   yr_d4 |  -30359.94   11920.95     -2.547   0.011      -53724.57   -6995.302
   yr_d5 |  -21727.33   12012.06     -1.809   0.070      -45270.55     1815.88
   yr_d6 |  -18844.58   12098.09     -1.558   0.119       -42556.4    4867.237
   yr_d7 |  -18310.63    12265.9     -1.493   0.135      -42351.35    5730.096
   yr_d8 |  -8681.317   12505.45     -0.694   0.488      -33191.54    15828.91
   yr_d9 |  -3143.059   12795.96     -0.246   0.806      -28222.67    21936.55
  yr_d10 |  -584.6816   13029.77     -0.045   0.964      -26122.56     24953.2
  yr_d11 |   2169.144   13283.35      0.163   0.870      -23865.75    28204.04
  yr_d12 |  -6033.303   13563.43     -0.445   0.656      -32617.14    20550.53
  yr_d13 |  -9073.006   13847.01     -0.655   0.512      -36212.64    18066.63
  yr_d14 |  -12889.28   14094.51     -0.914   0.360      -40514.02    14735.45
  yr_d15 |  -17540.05   14492.24     -1.210   0.226      -45944.32    10864.23
  yr_d16 |   -13109.6   14832.81     -0.884   0.377      -42181.36    15962.17
  yr_d17 |  -18116.71   15222.62     -1.190   0.234       -47952.5    11719.08
  yr_d18 |  -17955.28   15661.87     -1.146   0.252      -48651.97    12741.42
  yr_d19 |  -21209.29   15760.09     -1.346   0.178      -52098.49    9679.909
  yr_d20 |  -23476.66   16048.33     -1.463   0.144       -54930.8    7977.481
   cy_d2 |   990283.5    63801.6     15.521   0.000       865234.7     1115332
   cy_d3 |   165255.5   21311.54      7.754   0.000       123485.6    207025.3
   cy_d4 |  -158004.3    19527.8     -8.091   0.000      -196278.1   -119730.5
   cy_d5 |   585354.9   28322.73     20.667   0.000       529843.4    640866.5
   cy_d6 |  -173552.2   17604.64     -9.858   0.000      -208056.6   -139047.7
   cy_d7 |   319305.1   27812.08     11.481   0.000       264794.4    373815.8
   cy_d8 |    1653355   62492.19     26.457   0.000        1530873     1775838
   cy_d9 |   181415.9   12814.79     14.157   0.000       156299.4    206532.4
  cy_d10 |  -86977.59   18117.84     -4.801   0.000      -122487.9   -51467.28
  cy_d11 |   144201.4   29197.77      4.939   0.000       86974.85      201428
  cy_d12 |  -68250.22   17350.02     -3.934   0.000      -102255.6   -34244.81
  cy_d13 |   52430.57   11153.16      4.701   0.000       30570.78    74290.36
  cy_d14 |     161035   14086.59     11.432   0.000       133425.8    188644.2
  cy_d15 |   655273.6   26880.05     24.378   0.000       602589.6    707957.5
  cy_d16 |    3152810   131112.5     24.047   0.000        2895834     3409786
  cy_d17 |  -114509.3    17317.3     -6.612   0.000      -148450.6   -80568.06
   _cons |   20619.09   36566.88      0.564   0.573      -51050.68    92288.87
---------+--------------------------------------------------------------------
 sigma_u |          0
 sigma_e |  34557.691
     rho |          0   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

3(III)7

```
. xtreg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2-yr_d20, fe

Fixed-effects (within) regression               Number of obs      =       380
Group variable (i) : cocode                     Number of groups   =        19

R-sq:  within  = 0.5686                         Obs per group: min =        20
       between = 0.7817                                        avg =      20.0
       overall = 0.7291                                        max =      20

                                                F(23,338)          =     19.37
corr(u_i, Xb)  = -0.7571                        Prob > F           =    0.0000

------------------------------------------------------------------------------
     bod |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   1264.678   475.5987      3.062   0.000       520.9478     2391.96
sp_pcgdp |  -.1747041   .1449184     -1.131   0.057      -.4489675    .1211434
cp_pcgdp |   8.93E-06   .0000132      0.244   0.326      -.0000228    .0000293
   popln |    .008241   .0009682      7.028   0.000          .0049    .0087087
   yr_d2 |  -18634.71   112653.4     -0.165   0.869      -240224.8    202955.4
   yr_d3 |  -23692.54   112676.5     -0.210   0.834      -245327.9    197942.9
   yr_d4 |  -30791.26   112774.5     -0.273   0.785      -252619.5    191036.9
   yr_d5 |  -48543.98   112925.5     -0.430   0.668      -270669.3    173581.3
   yr_d6 |  -57439.21   113068.1     -0.508   0.612      -279845.1    164966.6
   yr_d7 |  -80771.93   113166.1     -0.714   0.476      -303370.4    141826.5
   yr_d8 |  -97847.02   113431.5     -0.863   0.389      -320967.6    125273.5
   yr_d9 |  -142902.2   113723.4     -1.257   0.210        -366597    80792.53
  yr_d10 |  -157295.4   114171.3     -1.378   0.169      -381871.1    67280.35
  yr_d11 |  -87220.09     114302     -0.763   0.446        -312053    137612.9
  yr_d12 |  -102855.8   114425.1     -0.899   0.369      -327930.7    122219.1
  yr_d13 |  -121859.6   114625.4     -1.063   0.288      -347328.6    103609.3
  yr_d14 |  -175359.3   115032.7     -1.524   0.128      -401629.5    50910.93
  yr_d15 |  -220283.5   115444.2     -1.908   0.057      -447363.1    6796.153
  yr_d16 |    -257089   116033.7     -2.216   0.027      -485328.1   -28849.98
  yr_d17 |  -327661.5   116845.5     -2.804   0.005      -557497.4    -97825.5
  yr_d18 |  -315155.7   117592.6     -2.680   0.008      -546461.2   -83850.15
  yr_d19 |    -279848   117998.1     -2.372   0.018      -511951.2    -47744.8
  yr_d20 |  -246980.3   118597.9     -2.083   0.038      -480263.3   -13697.29
   _cons |   -2713614   361412.2     -7.508   0.000       -3424514    -2002714
------------------------------------------------------------------------------
 sigma_u |  1216625.2
 sigma_e |  347099.75
     rho |  .92473192   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(18,338) =    66.78            Prob > F = 0.0000
```

3(III)8

```
. xtreg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2-yr_d10, fe

Fixed-effects (within) regression               Number of obs      =       360
Group variable (i) : cocode                     Number of groups   =        36

R-sq:  within  = 0.4050                         Obs per group: min =        10
       between = 0.7632                                        avg =      10.0
       overall = 0.7577                                        max =        10

                                                F(13,311)          =     16.29
corr(u_i, Xb)  = -0.6296                        Prob > F           =    0.0000

------------------------------------------------------------------------------
     bod |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   104.0539    32.2051      3.231   0.001       40.68651    167.4214
sp_pcgdp |  -.0059571    .002321     -2.567   0.011      -.0105239   -.0013902
cp_pcgdp |   9.88e-08   5.22e-08      1.891   0.059      -3.98e-09    2.02e-07
   popln |    .005286   .0004576     11.550   0.000       .0043855    .0061864
   yr_d2 |  -9066.925   19281.97     -0.470   0.639      -47006.53    28872.68
   yr_d3 |  -15581.66   19314.01     -0.807   0.420       -53584.3    22420.99
   yr_d4 |  -26691.82   19403.05     -1.376   0.170      -64869.68    11486.03
   yr_d5 |  -30343.88   19561.52     -1.551   0.122      -68833.55    8145.782
   yr_d6 |   -27580.4   19740.02     -1.397   0.163      -66421.28    11260.48
   yr_d7 |   -30927.4   20035.05     -1.544   0.124      -70348.78    8493.985
   yr_d8 |  -27012.01    20472.1     -1.319   0.188      -67293.35    13269.33
   yr_d9 |  -27346.13   21045.24     -1.299   0.195       -68755.2    14062.93
  yr_d10 |  -30432.69   21551.61     -1.412   0.159      -72838.08     11972.7
   _cons |  -378722.7   98797.75     -3.833   0.000      -573119.2   -184326.2
------------------------------------------------------------------------------
 sigma_u |  524670.44
 sigma_e |  81744.143
     rho |  .97630133   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(35,311) =   152.95             Prob > F = 0.0000
```

3(III)9

```
. xtreg bod p_pcgdp sp_pcgdp cp_pcgdp popln yr_d2-yr_d10, fe

Fixed-effects (within) regression               Number of obs      =       360
Group variable (i) : cocode                     Number of groups   =        36

R-sq:  within  = 0.3676                         Obs per group: min =        10
       between = 0.7747                                        avg =      10.0
       overall = 0.7635                                        max =        10

                                                F(13,311)          =     13.90
corr(u_i, Xb)  = -0.8786                        Prob > F           =    0.0000

------------------------------------------------------------------------------
     bod |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   298.5344   71.48811      4.176   0.000       157.8729    439.1959
sp_pcgdp |  -.0143756   .0043914     -3.274   0.001      -.0230162   -.005735
cp_pcgdp |   2.20e-07   8.41e-08      2.616   0.009       5.45e-08    3.86e-07
   popln |   .0103413   .0011121      9.299   0.000       .0081532    .0125295
   yr_d2 |  -22112.87   42470.55     -0.521   0.603      -105678.8    61453.09
   yr_d3 |  -43303.63   42822.61     -1.011   0.313      -127562.3    40955.05
   yr_d4 |  -75031.78   43275.71     -1.734   0.084        -160182    10118.41
   yr_d5 |  -98817.97   44439.38     -2.224   0.027      -186257.8    -11378.1
   yr_d6 |  -117320.1   45622.92     -2.572   0.011      -207088.7   -27551.51
   yr_d7 |  -155477.1   47465.83     -3.276   0.001      -248871.9   -62082.34
   yr_d8 |  -154405.1   49758.12     -3.103   0.002      -252310.3   -56500.01
   yr_d9 |    -138765   50160.76     -2.766   0.006      -237462.4   -40067.63
  yr_d10 |  -118896.1    51598.7     -2.304   0.022      -220422.8   -17369.46
   _cons |   -1695099   252958.1     -6.701   0.000       -2192824    -1197373
------------------------------------------------------------------------------
 sigma_u |  1396689.2
 sigma_e |  179628.33
     rho |  .98372858   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(35,311) =   125.99             Prob > F = 0.0000
```

- *3(IV)Energy Intensity of GDP*

3(IV)1

```
. xtreg eng_gdp p_pcgdp openness urbnsn ind_va yr_d2-yr_d20, fe

Fixed-effects (within) regression               Number of obs      =       780
Group variable (i) : cocode                     Number of groups   =        39

R-sq:  within  = 0.1441                         Obs per group: min =        20
       between = 0.1498                                        avg =      20.0
       overall = 0.1463                                        max =        20

                                                F(23,718)          =      5.26
corr(u_i, Xb)  = -0.4574                        Prob > F           =    0.0000

------------------------------------------------------------------------------
 eng_gdp |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |  -4.02e-06   1.61e-06     -2.491   0.013      -7.18e-06   -8.51e-07
openness |   .0002883   .0001198      2.407   0.016       .0000532    .0005234
  urbnsn |  -.0048606   .0008195     -5.931   0.000      -.0064695   -.0032517
  ind_va |  -.0015578   .0004748     -3.281   0.001      -.0024899   -.0006256
   yr_d2 |  -.0006556    .010536     -0.062   0.950      -.0213406    .0200293
   yr_d3 |   .0040646   .0105869      0.384   0.701      -.0167204    .0248496
   yr_d4 |   .0117363   .0106424      1.103   0.270      -.0091575    .0326301
   yr_d5 |   .0171243   .0107098      1.599   0.110       -.003902    .0381506
   yr_d6 |   .0171308   .0108261      1.582   0.114      -.0041237    .0383853
   yr_d7 |   .0194274   .0110452      1.759   0.079      -.0022574    .0411121
   yr_d8 |   .0177402   .0111596      1.590   0.112      -.0041691    .0396495
   yr_d9 |   .0139475   .0113211      1.232   0.218      -.0082788    .0361739
  yr_d10 |   .0159803   .0114253      1.399   0.162      -.0064506    .0384112
  yr_d11 |   .0143642   .0116008      1.238   0.216      -.0084112    .0371397
  yr_d12 |   .0150125   .0117864      1.274   0.203      -.0081273    .0381524
  yr_d13 |   .0166888    .011979      1.393   0.164      -.0068292    .0402068
  yr_d14 |   .0129716   .0121281      1.070   0.285      -.0108392    .0367825
  yr_d15 |   .0112062    .012391      0.904   0.366      -.0131207    .0355331
  yr_d16 |   .0099064   .0126686      0.782   0.434      -.0149655    .0347784
  yr_d17 |   .0091661   .0129497      0.708   0.479      -.0162578    .0345899
  yr_d18 |   .0077351   .0132712      0.583   0.560      -.0183198      .03379
  yr_d19 |   .0087478   .0135265      0.647   0.518      -.0178085    .0353041
  yr_d20 |   .0119596     .01381      0.866   0.387      -.0151532    .0390724
   _cons |   .5853826   .0456987     12.810   0.000       .4956635    .6751017
------------------------------------------------------------------------------
 sigma_u |  .18269824
 sigma_e |  .04647304
     rho |  .93922789   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(38,718) =   238.32             Prob > F = 0.0000
```

3(IV)2

```
. xtgls eng_gdp p_pcgdp openness urbnsn ind_va yr_d2-yr_d20 cy_d2-cy_d39,
corr(psar1) p(h)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic
Correlation:   panel-specific AR(1)

Estimated covariances      =        20          Number of obs      =       780
Estimated autocorrelations =        20          Number of groups   =        39
Estimated coefficients     =        62          No. of time periods=        20
                                                Wald chi2(61)      =  31901.80
Log likelihood             =  1528.677          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
 eng_gdp |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |  -3.61e-06   1.52e-06     -2.373   0.018      -6.60e-06   -6.29e-07
openness |    .000353   .0001106      3.191   0.001       .0001362    .0005698
  urbnsn |  -.0050779   .0008235     -6.166   0.000      -.0066919   -.0034638
  ind_va |  -.0011831    .000347     -3.410   0.001      -.0018632    -.000503
   yr_d2 |   -.000463   .0136216     -0.034   0.973      -.0271608    .0262348
   yr_d3 |   .0047615   .0131157      0.363   0.717      -.0209448    .0304678
   yr_d4 |   .0125734     .01445      0.870   0.384      -.0157481     .040895
   yr_d5 |   .0179825   .0141631      1.270   0.204      -.0097767    .0457416
   yr_d6 |   .0183815    .013346      1.377   0.168      -.0077761    .0445392
   yr_d7 |   .0212304   .0134037      1.584   0.113      -.0050403    .0475012
   yr_d8 |   .0193516   .0122906      1.575   0.115      -.0047375    .0434407
   yr_d9 |   .0155375   .0117712      1.320   0.187      -.0075336    .0386087
  yr_d10 |   .0171872   .0117473      1.463   0.143       -.005837    .0402114
  yr_d11 |   .0155326   .0119544      1.299   0.194      -.0078976    .0389629
  yr_d12 |   .0163392   .0124433      1.313   0.189      -.0080493    .0407277
  yr_d13 |   .0179189   .0125867      1.424   0.155      -.0067507    .0425884
  yr_d14 |   .0140576   .0129838      1.083   0.279      -.0113902    .0395054
  yr_d15 |   .0121277   .0135561      0.895   0.371      -.0144419    .0386972
  yr_d16 |   .0108817    .014035      0.775   0.438      -.0166264    .0383898
  yr_d17 |   .0099858   .0146718      0.681   0.496      -.0187704    .0387421
  yr_d18 |   .0085695    .015786      0.543   0.587      -.0223705    .0395095
  yr_d19 |    .009934   .0168735      0.589   0.556      -.0231373    .0430054
  yr_d20 |   .0131945    .018337      0.720   0.472      -.0227453    .0491344
   cy_d2 |   .1681215   .0331959      5.065   0.000       .1030588    .2331843
   cy_d3 |   .2918136   .0401543      7.267   0.000       .2131126    .3705146
   cy_d4 |  -.2434556   .0297806     -8.175   0.000      -.3018245   -.1850867
   cy_d5 |   .0958952   .0222346      4.313   0.000       .0523162    .1394742
   cy_d6 |   .3372134   .0371939      9.066   0.000       .2643147    .4101122
   cy_d7 |   .1665791   .0278918      5.972   0.000       .1119121    .2212461
   cy_d8 |   .1454683   .0235647      6.173   0.000       .0992824    .1916542
   cy_d9 |   .0404117   .0189673      2.131   0.033       .0032364     .077587
  cy_d10 |  -.0203393   .0125406     -1.622   0.105      -.0449185    .0042399
  cy_d11 |   .1061027   .0350698      3.025   0.002       .0373671    .1748382
  cy_d12 |   .1745944   .0339595      5.141   0.000        .108035    .2411539
  cy_d13 |  -.0927208   .0203364     -4.559   0.000      -.1325795   -.0528622
  cy_d14 |   .1335058   .0462217      2.888   0.004       .0429129    .2240988
  cy_d15 |  -.0613199   .0250181     -2.451   0.014      -.1103545   -.0122853
  cy_d16 |  -.0514642   .0205861     -2.500   0.012      -.0918122   -.0111162
```

```
   cy_d17 |   .1118673    .011289      9.909   0.000       .0897412    .1339934
   cy_d18 |   .0785202   .0290957      2.699   0.007       .0214937    .1355467
   cy_d19 |   .1807556   .0383675      4.711   0.000       .1055567    .2559545
   cy_d20 |   .1389616   .0268822      5.169   0.000       .0862736    .1916497
   cy_d21 |   .1580067    .021652      7.298   0.000       .1155695    .2004438
   cy_d22 |   .0119554   .0116864      1.023   0.306      -.0109495    .0348604
   cy_d23 |   .1182325   .0213864      5.528   0.000       .0763159    .1601491
   cy_d24 |  -.1267762   .0106539    -11.900   0.000      -.1476574   -.1058949
   cy_d25 |   .4837466    .025242     19.164   0.000       .4342732      .53322
   cy_d26 |  -.1097942   .0379555     -2.893   0.004      -.1841857   -.0354028
   cy_d27 |   .2594783   .0403777      6.426   0.000       .1803395    .3386171
   cy_d28 |    .608336   .0193543     31.432   0.000       .5704023    .6462697
   cy_d29 |  -.0558691    .020665     -2.704   0.007      -.0963717   -.0153664
   cy_d30 |   .0383382   .0174902      2.192   0.028        .004058    .0726185
   cy_d31 |   -.085476   .0101171     -8.449   0.000      -.1053052   -.0656469
   cy_d32 |   .1124219   .0118583      9.480   0.000         .08918    .1356638
   cy_d33 |   .1308517   .0282129      4.638   0.000       .0755554     .186148
   cy_d34 |   -.226533   .0277935     -8.151   0.000      -.2810073   -.1720587
   cy_d35 |   .1252593   .0125205     10.004   0.000       .1007196     .149799
   cy_d36 |  -.1855034   .0288256     -6.435   0.000      -.2420006   -.1290061
   cy_d37 |   .2519029   .0406671      6.194   0.000       .1721968    .3316089
   cy_d38 |   .3078632   .0433412      7.103   0.000        .222916    .3928104
   cy_d39 |   .3676276   .0279396     13.158   0.000        .312867    .4223881
    _cons |   .4781121   .0436661     10.949   0.000       .3925281    .5636961
------------------------------------------------------------------------------
```

3(IV)3

```
. sdtest  high = low

Variance ratio test

------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
    high |      20    .2181562    .0007686    .0034372    .2165476    .2197649
     low |      20    .3084246    .0050537    .0226009     .297847    .3190022
---------+--------------------------------------------------------------------
combined |      40    .2632904     .007655    .0484142    .2478068     .278774
------------------------------------------------------------------------------

                     Ho: sd(high) = sd(low)

           F(19,19) observed    = F_obs           =     0.023
           F(19,19) lower tail  = F_L    = F_obs  =     0.023
           F(19,19) upper tail  = F_U    = 1/F_obs =   43.236

Ha: sd(high) < sd(low)      Ha: sd(high) ~= sd(low)     Ha: sd(high) > sd(low)
  P < F_obs = 0.0000       P < F_L + P > F_U = 0.0000      P > F_obs = 1.0000
```

3(IV)4

```
. ttest  high= low, unpaired unequal welch

Two-sample t test with unequal variances

------------------------------------------------------------------------------
Variable |     Obs        Mean    Std. Err.   Std. Dev.   [95% Conf. Interval]
---------+--------------------------------------------------------------------
    high |      20    .2181562    .0007686    .0034372    .2165476    .2197649
     low |      20    .3084246    .0050537    .0226009     .297847    .3190022
---------+--------------------------------------------------------------------
combined |      40    .2632904     .007655    .0484142    .2478068     .278774
---------+--------------------------------------------------------------------
    diff |           -.0902684    .0051118               -.1009324   -.0796043
------------------------------------------------------------------------------
Welch's degrees of freedom:  19.9709

                   Ho: mean(high) - mean(low) = diff = 0

    Ha: diff < 0               Ha: diff ~= 0              Ha: diff > 0
      t = -17.6587               t = -17.6587               t = -17.6587
  P < t =   0.0000         P > |t| =   0.0000         P > t =   1.0000
```

3(IV)5(a)

```
. xtgls ln_eng ln_gdp cy_d2-cy_d18 yr_d2-yr_d10, panels(correlated) corr(psar1)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   panel-specific AR(1)

Estimated covariances       =       171      Number of obs      =       180
Estimated autocorrelations  =        18      Number of groups   =        18
Estimated coefficients      =        28      No. of time periods=        10
                                             Wald chi2(19)      = 190921.46
Log likelihood              =  1710.339      Pr > chi2          =    0.0000

------------------------------------------------------------------------------
  ln_eng |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
  ln_gdp |   .6498071   .0362796     17.911   0.000       .5787004    .7209138
   cy_d2 |   .6215802   .0263387     23.599   0.000       .5699572    .6732031
   cy_d3 |  (dropped)
   cy_d4 |  (dropped)
   cy_d5 |  (dropped)
   cy_d6 |   .7653147   .0506445     15.112   0.000       .6660534    .8645761
   cy_d7 |  -.8222779   .0573056    -14.349   0.000      -.9345949   -.7099609
   cy_d8 |  (dropped)
   cy_d9 |   .8682754   .0793758     10.939   0.000       .7127017    1.023849
  cy_d10 |  (dropped)
  cy_d11 |  -.0517027   .0643041     -0.804   0.421      -.1777365    .0743311
  cy_d12 |  (dropped)
  cy_d13 |   .5063628   .0304202     16.646   0.000       .4467403    .5659854
```

```
  cy_d14 |   .6353689   .0358297     17.733   0.000       .5651439    .7055938
  cy_d15 |  (dropped)
  cy_d16 |   .8085734   .0698024     11.584   0.000       .6717632    .9453836
  cy_d17 |  (dropped)
  cy_d18 |   .5913342   .0501805     11.784   0.000       .4929822    .6896863
   yr_d2 |  -.0072503   .0017238     -4.206   0.000      -.0106289   -.0038716
   yr_d3 |  -.0041057   .0023166     -1.772   0.076      -.0086462    .0004348
   yr_d4 |   .0026347   .0033139      0.795   0.427      -.0038604    .0091299
   yr_d5 |   .0155186   .0045503      3.410   0.001       .0066002    .0244371
   yr_d6 |   .0173697     .00465      3.735   0.000       .0082558    .0264836
   yr_d7 |    .030034   .0060883      4.933   0.000       .0181013    .0419668
   yr_d8 |   .0332089   .0075518      4.397   0.000       .0184076    .0480102
   yr_d9 |    .047173   .0089285      5.283   0.000       .0296734    .0646726
  yr_d10 |    .064279   .0093995      6.839   0.000       .0458563    .0827016
   _cons |   7.283499   .9533756      7.640   0.000       5.414917    9.152081
------------------------------------------------------------------------------
Note: You estimated at least as many quantities as you have observations.
```

3(IV)5(b)

```
. xtgls ln_eng ln_gdp cy_d2-cy_d18 yr_d2-yr_d10, panels(correlated) corr(psar1)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   panel-specific AR(1)

Estimated covariances      =       171          Number of obs      =       180
Estimated autocorrelations =        18          Number of groups   =        18
Estimated coefficients     =        28          No. of time periods=        10
                                                Wald chi2(18)      = 282251.81
Log likelihood             =         .          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
  ln_eng |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
  ln_gdp |   .7609168   .0310774     24.485   0.000       .7000061    .8218275
   cy_d2 |  (dropped)
   cy_d3 |  (dropped)
   cy_d4 |   .5048806   .0383152     13.177   0.000       .4297841    .5799771
   cy_d5 |  -.6202744   .0499198    -12.425   0.000      -.7181154   -.5224334
   cy_d6 |   .0774734   .0435839      1.778   0.075      -.0079494    .1628963
   cy_d7 |  -1.025367   .1226244     -8.362   0.000      -1.265706   -.7850274
   cy_d8 |  (dropped)
   cy_d9 |   .0763632    .070614      1.081   0.280      -.0620378    .2147641
  cy_d10 |   .0425762   .0443064      0.961   0.337      -.0442627    .1294152
  cy_d11 |  (dropped)
  cy_d12 |  (dropped)
  cy_d13 |  (dropped)
  cy_d14 |   .1692629   .0305646      5.538   0.000       .1093574    .2291684
  cy_d15 |  (dropped)
  cy_d16 |  (dropped)
  cy_d17 |  (dropped)
  cy_d18 |   .2079813   .0490279      4.242   0.000       .1118883    .3040742
   yr_d2 |    .012474   .0032346      3.856   0.000       .0061343    .0188137
   yr_d3 |   .0209227   .0037834      5.530   0.000       .0135073    .0283382
```

```
   yr_d4 |  .0368015    .004005      9.189   0.000      .0289518    .0446511
   yr_d5 |  .0379874   .0044168      8.601   0.000      .0293306    .0466441
   yr_d6 |  .0473121   .0051379      9.208   0.000      .0372421    .0573822
   yr_d7 |  .0613189   .0058023     10.568   0.000      .0499465    .0726912
   yr_d8 |  .0667379   .0063859     10.451   0.000      .0542217    .0792541
   yr_d9 |  .0838943   .0064274     13.053   0.000      .0712968    .0964918
  yr_d10 |  .1074465   .0073584     14.602   0.000      .0930243    .1218687
   _cons |  4.922253   .8270489      5.952   0.000      3.301267    6.543239
------------------------------------------------------------------------------
Note: You estimated at least as many quantities as you have observations.
```

3(IV)5(c)

```
. xtgls ln_eng ln_gdp cy_d2-cy_d18 yr_d2-yr_d10, panels(correlated) corr(psar1)

Cross-sectional time-series FGLS regression
Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   panel-specific AR(1)
Estimated covariances      =       231      Number of obs      =        210
Estimated autocorrelations =        21      Number of groups   =         21
Estimated coefficients     =        28      No. of time periods=         10
                                            Wald chi2(16)      =    2655.59
Log likelihood             =         .      Pr > chi2          =     0.0000
------------------------------------------------------------------------------
  ln_eng |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
  ln_gdp |   .421843   .0466819      9.037   0.000      .3303482    .5133378
   cy_d2 |  (dropped)
   cy_d3 |  (dropped)
   cy_d4 |  (dropped)
   cy_d5 |  .1673327   .0342146      4.891   0.000      .1002733    .2343921
   cy_d6 |  .2365818   .0796441      2.970   0.003      .0804822    .3926813
   cy_d7 |  (dropped)
   cy_d8 |  (dropped)
   cy_d9 |  (dropped)
  cy_d10 | -.0312059   .2669471     -0.117   0.907     -.5544127    .4920008
  cy_d11 |  (dropped)
  cy_d12 |  (dropped)
  cy_d13 |  .4863594   .1359908      3.576   0.000      .2198224    .7528964
  cy_d14 |  (dropped)
  cy_d15 |  (dropped)
  cy_d16 |  (dropped)
  cy_d17 | -.3142045   .0453815     -6.924   0.000     -.4031507   -.2252583
  cy_d18 |  .0289608   .0380789      0.761   0.447     -.0456724    .1035941
   yr_d2 |   .007744   .0073218      1.058   0.290     -.0066065    .0220945
   yr_d3 |  .0420555    .009738      4.319   0.000      .0229695    .0611416
   yr_d4 |  .0582256   .0102941      5.656   0.000      .0380495    .0784016
   yr_d5 |  .0949982   .0108591      8.748   0.000      .0737148    .1162817
   yr_d6 |  .1023523   .0105738      9.680   0.000      .0816281    .1230765
   yr_d7 |  .1275053   .0112319     11.352   0.000      .1054911    .1495194
   yr_d8 |  .1464604    .012725     11.510   0.000      .1215198     .171401
   yr_d9 |    .17014   .0125216     13.588   0.000      .1455981     .194682
  yr_d10 |  .1748117   .0120472     14.511   0.000      .1511997    .1984237
   _cons |  12.81861   1.187148     10.798   0.000      10.49184    15.14538
------------------------------------------------------------------------------
Note: You estimated at least as many quantities as you have observations.
```

3(IV)5(d)

```
. xtgls ln_eng ln_gdp cy_d2-cy_d18 yr_d2-yr_d10, panels(correlated) corr(psar1)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   panel-specific AR(1)

Estimated covariances      =       231          Number of obs      =       210
Estimated autocorrelations =        21          Number of groups   =        21
Estimated coefficients     =        28          No. of time periods=        10
                                                Wald chi2(16)      = 120120.64
Log likelihood             =         .          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
  ln_eng |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
  ln_gdp |    .719803   .0579415     12.423   0.000       .6062398    .8333663
   cy_d2 |  (dropped)
   cy_d3 |   8.152349   .9707674      8.398   0.000       6.249679    10.05502
   cy_d4 |  -.3383212   .0422124     -8.015   0.000      -.4210559   -.2555865
   cy_d5 |  (dropped)
   cy_d6 |   .4990798   .1351512      3.693   0.000       .2341884    .7639712
   cy_d7 |  (dropped)
   cy_d8 |  (dropped)
   cy_d9 |   .4766189     .05552      8.585   0.000       .3678018     .585436
  cy_d10 |   .5675378   .0523856     10.834   0.000        .464864    .6702117
  cy_d11 |  (dropped)
  cy_d12 |  (dropped)
  cy_d13 |  (dropped)
  cy_d14 |  (dropped)
  cy_d15 |   1.308482   .0793451     16.491   0.000       1.152968    1.463995
  cy_d16 |  (dropped)
  cy_d17 |  (dropped)
  cy_d18 |  (dropped)
   yr_d2 |   .0044858   .0076379      0.587   0.557      -.0104842    .0194557
   yr_d3 |   .0087273   .0092068      0.948   0.343      -.0093176    .0267723
   yr_d4 |   .0013658   .0114317      0.119   0.905      -.0210399    .0237715
   yr_d5 |   .0047493   .0135799      0.350   0.727      -.0218669    .0313655
   yr_d6 |   .0071722   .0149573      0.480   0.632      -.0221436     .036488
   yr_d7 |    .017048   .0167452      1.018   0.309      -.0157721     .049868
   yr_d8 |    .016323   .0186277      0.876   0.381      -.0201866    .0528326
   yr_d9 |   .0149681    .016887      0.886   0.375      -.0181297     .048066
  yr_d10 |   .0246982   .0177821      1.389   0.165      -.0101541    .0595505
   _cons |   5.600059   1.519178      3.686   0.000       2.622524    8.577593
------------------------------------------------------------------------------
Note: You estimated at least as many quantities as you have observations.
```

- *3(V)Nitrogen-di-oxide (NO2)*

3(V)1

```
. xtreg no2 p_pcgdp sp_pcgdp cp_pcgdp popln, fe

Fixed-effects (within) regression               Number of obs      =       540
Group variable (i) : cocode                     Number of groups   =        27

R-sq:  within  = 0.3817                         Obs per group: min =        20
       between = 0.9244                                        avg =      20.0
       overall = 0.9218                                        max =        20

                                                F(4,509)           =     78.55
corr(u_i, Xb)  = 0.8787                         Prob > F           =    0.0000

------------------------------------------------------------------------------
     no2 |      Coef.   Std. Err.       t     P>|t|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   .1114915   .0267286      4.171   0.000        .0589796    .1640035
sp_pcgdp |  -5.99e-06   1.38e-06     -4.330   0.000       -8.71e-06   -3.27e-06
cp_pcgdp |   9.36e-11   2.26e-11      4.134   0.000        4.91e-11    1.38e-10
   popln |   .0000392   2.37e-06     16.532   0.000        .0000345    .0000439
   _cons |  -205.3817   167.7439     -1.224   0.221       -534.9374     124.174
------------------------------------------------------------------------------
 sigma_u |  2457.5352
 sigma_e |  167.37653
     rho |  .99538279   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(26,509) =   907.07             Prob > F = 0.0000
```

3(V)2

```
. xtgls no2 p_pcgdp sp_pcgdp cp_pcgdp popln cy_d2-cy_d27 yr_d2-yr_d20,
panels(correlated) corr(psar1)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   panel-specific AR(1)

Estimated covariances      =       378          Number of obs      =       540
Estimated autocorrelations =        27          Number of groups   =        27
Estimated coefficients     =        50          No. of time periods=        20
                                                Wald chi2(40)      = 133596.29
Log likelihood             = -1662.966          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
     no2 |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   .0413518    .003274     12.630   0.000         .034935    .0477687
sp_pcgdp |  -9.12e-07   1.23e-07     -7.425   0.000       -1.15e-06   -6.72e-07
cp_pcgdp |   8.79e-12   1.59e-12      5.535   0.000        5.68e-12    1.19e-11
   popln |   .0000368   1.75e-06     21.017   0.000        .0000333    .0000402
```

```
      cy_d2 |  -131.7372   68.86732     -1.913   0.056     -266.7147    3.240281
      cy_d3 |   97.87869   75.37077      1.299   0.194     -49.8453     245.6027
      cy_d4 |   705.6062   91.50495      7.711   0.000      526.2598    884.9526
      cy_d5 |  (dropped)
      cy_d6 |  -228.0519    70.1201     -3.252   0.001     -365.4847   -90.61899
      cy_d7 |  (dropped)
      cy_d8 |  -161.3882   67.17574     -2.402   0.016     -293.0503   -29.72621
      cy_d9 |  -599.2061   148.7273     -4.029   0.000     -890.7062    -307.706
     cy_d10 |  -122.0466   67.27984     -1.814   0.070     -253.9127    9.819412
     cy_d11 |  (dropped)
     cy_d12 |  -279.7136   62.55113     -4.472   0.000     -402.3116   -157.1157
     cy_d13 |  (dropped)
     cy_d14 |   -591.818   153.2244     -3.862   0.000     -892.1322   -291.5038
     cy_d15 |   103.0368   76.87195      1.340   0.180     -47.62945     253.703
     cy_d16 |  -342.0544   66.56317     -5.139   0.000     -472.5158    -211.593
     cy_d17 |  (dropped)
     cy_d18 |  (dropped)
     cy_d19 |  (dropped)
     cy_d20 |  -380.3053     82.893     -4.588   0.000     -542.7726    -217.838
     cy_d21 |  -67.78625   68.06119     -0.996   0.319     -201.1837    65.61123
     cy_d22 |  -273.1201   102.9426     -2.653   0.008      -474.884   -71.35631
     cy_d23 |  -234.6084   75.62504     -3.102   0.002     -382.8307     -86.386
     cy_d24 |  (dropped)
     cy_d25 |  -1333.568   117.5186    -11.348   0.000       -1563.9   -1103.236
     cy_d26 |   504.3619   131.0141      3.850   0.000       247.579    761.1448
     cy_d27 |    12489.1   463.2839     26.958   0.000      11581.08    13397.12
      yr_d2 |  -22.09583   2.423561     -9.117   0.000     -26.84592   -17.34574
      yr_d3 |  -58.21721    3.64315    -15.980   0.000     -65.35765   -51.07677
      yr_d4 |  -88.06304   4.572226    -19.260   0.000     -97.02444   -79.10164
      yr_d5 |  -87.35436   5.278062    -16.550   0.000     -97.69917   -77.00955
      yr_d6 |  -144.1023   5.899867    -24.425   0.000     -155.6658   -132.5388
      yr_d7 |  -171.5729   6.391808    -26.843   0.000     -184.1006   -159.0452
      yr_d8 |  -167.7072   6.877475    -24.385   0.000     -181.1868   -154.2276
      yr_d9 |  -149.4283   7.330695    -20.384   0.000     -163.7962   -135.0604
     yr_d10 |  -143.1827   7.829669    -18.287   0.000     -158.5286   -127.8369
     yr_d11 |   -140.577   8.185238    -17.174   0.000     -156.6198   -124.5343
     yr_d12 |  -140.2185   8.273951    -16.947   0.000     -156.4352   -124.0019
     yr_d13 |  -134.5195    8.35169    -16.107   0.000     -150.8885   -118.1504
     yr_d14 |  -138.8347   8.564185    -16.211   0.000     -155.6202   -122.0492
     yr_d15 |  -148.5355   8.924653    -16.643   0.000     -166.0275   -131.0435
     yr_d16 |  -174.0043   9.282313    -18.746   0.000     -192.1973   -155.8113
     yr_d17 |  -156.8936   9.649435    -16.259   0.000     -175.8062   -137.9811
     yr_d18 |  -173.6311   10.07735    -17.230   0.000     -193.3823   -153.8798
     yr_d19 |  -205.8774    10.5337    -19.545   0.000     -226.5231   -185.2318
     yr_d20 |  -243.4752   11.01742    -22.099   0.000      -265.069   -221.8815
      _cons |  -113.4476   71.68563     -1.583   0.114     -253.9489    27.05362
------------------------------------------------------------------------------
```

- *3(VI)Deforestation*

3(VI)1

```
. xtgls dfrstn p_pcgdp sp_pcgdp cp_pcgdp urbnsn openness debt cy_d2-cy_d35,
panels(correlated) corr(ar1)

Cross-sectional time-series FGLS regression
Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   common AR(1) coefficient for all panels  (0.8563)
Estimated covariances      =       630       Number of obs       =       700
Estimated autocorrelations =         1       Number of groups    =        35
Estimated coefficients     =        41       No. of time periods=         20
                                             Wald chi2(23)       =   3158.53
Log likelihood             =         .       Pr > chi2           =    0.0000
------------------------------------------------------------------------------
  dfrstn |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
 p_pcgdp |   .0011513   .0001497      7.693   0.000       .0008579    .0014446
sp_pcgdp |  -1.15e-07   8.57e-09    -13.405   0.000      -1.32e-07   -9.80e-08
cp_pcgdp |   2.46e-12   1.52e-13     16.127   0.000       2.16e-12    2.75e-12
  urbnsn |   .6100957   .0344731     17.698   0.000       .5425297    .6776618
openness |   .7297934    .156126      4.674   0.000        .423792    1.035795
    debt |   .0037556   .0022805      1.647   0.100       -.000714    .0082252
   cy_d2 |  (dropped)
   cy_d3 |  (dropped)
   cy_d4 |  -76.53623    17.9588     -4.262   0.000      -111.7348   -41.33763
   cy_d5 |  (dropped)
   cy_d6 |  -42.92828   17.13363     -2.505   0.012      -76.50958   -9.346977
   cy_d7 |  (dropped)
   cy_d8 |  -60.86678   17.78632     -3.422   0.001      -95.72733   -26.00623
   cy_d9 |  -5.242181   20.06207     -0.261   0.794      -44.56312    34.07876
  cy_d10 |  (dropped)
  cy_d11 |  -24.68576   21.41316     -1.153   0.249      -66.65478    17.28325
  cy_d12 |  -90.52065   17.93668     -5.047   0.000      -125.6759   -55.36541
  cy_d13 |  -23.70305   18.46943     -1.283   0.199      -59.90246    12.49636
  cy_d14 |  -48.02359   19.05657     -2.520   0.012      -85.37379    -10.6734
  cy_d15 |  (dropped)
  cy_d16 |  (dropped)
  cy_d17 |  (dropped)
  cy_d18 |   -9.54914   19.29974     -0.495   0.621      -47.37593    28.27765
  cy_d19 |  -78.45515   18.18624     -4.314   0.000      -114.0995   -42.81079
  cy_d20 |  (dropped)
  cy_d21 |  (dropped)
  cy_d22 |  -65.74163   17.88631     -3.676   0.000      -100.7982    -30.6851
  cy_d23 |  -41.79702   17.60969     -2.374   0.018      -76.31137   -7.282665
  cy_d24 |   45.97622   20.73406      2.217   0.027       5.338217    86.61422
  cy_d25 |  (dropped)
  cy_d26 |  -35.36709   18.39702     -1.922   0.055      -71.42458    .6904047
  cy_d27 |  (dropped)
  cy_d28 |  -12.10901   19.70938     -0.614   0.539      -50.73868    26.52067
  cy_d29 |  -32.24563   19.08174     -1.690   0.091      -69.64516      5.1539
  cy_d30 |  (dropped)
  cy_d31 |  -3.574864   17.86851     -0.200   0.841       -38.5965    31.44677
  cy_d32 |  (dropped)
  cy_d33 |  (dropped)
  cy_d34 |  -76.08961   17.71221     -4.296   0.000      -110.8049   -41.37431
  cy_d35 |  (dropped)
   _cons |   33.37698   17.99001      1.855   0.064      -1.882784    68.63675
------------------------------------------------------------------------------
```

Appendix to chapter 4

- *4(A)Principal Component Analysis*

Notations: sco2 = standardized value of co2
Sbod = standardized value of bod
scomen = standardized value of commercial energy
sdfrst = standardized value of deforestation
smd = standarized value of mineral depletion

1980

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                 (principal components; 5 components retained)
Component     Eigenvalue      Difference      Proportion     Cumulative
------------------------------------------------------------------------
     1          1.92720         0.70415        0.3854          0.3854
     2          1.22304         0.22110        0.2446          0.6300
     3          1.00195         0.39749        0.2004          0.8304
     4          0.60446         0.36111        C.1209          0.9513
     5          0.24335            .           0.0487          1.0000

                Eigenvectors
 Variable |        1          2           3           4           5
----------+-------------------------------------------------------------
      co2 |    0.58774   -0.38178     0.19627    -0.09047     0.67977
      bod |    0.59815    0.17130     0.12573    -0.56052    -0.53187
    comen |    0.52479    0.25265    -0.09353     0.78714    -0.18009
   dfrstn |   -0.00702    0.87184     0.05386    -0.16389     0.45835
       md |   -0.14601    0.03111     0.96645     0.17660    -0.11183


. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)80  =  (1/1.92720)  *  (  (0.58774)*(sco2)  +  (0.59815)*(sbod)  +  (0.52479)*(scomen)
(-0.00702)*(sdfrst) + (-0.14601)*(smd) ) + (1/1.22304) * ( (-0.38178)*(sco2) + (0.17130)*(sbod)
(0.25265)*(scomen) + (0.87184)*(sdfrst) + (0.03111)*(smd) ) + (1/1.00195) * ( (0.19627)*(sco2)
(0.12573)*(sbod) + (-0.09353)*(scomen) + (0.05386)*(sdfrst) + (0.96645)*(smd) )

. edit sc(3)80
```

1981

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                 (principal components; 5 components retained)
Component     Eigenvalue      Difference      Proportion      Cumulative
----------------------------------------------------------------------------
     1         1.92565          0.56665        0.3851          0.3851
     2         1.35900          0.38857        0.2718          0.6569
     3         0.97043          0.43559        0.1941          0.8510
     4         0.53484          0.32476        0.1070          0.9580
     5         0.21007           .             0.0420          1.0000

                 Eigenvectors
  Variable |        1           2           3           4           5
-----------+-----------------------------------------------------------
       co2 |   0.58437    -0.42081    -0.02779    -0.00983     0.69322
       bod |   0.61312     0.08333     0.13707    -0.61476    -0.46948
     comen |   0.52467     0.34452     0.03008     0.74573    -0.22137
    dfrstn |  -0.01449     0.77898     0.31879    -0.21566     0.49481
        md |  -0.08427    -0.30077     0.93697     0.13908    -0.07200


. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)81  =  (1/1.92565)  *  (  (0.58437)*(sco2)  +  (0.61312)*(sbod)  +  (0.52467)*(scomen)
(-0.01449)*(sdfrst)  +  (-0.08427)*(smd)  )  +  (1/1.35900)  *  (  (-0.42081)*(sco2)  +  (0.08333)*(sbod)
(0.34452)*(scomen)  +  (0.77898)*(sdfrst)  +  (-0.30077)*(smd)  )  +  (1/0.97043)  *  (  (-0.02779)*(sco2)
(0.13707)*(sbod)  +  (0.03008)*(scomen)  +  (0.31879)*(sdfrst)  +  (0.93697)*(smd)  )

. edit sc(3)81
```

1982

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                 (principal components; 5 components retained)
Component     Eigenvalue      Difference      Proportion      Cumulative
----------------------------------------------------------------------------
     1         1.78356          0.37760        0.3567          0.3567
     2         1.40595          0.44891        0.2812          0.6379
     3         0.95704          0.34401        0.1914          0.8293
     4         0.61303          0.37262        0.1226          0.9519
     5         0.24041           .             0.0481          1.0000

                 Eigenvectors
  Variable |        1           2           3           4           5
-----------+-----------------------------------------------------------
       co2 |   0.51499    -0.54815    -0.00521    -0.01563     0.65882
       bod |   0.61742     0.07303     0.14551    -0.63434    -0.43577
     comen |   0.56432     0.21192     0.05949     0.75657    -0.24638
    dfrstn |   0.10074     0.76352     0.28481    -0.13044     0.55567
        md |  -0.15802    -0.25756     0.94559     0.08922    -0.08118
```

```
. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)82  =  (1/1.78356)  *  (  (0.51499)*(sco2)  +  (0.61742)*(sbod)  +  (0.56432)*(scomen)
(0.10074)*(sdfrst)  +  (-0.15802)*(smd)  )  +  (1/1.40595)  *  (  (-0.54815)*(sco2)  +  (0.07303)*(sbod
(0.21192)*(scomen)  +  (0.76352)*(sdfrst)  +  (-0.25756)*(smd)  )  +  (1/0.95704)  *  (  (-0.00521)*(sco2
(0.14551)*(sbod) + (0.05949)*(scomen) + (0.28481)*(sdfrst) + (0.94559 )*(smd) )

. edit sc(3)82
```

1983

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
              (principal components; 5 components retained)
Component     Eigenvalue      Difference  - Proportion    Cumulative
------------------------------------------------------------------
     1         1.78524         0.37672       0.3570          0.3570
     2         1.40851         0.42710       0.2817          0.6387
     3         0.98141         0.42502       0.1963          0.8350
     4         0.55640         0.28795       0.1113          0.9463
     5         0.26844               .       0.0537          1.0000

              Eigenvectors
 Variable |     1          2          3          4          5
----------+-----------------------------------------------------
      co2 |  0.48294   -0.57161    0.00762    0.13498    0.64942
      bod |  0.64454    0.07856    0.12561    0.53736   -0.52332
    comen |  0.57191    0.22397    0.01823   -0.78626   -0.06496
   dfrstn |  0.09767    0.76251    0.22605    0.24853    0.54421
       md | -0.12130   -0.18841    0.96578   -0.11429   -0.06321

. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)83  =  (1/1.78524)  *  (  (0.48294)*(sco2)  +  (0.64454)*(sbod)  +  (0.57191)*(scomen)
(0.09767)*(sdfrst)  +  (-0.12130)*(smd)  )  +  (1/1.40851)  *  (  (-0.57161)*(sco2)  +  (0.07856)*(sbod)
(0.22397)*(scomen)  +  (0.76251)*(sdfrst)  +  (-0.18841)*(smd)  )  +  (1/0.98141)  *  (  (0.00762)*(sco2)
(0.12561)*(sbod) + (0.01823)*(scomen) + (0.22605)*(sdfrst) + (0.96578)*(smd) )

. edit sc(3)83
```

1984

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                (principal components; 5 components retained)
Component     Eigenvalue      Difference     Proportion     Cumulative
------------------------------------------------------------------
     1         1.80052         0.37819        0.3601         0.3601
     2         1.42232         0.48185        0.2845         0.6446
     3         0.94047         0.42200        0.1881         0.8327
     4         0.51847         0.20025        0.1037         0.9364
     5         0.31822               .        0.0636         1.0000

                Eigenvectors
  Variable |       1          2          3          4          5
-----------+------------------------------------------------------
       co2 |   0.34095   -0.66877   -0.01963    0.27752    0.59925
       bod |   0.63590   -0.01883    0.26439    0.43843   -0.57719
     comen |   0.60534    0.10341    0.11441   -0.76978    0.13123
    dfrstn |   0.20410    0.72807    0.11334    0.36564    0.53077
        md |  -0.26700   -0.10782    0.95067   -0.06716    0.09382


. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)84  =  (1/1.80052)  *  (  (0.34095)*(sco2)  +  (0.63590)*(sbod)  +  (0.60534)*(scomen)
(0.20410)*(sdfrst) + (-0.26700)*( smd) ) + (1/1.42232) * ( (-0.66877)*(sco2) +  (-0.01883)*(sbod)
(0.10341)*(scomen) + (0.72807)*(sdfrst) + (-0.10782)*(smd) ) + (1/0.94047) * ( (-0.01963)*(sco2)
(0.26439)*(sbod) + (0.11441)*(scomen) + (0.11334)*(sdfrst) + (0.95067)*( smd) )

. edit sc(3)84
```

1985

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                (principal components; 5 components retained)
Component     Eigenvalue      Difference     Proportion     Cumulative
------------------------------------------------------------------
     1         1.81031         0.38423        0.3621         0.3621
     2         1.42608         0.49388        0.2852         0.6473
     3         0.93220         0.43604        0.1864         0.8337
     4         0.49616         0.16090        0.0992         0.9329
     5         0.33526               .        0.0671         1.0000

                Eigenvectors
  Variable |       1          2          3          4          5
-----------+------------------------------------------------------
       co2 |   0.09227    0.75506   -0.09235    0.39571    0.50622
       bod |   0.62161    0.22775    0.19728    0.30513   -0.65553
     comen |   0.62221    0.07772    0.13101   -0.69107    0.33477
    dfrstn |   0.38132   -0.59873    0.16062    0.52194    0.44486
        md |  -0.26933    0.11616    0.95372   -0.01777    0.06370
```

```
. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

. gen sc(3)85 = (1/1.81031) * ( (0.09227)*(sco2) + (0.62161)*(sbod) + (0.62221)*(scomen)
(0.38132)*(sdfrst) + (-0.26933)*( smd) ) + (1/1.42608) * ( (0.75506)*(sco2) + (0.22775)*(sbod
(0.07772)*(scomen) + (-0.59873)*(sdfrst) + (0.11616)*(smd) ) + (1/0.93220) * ( (-0.09235)*(sco2
(0.19728)*(sbod) + (0.13101)*(scomen) + (0.16062)*(sdfrst) + (0.95372)*(smd) )

. edit sc(3)85
```

1986

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
            (principal components; 5 components retained)
Component    Eigenvalue      Difference     Proportion     Cumulative
----------------------------------------------------------------------
     1         1.84568         0.43045        0.3691          0.3691
     2         1.41522         0.47811        0.2830          0.6522
     3         0.93711         0.45068        0.1874          0.8396
     4         0.48642         0.17085        0.0973          0.9369
     5         0.31557               .        0.0631          1.0000

            Eigenvectors
  Variable |      1          2          3          4          5
-----------+----------------------------------------------------
       co2 |   0.06389    0.74222   -0.14715    0.58730    0.28008
       bod |   0.63674    0.22239    0.12400    0.02760   -0.72731
     comen |   0.64144    0.11020    0.07504   -0.47169    0.59016
    dfrstn |   0.36535   -0.58232    0.23304    0.65613    0.20642
        md |  -0.21344    0.22002    0.95028   -0.03631    0.04105

. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)


. gen sc(3)86 = (1/1.84568) * ( (0.06389)*(sco2) + (0.63674)*(sbod) + (0.64144)*(scomen)
(0.36535)*(sdfrst) + (-0.21344)*( smd) ) + (1/1.41522) * ( (0.74222)*(sco2) + (0.22239)*(sbod)
(0.11020)*(scomen) + (-0.58232)*(sdfrst) + (0.22002)*(smd) ) + (1/0.93711) * ( (-0.14715)*(sco2)
(0.12400)*(sbod) + (0.07504)*(scomen) + (0.23304)*(sdfrst) + (0.95028)*(smd) )

. edit sc(3)86
```

1987

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                (principal components; 5 components retained)
Component     Eigenvalue      Difference     Proportion     Cumulative
------------------------------------------------------------------
     1          1.93108         0.54534        0.3862          0.3862
     2          1.38574         0.43374        0.2771          0.6634
     3          0.95199         0.41312        0.1904          0.8538
     4          0.53888         0.34656        0.1078          0.9615
     5          0.19231               .        0.0385          1.0000

                Eigenvectors
  Variable |      1           2           3           4           5
----------+-----------------------------------------------------------
       co2 |   0.00657     0.72954    -0.20226     0.63868     0.13754
       bod |   0.63411     0.21356     0.12406    -0.34983     0.64384
     comen |   0.66820     0.15418     0.06234    -0.00709    -0.72512
    dfrstn |   0.34495    -0.59443     0.15427     0.68164     0.19807
        md |  -0.17994     0.21226     0.95708     0.07091    -0.03909


. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

egen sdfrst=std(dfrstn)

. egen smd=std(md)


.  gen  sc(3)87  =  (1/1.93108)  *  (  (0.00657)*(sco2)  +  (0.63411)*(sbod)  +  (0.66820)*(scomen)
(0.34495)*(sdfrst)  +  (-0.17994)*( smd)  )  +  (1/1.38574)  *  (  (0.72954)*(sco2)  +  (0.21356)*(sbod)
(0.15418)*(scomen)  +  (-0.59443)*(sdfrst)  +  (0.21226)*(smd)  )  +  (1/0.95199)  *  (  (-0.20226)*(sco2)
(0.12406)*(sbod)  +  (0.06234)*(scomen)  +  (0.15427)*(sdfrst)  +  (0.95708)*(smd)  )

. edit sc(3)87
```

1988

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                (principal components; 5 components retained)
Component     Eigenvalue      Difference     Proportion     Cumulative
------------------------------------------------------------------
     1          1.96597         0.60287        0.3932          0.3932
     2          1.36310         0.39632        0.2726          0.6658
     3          0.96678         0.45100        0.1934          0.8592
     4          0.51578         0.32740        0.1032          0.9623
     5          0.18838               .        0.0377          1.0000

                Eigenvectors
  Variable |      1           2           3           4           5
----------+-----------------------------------------------------------
       co2 |  -0.03358     0.75264    -0.17953     0.60312     0.19084
       bod |   0.60331     0.22834     0.27859    -0.36221     0.61243
     comen |   0.65443     0.18338     0.10914     0.06858    -0.72213
    dfrstn |   0.38135    -0.58885    -0.03643     0.66493     0.25371
        md |  -0.24736     0.03209     0.93644     0.24126    -0.05158
```

```
. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)88  =  (1/1.96597)  *  (  (-0.03358)*(sco2)  +  (0.60331)*(sbod)  +  (0.65443)*(scomen)
(0.38135)*(sdfrst)  +  (-0.24736)*(smd)  )  +  (1/1.36310)  *  (  (0.75264)*(sco2)  +  (0.22834)*(sbod
(0.18338)*(scomen)  +  (-0.58885)*(sdfrst)  +  (0.03209)*(smd)  )  +  (1/0.96678)  *  (  (-0.17953)*(sco2
(0.27859)*(sbod)  +  (0.10914)*(scomen)  +  (-0.03643)*(sdfrst)  +  (0.93644)*(smd)  )

. edit sc(3)88
```

1989

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
            (principal components; 5 components retained)
Component     Eigenvalue     Difference     Proportion     Cumulative
------------------------------------------------------------------
    1          1.90371         0.52898        0.3807         0.3807
    2          1.37473         0.40540        0.2749         0.6557
    3          0.96933         0.51970        0.1939         0.8496
    4          0.44963         0.14702        0.0899         0.9395
    5          0.30261            .           0.0605         1.0000

             Eigenvectors
  Variable |     1           2           3           4          5
-----------+------------------------------------------------------
       co2 |  0.01371     0.77289    -0.12662     0.55910    0.27171
       bod |  0.59010     0.21998     0.27360    -0.50891    0.51918
     comen |  0.64074     0.17530     0.08728     0.11792   -0.73294
    dfrstn |  0.43027    -0.56765     0.02054     0.61290    0.34143
        md | -0.23648     0.03586     0.94925     0.19716   -0.05340

. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)89  =  (1/1.90371)  *  (  (0.01371)*(sco2)  +  (0.59010)*(sbod)  +  (0.64074)*(scomen)
(0.43027)*(sdfrst)  +  (-0.23648)*( smd)  )  +  (1/1.37473)  *  (  (0.77289)*(sco2)  +  (0.21998)*(sbod)
(0.17530)*(scomen)  +  (-0.56765)*(sdfrst)  +  (0.03586)*(smd)  )  +  (1/0.96933)  *  (  (-0.12662)*(sco2)
(0.27360)*(sbod)  +  (0.08728)*(scomen)  +  (0.02054)*(sdfrst)  +  (0.94925)*(smd)  )

. edit sc(3)89
```

1990

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                 (principal components; 5 components retained)
Component      Eigenvalue      Difference      Proportion     Cumulative
------------------------------------------------------------------------
     1          1.79311          0.35116         0.3586          0.3586
     2          1.44195          0.47799         0.2884          0.6470
     3          0.96396          0.49161         0.1928          0.8398
     4          0.47235          0.14372         0.0945          0.9343
     5          0.32862             .            0.0657          1.0000

                Eigenvectors
  Variable |        1           2           3           4           5
-----------+-----------------------------------------------------------
       co2 |   0.03826     0.74415    -0.21199     0.40997     0.48141
       bod |   0.55598     0.32558     0.20209    -0.72101     0.15552
     comen |   0.65391     0.12380     0.02877     0.43800    -0.60366
    dfrstn |   0.46685    -0.53918     0.15922     0.29403     0.61606
        md |  -0.20946     0.18490     0.94236     0.18379    -0.01072


. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)90  =  (1/1.79311)  *  (  (0.03826)*(sco2)  +  (0.55598)*(sbod)  +  (0.65391)*(scomen)
(0.46685)*(sdfrst)  +  (-0.20946)*( smd)  )  +  (1/1.44195)  *  (  (0.74415)*(sco2)  +  (0.32558)*(sbod)
(0.12380)*(scomen)  +  (-0.53918)*(sdfrst)  +  (0.18490)*(smd)  )  +  (1/0.96396)  *  (  (-0.21199)*(sco2)
(0.20209)*(sbod)  +  (0.02877)*(scomen)  +  (0.15922)*(sdfrst)  +  (0.94236)*(smd)  )

. edit sc(3)90
```

1991

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                 (principal components; 5 components retained)
Component      Eigenvalue      Difference      Proportion     Cumulative
------------------------------------------------------------------------
     1          1.81355          0.43639         0.3627          0.3627
     2          1.37716          0.39256         0.2754          0.6381
     3          0.98460          0.46137         0.1969          0.8351
     4          0.52323          0.22177         0.1046          0.9397
     5          0.30146             .            0.0603          1.0000

                Eigenvectors
  Variable |        1           2           3           4           5
-----------+-----------------------------------------------------------
       co2 |  -0.03563     0.75843    -0.28348     0.32174     0.48952
       bod |   0.51295     0.37982     0.17718    -0.74791     0.04305
     comen |   0.63622     0.17558    -0.06503     0.47691    -0.57683
    dfrstn |   0.55496    -0.43827     0.14566     0.23011     0.65252
        md |  -0.15120     0.24004     0.92887     0.23816    -0.00152
```

```
. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)91  =  (1/1.81355)  *  (  (-0.03563)*(sco2)  +  (0.51295)*(sbod)  +  (0.63622)*(scomen
(0.55496)*(sdfrst)  +  (-0.15120)*(smd)  )  +  (1/1.37716)  *  (  (0.75843)*(sco2)  +  (0.37982)*(sbod
(0.17558)*(scomen)  +  (-0.43827)*(sdfrst)  +  (0.24004)*(smd)  )  +  (1/0.98460)  *  (  (-0.28348)*(sco2
(0.17718)*(sbod) + (-0.06503)*(scomen) + (0.14566)*(sdfrst) + (0.92887)*(smd) )

. edit sc(3)91
```

1992

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                     (principal components; 5 components retained)
Component      Eigenvalue      Difference      Proportion      Cumulative
------------------------------------------------------------------
    1           1.83779         0.53501         0.3676          0.3676
    2           1.30278         0.30082         0.2606          0.6281
    3           1.00196         0.45982         0.2004          0.8285
    4           0.54214         0.22679         0.1084          0.9369
    5           0.31534               .         0.0631          1.0000

                   Eigenvectors
 Variable |         1           2           3           4           5
----------+-------------------------------------------------------
      co2 |  -0.18539     0.74674    -0.32322     0.20979     0.50944
      bod |   0.46065     0.47587     0.17523    -0.71799    -0.12305
    comen |   0.59224     0.24579    -0.12973     0.59190    -0.47081
   dfrstn |   0.61713    -0.30769     0.11536     0.09881     0.70810
       md |  -0.14777     0.24666     0.91361     0.28350     0.04757


. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)92  =  (1/1.83779)  *  (  (-0.18539)*(sco2)  +  (0.46065)*(sbod)  +  (0.59224)*(scomen)
(0.61713)*(sdfrst)  +  (-0.14777)*(smd)  )  +  (1/1.30278)  *  (  (0.74674)*(sco2)  +  (0.47587)*(sbod)
(0.24579)*(scomen)  +  (-0.30769)*(sdfrst)  +  (0.24666)*(smd)  )  +  (1/1.00196)  *  (  (-0.32322)*(sco2)
(0.17523)*(sbod) + (-0.12973)*(scomen) + (0.11536)*(sdfrst) + (0.91361)*(smd) )

. edit sc(3)92
```

1993

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                (principal components; 5 components retained)
Component     Eigenvalue      Difference      Proportion      Cumulative
--------------------------------------------------------------------------
     1         1.89115          0.70418         0.3782          0.3782
     2         1.18697          0.17196         0.2374          0.6156
     3         1.01501          0.39332         0.2030          0.8186
     4         0.62169          0.33651         0.1243          0.9430
     5         0.28518             .            0.0570          1.0000

               Eigenvectors
 Variable |       1           2           3           4           5
----------+-----------------------------------------------------------
      co2 |  -0.24042     0.80646    -0.21431     0.07660     0.48993
      bod |   0.46246     0.38090     0.29091    -0.72882    -0.15885
    comen |   0.54268     0.35738    -0.13714     0.57938    -0.47254
   dfrstn |   0.63719    -0.24046     0.06561     0.14925     0.71386
       md |  -0.16679     0.13784     0.91996     0.32404     0.04300


. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)93  =  (1/1.89115)  *  (  (-0.24042)*(sco2)  +  (0.46246)*(sbod)  +  (0.54268)*(scomen)
(0.63719)*(sdfrst)  +  (-0.16679)*(smd)  )  +  (1/1.18697)  *  (  (0.80646)*(sco2)  +  (0.38090)*(sbod)
(0.35738)*(scomen)  +  (-0.24046)*(sdfrst)  +  (0.13784)*(smd)  )  +  (1/1.01501)  *  (  (-0.21431)*(sco2
(0.29091)*(sbod)  +  (-0.13714)*(scomen)  +  (0.06561)*(sdfrst)  +  (0.91996)*(smd)  )

. edit sc(3)93
```

1994

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                (principal components; 5 components retained)
Component     Eigenvalue      Difference      Proportion      Cumulative
--------------------------------------------------------------------------
     1         1.78319          0.54484         0.3566          0.3566
     2         1.23834          0.23541         0.2477          0.6043
     3         1.00294          0.27558         0.2006          0.8049
     4         0.72736          0.47918         0.1455          0.9504
     5         0.24817             .            0.0496          1.0000

               Eigenvectors
 Variable |       1           2           3           4           5
----------+-----------------------------------------------------------
      co2 |  -0.20431     0.82803    -0.07756     0.09481     0.50755
      bod |   0.45017     0.25639     0.30657    -0.79745    -0.04125
    comen |   0.55755     0.41808    -0.06255     0.45367    -0.55193
   dfrstn |   0.64815    -0.27053     0.04545     0.26223     0.66022
       md |  -0.15698     0.02546     0.94553     0.28374    -0.01324
```

```
. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)94  =  (1/1.78319)  *  (  (-0.20431)*(sco2)  +  (0.45017)*(sbod)  +  (0.55755)*(scomen)
(0.64815)*(sdfrst)  +  (-0.15698)*(smd)  )  +  (1/1.23834)  *  (  (0.82803)*(sco2)  +  (0.25639)*(sbod
(0.41808)*(scomen)  +  (-0.27053)*(sdfrst)  +  (0.02546)*(smd)  )  +  (1/1.00294)  *  (  (-0.07756)*(sco2
(0.30657)*(sbod)  +  (-0.06255)*(scomen)  +  (0.04545)*(sdfrst)  +  (0.94553)*(smd)  )

. edit sc(3)94
```

1995

```
. factor   co2 bod comen dfrstn md, pc
(obs=35)
                (principal components; 5 components retained)
Component     Eigenvalue      Difference      Proportion     Cumulative
------------------------------------------------------------------
     1          1.79173         0.56130        0.3583          0.3583
     2          1.23043         0.23336        0.2461          0.6044
     3          0.99707         0.24941        0.1994          0.8038
     4          0.74765         0.51454        0.1495          0.9534
     5          0.23312               .        0.0466          1.0000

                Eigenvectors
  Variable |       1           2           3           4           5
-----------+------------------------------------------------------
       co2 |  -0.23956     0.81752     0.03972     0.13715     0.50386
       bod |   0.41310     0.27055     0.40582    -0.76623    -0.06599
     comen |   0.55262     0.40937     0.00353     0.49045    -0.53524
    dfrstn |   0.65984    -0.25740     0.00175     0.20768     0.67470
        md |  -0.17658    -0.15690     0.91308     0.33229     0.00819

. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)95  =  (1/1.79173)  *  (  (-0.23956)*(sco2)  +  (0.41310)*(sbod)  +  (0.55262)*(scomen)
(0.65984)*(sdfrst)  +  (-0.17658*(  smd)  )  +  (1/1.23043)  *  (  (0.81752)*(sco2)  +  (0.27055)*(sbod)
(0.40937)*(scomen)  +  (-0.25740)*(sdfrst)  +  (-0.15690)*(smd)  )  +  (1/0.99707)  *  (  (0.03972)*(sco2)
(0.40582)*(sbod)  +  (0.00353)*(scomen)  +  (0.00175)*(sdfrst)  +  (0.91308)*(smd)  )

. edit sc(3)95
```

1996

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                 (principal components; 5 components retained)
Component     Eigenvalue      Difference     Proportion     Cumulative
------------------------------------------------------------------
     1          1.69972         0.43695       0.3399          0.3399
     2          1.26277         0.25770       0.2526          0.5925
     3          1.00507         0.20488       0.2010          0.7935
     4          0.80019         0.56795       0.1600          0.9536
     5          0.23225               .       0.0464          1.0000

               Eigenvectors
 Variable |      1          2          3          4          5
----------+------------------------------------------------------
      co2 |  -0.23846    0.81053   -0.06094    0.08839    0.52408
      bod |   0.38255    0.29092    0.41050   -0.76864   -0.09850
    comen |   0.54353    0.44502   -0.06293    0.47301   -0.52804
   dfrstn |   0.68334   -0.24330    0.04509    0.18741    0.66083
       md |  -0.18552   -0.03426    0.90652    0.37752    0.01031


. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)96  =  (1/1.69972)  *  (  (-0.23846)*(sco2)  +  (0.38255)*(sbod)  +  (0.54353)*(scomen)
(0.68334)*(sdfrst)  +  (-0.18552)*(smd)  )  +  (1/1.26277)  *  (  (0.81053)*(sco2)  +  (0.29092)*(sbod)
(0.44502)*(scomen)  + (-0.24330)*(sdfrst) + (-0.03426)*(smd)  ) + (1/1.00507)  *  (  (-0.06094)*(sco2)
(0.41050)*(sbod)  + (-0.06293)*(scomen) + (0.04509)*(sdfrst) + (0.90652)*(smd) )

. edit sc(3)96
```

1997

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                 (principal components; 5 components retained)
Component     Eigenvalue      Difference     Proportion     Cumulative
------------------------------------------------------------------
     1          1.61854         0.36764       0.3237          0.3237
     2          1.25090         0.23803       0.2502          0.5739
     3          1.01287         0.11150       0.2026          0.7765
     4          0.90137         0.68504       0.1803          0.9567
     5          0.21633               .       0.0433          1.0000

               Eigenvectors
 Variable |      1          2          3          4          5
----------+------------------------------------------------------
      co2 |  -0.33037    0.76237   -0.16821    0.09956    0.52100
      bod |   0.17200    0.40662    0.59423   -0.65049   -0.16978
    comen |   0.52678    0.49179   -0.18843    0.41161   -0.52509
   dfrstn |   0.73027   -0.10751    0.15022    0.09318    0.65108
       md |  -0.22468   -0.00610    0.74868    0.62357   -0.01098
```

```
. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)97  =  (1/1.61854)  *  (  (-0.33037)*(sco2)  +  (0.17200)*(sbod)  +  (0.52678)*(scomen)
(0.73027)*(sdfrst)  +  (-0.22468)*(smd)  )  +  (1/1.25090)  *  (  (0.76237)*(sco2)  +  (0.40662)*(sbod
(0.49179)*(scomen)  +  (-0.10751)*(sdfrst)  +  (-0.00610)*(smd)  )  +  (1/1.01287)  *  (  (-0.16821)*(sco2
(0.59423)*(sbod)  +  (-0.18843)*(scomen)  +  (0.15022)*(sdfrst)  +  (0.74868)*(smd)  )

. edit sc(3)97
```

1998

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
                    (principal components; 5 components retained)
Component     Eigenvalue     Difference     Proportion     Cumulative
------------------------------------------------------------------
     1          1.59398        0.30404        0.3188          0.3188
     2          1.28994        0.23594        0.2580          0.5768
     3          1.05400        0.19622        0.2108          0.7876
     4          0.85778        0.65347        0.1716          0.9591
     5          0.20431              .        0.0409          1.0000

                 Eigenvectors
 Variable |        1           2           3           4           5
----------+-------------------------------------------------------
      co2 |  -0.28054     0.78341    -0.11171     0.12020     0.52976
      bod |   0.14538     0.34136     0.67714    -0.61879    -0.14462
    comen |   0.55456     0.48413    -0.11589     0.39595    -0.53654
   dfrstn |   0.73258    -0.16396     0.13808     0.08303     0.64069
       md |  -0.23654    -0.09208     0.70463     0.66256     0.00918


. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)98  =  (1/1.59398)  *  (  (-0.28054)*(sco2)  +  (0.14538)*(sbod)  +  (0.55456)*(scomen)
(0.73258)*(sdfrst)  +  (-0.23654)*(smd)  )  +  (1/1.28994)  *  (  (0.78341)*(sco2)  +  (0.34136)*(sbod)
(0.48413)*(scomen)  +  (-0.16396)*(sdfrst)  +  (-0.09208)*(smd)  )  +  (1/1.05400)  *  (  (-0.11171)*(sco2)
(0.67714)*(sbod)  +  (-0.11589)*(scomen)  +  (0.13808)*(sdfrst)  +  (0.70463)*(smd)  )

. edit sc(3)98
```

1999

```
. factor  co2 bod comen dfrstn md, pc
(obs=35)
            (principal components; 5 components retained)
Component    Eigenvalue      Difference     Proportion    Cumulative
------------------------------------------------------------------
      1       1.58382         0.26046        0.3168         0.3168
      2       1.32337         0.30438        0.2647         0.5814
      3       1.01898         0.13439        0.2038         0.7852
      4       0.88459         0.69535        0.1769         0.9622
      5       0.18924               .        0.0378         1.0000

             Eigenvectors
 Variable |       1          2          3          4          5
----------+-----------------------------------------------------
      co2 |  -0.20552    0.79842   -0.12387    0.15239    0.53077
      bod |   0.14836    0.34127    0.65993   -0.64202   -0.11757
    comen |   0.59184    0.43429   -0.08233    0.38439   -0.55370
   dfrstn |   0.72438   -0.22568    0.14278    0.07871    0.63068
       md |  -0.24647   -0.08075    0.72248    0.64081    0.01066


. egen sco2=std(co2)

. egen sbod=std(bod)

. egen scomen=std(comen)

. egen sdfrst=std(dfrstn)

. egen smd=std(md)

.  gen  sc(3)99  =  (1/1.58382)  *  (  (-0.20552)*(sco2)  +  (0.14836)*(sbod)  +  (0.59184)*(scomen)
(0.72438)*(sdfrst)  +  (-0.24647)*(smd)  )  +  (1/1.32337)  *  (  (0.79842)*(sco2)  +  (0.34127)*(sbod)
(0.43429)*(scomen)  +  (-0.22568)*(sdfrst)  +  (-0.08075)*(smd)  )  +  (1/1.01898)  *  (  (-0.12387)*(sco2
(0.65993)*(sbod)  +  (-0.08233)*(scomen)  +  (0.14278)*(sdfrst)  +  (0.72248)*(smd)  )

. edit sc(3)99
```

Appendix to chapter 4

• 4(B) *Regressions on the index of Environmental quality*

4(B)(a)

```
. xtgls index openness cy_d2-cy_d35 yr_d2-yr_d20, p(h)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic
Correlation:   no autocorrelation

Estimated covariances      =        35     Number of obs      =       700
Estimated autocorrelations =         0     Number of groups   =        35
Estimated coefficients     =        55     No. of time periods=        20
                                           Wald chi2(54)      =   4490.87
Log likelihood             = -295.1056     Pr > chi2          =    0.0000

------------------------------------------------------------------------------
   index |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
openness |  -.8616867   .0551046    -15.637   0.000      -.9696897   -.7536837
   cy_d2 |  -1.104153   .0842481    -13.106   0.000      -1.269276   -.9390294
   cy_d3 |  -.3884332   .1091881     -3.557   0.000      -.6024379   -.1744284
   cy_d4 |   .3845569   .0870621      4.417   0.000       .2139184    .5551954
   cy_d5 |    3.73709   .2900065     12.886   0.000       3.168687    4.305492
   cy_d6 |   4.537681   .1615201     28.094   0.000       4.221108    4.854255
   cy_d7 |  -1.028267   .0791742    -12.987   0.000      -1.183445    -.873088
   cy_d8 |   .8693262   .0918985      9.460   0.000       .6892086    1.049444
   cy_d9 |   1.281836   .2597363      4.935   0.000       .7727619    1.790909
  cy_d10 |  -.7970933   .0691802    -11.522   0.000      -.9326841   -.6615026
  cy_d11 |    .212585   .1136413      1.871   0.061      -.0101478    .4353178
  cy_d12 |    .474983   .1050079      4.523   0.000       .2691712    .6807948
  cy_d13 |   .7680273   .1002588      7.660   0.000       .5715236     .964531
  cy_d14 |   .8245823   .1471812      5.602   0.000       .5361124    1.113052
  cy_d15 |  -.1503522   .1159788     -1.296   0.195      -.3776665    .0769622
  cy_d16 |  -1.254103   .0757075    -16.565   0.000      -1.402487   -1.105719
  cy_d17 |  -1.060841   .0746015    -14.220   0.000      -1.207057   -.9146246
  cy_d18 |   2.605276   .2416722     10.780   0.000       2.131608    3.078945
  cy_d19 |   -.013107   .0766087     -0.171   0.864      -.1632572    .1370433
  cy_d20 |   1.535337   .1512591     10.150   0.000       1.238875      1.8318
  cy_d21 |  -.7980247   .0771669    -10.342   0.000      -.9492691   -.6467803
  cy_d22 |  -.0734607    .094377     -0.778   0.436      -.2584362    .1115148
  cy_d23 |   2.566679   .3265715      7.859   0.000       1.926611    3.206748
  cy_d24 |   1.855153   .4508194      4.115   0.000        .971563    2.738742
  cy_d25 |  -.1663136   .0701273     -2.372   0.018      -.3037606   -.0288666
  cy_d26 |  -.1980165   .0854656     -2.317   0.021       -.365526    -.030507
  cy_d27 |    .462892   .2721474      1.701   0.089      -.0705072    .9962911
  cy_d28 |   .0808152   .1204565      0.671   0.502      -.1552752    .3169056
  cy_d29 |   2.030403   .2276682      8.918   0.000       1.584181    2.476624
  cy_d30 |  -.7923035   .0641797    -12.345   0.000      -.9180934   -.6665137
  cy_d31 |   .7678703   .1846035      4.160   0.000       .4060541    1.129687
  cy_d32 |   .7333031   .1433516      5.115   0.000       .4523391    1.014267
  cy_d33 |  -.3739575   .0745029     -5.019   0.000      -.5199804   -.2279345
```

```
    cy_d34 |  -.4784841   .0888415     -5.386   0.000      -.6526102   -.3043579
    cy_d35 |   1.303835   .2203655      5.917   0.000        .871927    1.735744
     yr_d2 |   -.085847   .0572818     -1.499   0.134      -.1981172    .0264232
     yr_d3 |  -.1581445    .057283     -2.761   0.006       -.270417   -.0458719
     yr_d4 |  -.1066885   .0572817     -1.863   0.063      -.2189586    .0055815
     yr_d5 |  -.0736849   .0572851     -1.286   0.198      -.1859616    .0385918
     yr_d6 |   .0477989   .0572901      0.834   0.404      -.0644877    .1600855
     yr_d7 |  -.0179354   .0572922     -0.313   0.754       -.130226    .0943552
     yr_d8 |    .054148   .0573237      0.945   0.345      -.0582044    .1665003
     yr_d9 |   .1460155    .057392      2.544   0.011       .0335294    .2585017
    yr_d10 |   .0738319   .0574716      1.285   0.199      -.0388104    .1864742
    yr_d11 |   .0050501   .0575433      0.088   0.930      -.1077328    .1178329
    yr_d12 |   .0155168   .0576783      0.269   0.788      -.0975306    .1285642
    yr_d13 |   .0355784   .0579114      0.614   0.539      -.0779258    .1490826
    yr_d14 |  -.0473059   .0580464     -0.815   0.415      -.1610747    .0664628
    yr_d15 |  -.0192746   .0583719     -0.330   0.741      -.1336814    .0951322
    yr_d16 |   .0150928   .0588086      0.257   0.797      -.1001698    .1303555
    yr_d17 |   .0196748   .0590543      0.333   0.739      -.0960695    .1354191
    yr_d18 |   .0767804   .0595436      1.289   0.197      -.0399228    .1934836
    yr_d19 |   .0717113   .0597893      1.199   0.230      -.0454736    .1888962
    yr_d20 |   .1002218   .0600792      1.668   0.095      -.0175312    .2179748
     _cons |  -.0766636    .077547     -0.989   0.323       -.228653    .0753258
------------------------------------------------------------------------------
```

4(B) (b)

```
. xtgls index openness p_pcgdp cy_d2-cy_d35 yr_d2-yr_d20, corr(ar1) p(h)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic
Correlation:   common AR(1) coefficient for all panels  (0.7004)

Estimated covariances      =        35          Number of obs      =       700
Estimated autocorrelations =         1          Number of groups   =        35
Estimated coefficients     =        56          No. of time periods=        20
                                                Wald chi2(55)      =   1139.22
Log likelihood             = -8.480878          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
     index |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
  openness |  -.6245696   .1093802     -5.710   0.000      -.8389509   -.4101883
   p_pcgdp |  -.0000449   .0000125     -3.597   0.000      -.0000694   -.0000204
     cy_d2 |   -.714785   .1644526     -4.346   0.000      -1.037106   -.3924639
     cy_d3 |   -.220963   .2114207     -1.045   0.296      -.6353399    .1934139
     cy_d4 |   1.210258    .287508      4.209   0.000        .646753    1.773764
     cy_d5 |   3.582949   .5732166      6.251   0.000       2.459465    4.706433
     cy_d6 |   4.499823   .4811836      9.352   0.000       3.556721    5.442926
     cy_d7 |  -.9042172   .1468521     -6.157   0.000      -1.192042   -.6163924
     cy_d8 |   .8557273    .174234      4.911   0.000        .514235     1.19722
     cy_d9 |   1.122246   .6494137      1.728   0.084       -.150582    2.395073
    cy_d10 |  -.0502035   .2250091     -0.223   0.823      -.4912133    .3908063
    cy_d11 |   .1754499   .2715781      0.646   0.518      -.3568335    .7077332
    cy_d12 |    .705341   .2213377      3.187   0.001       .2715271    1.139155
    cy_d13 |    .778384   .1846231      4.216   0.000       .4165294    1.140239
```

```
     cy_d14 |   .7666739   .2589154      2.961   0.003       .2592091    1.274139
     cy_d15 |  -.1313349   .2083647     -0.630   0.528      -.5397221    .2770524
     cy_d16 |  -.5485134   .2211773     -2.480   0.013       -.982013   -.1150138
     cy_d17 |  -.2038417   .2511753     -0.812   0.417      -.6961362    .2884528
     cy_d18 |   2.604452   .3983696      6.538   0.000       1.823662    3.385242
     cy_d19 |   .2716731   .1814424      1.497   0.134      -.0839475    .6272937
     cy_d20 |   1.522393    .226256      6.729   0.000       1.078939    1.965846
     cy_d21 |  -.6230049   .1392226     -4.475   0.000      -.8958762   -.3501335
     cy_d22 |  -.0874159   .2731965     -0.320   0.749      -.6228712    .4480394
     cy_d23 |   2.025804   .5360725      3.779   0.000        .975121    3.076487
     cy_d24 |   2.029708   .8007845      2.535   0.011       .4601992    3.599217
     cy_d25 |   .4231563   .2080692      2.034   0.042       .0153482    .8309644
     cy_d26 |  -.2034045   .1555094     -1.308   0.191      -.5081973    .1013884
     cy_d27 |   .4731113   .5591912      0.846   0.398      -.6228834    1.569106
     cy_d28 |    .124146   .2722105      0.456   0.648      -.4093767    .6576687
     cy_d29 |   2.462864    .630669      3.905   0.000       1.226775    3.698952
     cy_d30 |  -.2800735   .1708731     -1.639   0.101      -.6149787    .0548316
     cy_d31 |   .6993344   .3811107      1.835   0.067      -.0476288    1.446298
     cy_d32 |   .6623243   .3020493      2.193   0.028       .0703185     1.25433
     cy_d33 |   .2733671   .2180633      1.254   0.210      -.1540292    .7007634
     cy_d34 |   .5936514   .3431944      1.730   0.084      -.0789972      1.2663
     cy_d35 |    1.44109   .3906201      3.689   0.000       .6754888    2.206692
      yr_d2 |  -.0764649   .0291928     -2.619   0.009      -.1336817   -.0192481
      yr_d3 |  -.1275986   .0381196     -3.347   0.001      -.2023116   -.0528856
      yr_d4 |  -.0612201   .0433893     -1.411   0.158      -.1462615    .0238213
      yr_d5 |  -.0208751   .0470211     -0.444   0.657      -.1130348    .0712847
      yr_d6 |   .0724859   .0495639      1.462   0.144      -.0246576    .1696295
      yr_d7 |   .0383754   .0519452      0.739   0.460      -.0634353    .1401861
      yr_d8 |   .1389219   .0543399      2.557   0.011       .0324177    .2454261
      yr_d9 |   .2330942    .057224      4.073   0.000       .1209372    .3452512
     yr_d10 |   .1704728   .0596946      2.856   0.004       .0534735    .2874721
     yr_d11 |   .1315721   .0621738      2.116   0.034       .0097137    .2534304
     yr_d12 |   .1435954   .0641958      2.237   0.025        .017774    .2694169
     yr_d13 |   .1558971   .0657163      2.372   0.018       .0270956    .2846987
     yr_d14 |   .0416337   .0659106      0.632   0.528      -.0875487    .1708161
     yr_d15 |   .0718376   .0682299      1.053   0.292      -.0618906    .2055659
     yr_d16 |   .1006965   .0699264      1.440   0.150      -.0363568    .2377497
     yr_d17 |   .1254509   .0729998      1.719   0.086      -.0176262    .2685279
     yr_d18 |   .1827653   .0763197      2.395   0.017       .0331814    .3323492
     yr_d19 |   .1834094   .0774935      2.367   0.018       .0315249    .3352938
     yr_d20 |   .2188461   .0798966      2.739   0.006       .0622517    .3754405
      _cons |  -.1134022   .1246556     -0.910   0.363      -.3577228    .1309183
------------------------------------------------------------------------------
```

4 (B) (c)

```
.xtgls index openness p_pcgdp urbnsn cy_d2-cy_d35 yr_d2-yr_d20, corr(ar1) p(h)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic
Correlation:   common AR(1) coefficient for all panels  (0.6966)

Estimated covariances      =        35         Number of obs      =       700
Estimated autocorrelations =         1         Number of groups   =        35
Estimated coefficients     =        57         No. of time periods=        20
                                               Wald chi2(56)      =   1180.45
Log likelihood             = -5.137286         Pr > chi2          =    0.0000

------------------------------------------------------------------------------
   index |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
openness |  -.6837044   .1095903     -6.239   0.000      -.8984974   -.4689113
 p_pcgdp |  -.0000357   .0000131     -2.727   0.006      -.0000613     -.00001
  urbnsn |   .0228269   .0095679      2.386   0.017       .0040741    .0415796
   cy_d2 |  -1.585841   .3990856     -3.974   0.000      -2.368034   -.8036472
   cy_d3 |  -.7693812   .3103497     -2.479   0.013      -1.377655    -.161107
   cy_d4 |   .4838748   .4196667      1.153   0.249       -.338657    1.306406
   cy_d5 |   2.848571   .6464825      4.406   0.000       1.581489    4.115653
   cy_d6 |   5.101389   .5375461      9.490   0.000       4.047818     6.15496
   cy_d7 |  -1.321298    .224931     -5.874   0.000      -1.762154   -.8804413
   cy_d8 |   1.043014   .1917312      5.440   0.000       .6672275      1.4188
   cy_d9 |   2.022249   .7451856      2.714   0.007        .561712    3.482786
  cy_d10 |  -.7126009   .3575756     -1.993   0.046      -1.413436   -.0117656
  cy_d11 |   .6083526   .3232179      1.882   0.060      -.0251428    1.241848
  cy_d12 |  -.3510425    .496806     -0.707   0.480      -1.324764    .6226793
  cy_d13 |    1.38376   .3119536      4.436   0.000       .7723427    1.995178
  cy_d14 |   1.269901   .3268439      3.885   0.000       .6292984    1.910503
  cy_d15 |  -.2273753   .2068639     -1.099   0.272      -.6328212    .1780706
  cy_d16 |  -1.032755    .299187     -3.452   0.001       -1.61915   -.4463591
  cy_d17 |  -.9642691   .4063783     -2.373   0.018      -1.760756   -.1677823
  cy_d18 |   3.270662     .48084      6.802   0.000       2.328233    4.213091
  cy_d19 |    -.21091     .26746     -0.789   0.430       -.735122    .3133019
  cy_d20 |    1.61073   .2236452      7.202   0.000       1.172393    2.049066
  cy_d21 |  -1.098133   .2401617     -4.572   0.000      -1.568841   -.6274244
  cy_d22 |   .0068141   .2713395      0.025   0.980      -.5250015    .5386297
  cy_d23 |   2.659939   .5988781      4.442   0.000       1.486159    3.833719
  cy_d24 |   3.026096   .8957843      3.378   0.001       1.270391    4.781801
  cy_d25 |  -.5346662   .4542758     -1.177   0.239       -1.42503     .355698
  cy_d26 |   .2635877   .2484616      1.061   0.289      -.2233882    .7505636
  cy_d27 |   .0708648   .5772255      0.123   0.902      -1.060476    1.202206
  cy_d28 |   .2214238   .2776947      0.797   0.425      -.3228478    .7656953
  cy_d29 |   2.470431   .6198358      3.986   0.000       1.255575    3.685287
  cy_d30 |   -.914445   .3155301     -2.898   0.004      -1.532873   -.2960173
  cy_d31 |   1.412017   .4801541      2.941   0.003       .4709319    2.353101
  cy_d32 |   .7193425   .2995396      2.401   0.016       .1322556    1.306429
  cy_d33 |  -.7063665   .4656672     -1.517   0.129      -1.619058    .2063245
  cy_d34 |  -.1623228   .4676262     -0.347   0.729      -1.078853    .7542077
  cy_d35 |   .6980349   .4971262      1.404   0.160      -.2763144    1.672384
   yr_d2 |  -.0826608   .0293558     -2.816   0.005       -.140197   -.0251246
   yr_d3 |  -.1405728   .0385957     -3.642   0.000      -.2162189   -.0649267
```

```
    yr_d4 |  -.0821584   .0443637    -1.852   0.064      -.1691096    .0047929
    yr_d5 |  -.0505264   .0487357    -1.037   0.300      -.1460466    .0449938
    yr_d6 |   .0334763   .0521355     0.642   0.521      -.0687075      .13566
    yr_d7 |  -.0098285   .0558713    -0.176   0.860      -.1193342    .0996772
    yr_d8 |   .0805198   .0597891     1.347   0.178      -.0366646    .1977042
    yr_d9 |   .1635122    .064384     2.540   0.011       .0373219    .2897025
   yr_d10 |   .0907239   .0684868     1.325   0.185      -.0435078    .2249556
   yr_d11 |   .0426481   .0726797     0.587   0.557      -.0998015    .1850976
   yr_d12 |   .0473774   .0759697     0.624   0.533      -.1015205    .1962753
   yr_d13 |   .0543552   .0786254     0.691   0.489      -.0997477    .2084581
   yr_d14 |  -.0657359   .0799453    -0.822   0.411      -.2224259    .0909541
   yr_d15 |  -.0426114   .0835005    -0.510   0.610      -.2062694    .1210467
   yr_d16 |  -.0195197   .0862411    -0.226   0.821      -.1885492    .1495098
   yr_d17 |  -.0040623   .0907834    -0.045   0.964      -.1819945    .1738698
   yr_d18 |     .04516   .0953661     0.474   0.636      -.1417542    .2320741
   yr_d19 |   .0400923    .097813     0.410   0.682      -.1516176    .2318022
   yr_d20 |   .0672022   .1016796     0.661   0.509      -.1320861    .2664905
    _cons |  -1.225435   .4830306    -2.537   0.011      -2.172157    -.278712
------------------------------------------------------------------------------
```

4 (B) (d)

```
.xtgls index openness p_pcgdp urbnsn debt cy_d2-cy_d35 yr_d2-yr_d20,
panels(correlated) corr(psar1)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   panel-specific AR(1)

Estimated covariances      =       630          Number of obs      =       700
Estimated autocorrelations =        35          Number of groups   =        35
Estimated coefficients     =        58          No. of time periods=        20
                                                Wald chi2(42)      =  12360.71
Log likelihood             =  5275.849          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
   index |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
openness |  -.8219902   .1051535    -7.817   0.000      -1.028087   -.6158931
 p_pcgdp |  -.0000463   .0000167    -2.768   0.006      -.0000791   -.0000135
  urbnsn |   .0437294   .0108808     4.019   0.000       .0224035    .0650553
    debt |  -.0082767   .0005089   -16.265   0.000       -.009274   -.0072793
   cy_d2 |  -2.159159   .4679437    -4.614   0.000      -3.076312   -1.242006
   cy_d3 |  -1.114023   .3700971    -3.010   0.003        -1.8394   -.3886461
   cy_d4 |  (dropped)
   cy_d5 |   2.138349   .6937421     3.082   0.002       .7786396    3.498059
   cy_d6 |   5.292794   .3147198    16.817   0.000       4.675954    5.909633
   cy_d7 |  -1.786051   .2611297    -6.840   0.000      -2.297856   -1.274246
   cy_d8 |    .974746   .1952142     4.993   0.000       .5921332    1.357359
   cy_d9 |   2.671082   .5983569     4.464   0.000       1.498324     3.84384
  cy_d10 |  (dropped)
  cy_d11 |    .805229   .3249513     2.478   0.013       .1683361    1.442122
  cy_d12 |  (dropped)
  cy_d13 |    1.67525   .3983671     4.205   0.000       .8944647    2.456035
  cy_d14 |    1.58343   .3614391     4.381   0.000       .8750222    2.291837
```

```
    cy_d15 |  (dropped)
    cy_d16 |  (dropped)
    cy_d17 |  (dropped)
    cy_d18 |   4.122123   .7535144      5.471   0.000       2.645262    5.598985
    cy_d19 |  (dropped)
    cy_d20 |  (dropped)
    cy_d21 |  (dropped)
    cy_d22 |  -.0166861   .1731256     -0.096   0.923      -.3560061    .3226339
    cy_d23 |   2.092281   .8047379      2.600   0.009       .5150232    3.669538
    cy_d24 |   3.551799   1.071581      3.315   0.001       1.451538    5.652059
    cy_d25 |  (dropped)
    cy_d26 |  (dropped)
    cy_d27 |  -.5862723   .4996024     -1.173   0.241      -1.565475    .3929305
    cy_d28 |  (dropped)
    cy_d29 |   2.227077   .2840187      7.841   0.000        1.67041    2.783743
    cy_d30 |  (dropped)
    cy_d31 |   1.816229   .5413488      3.355   0.001       .7552043    2.877253
    cy_d32 |   .4753326   .2182351      2.178   0.029       .0475997    .9030655
    cy_d33 |  (dropped)
    cy_d34 |  (dropped)
    cy_d35 |   .1086173   .6330291      0.172   0.864      -1.132097    1.349332
     yr_d2 |  -.0239519   .0144901     -1.653   0.098       -.052352    .0044482
     yr_d3 |  -.0465374   .0218155     -2.133   0.033       -.089295   -.0037798
     yr_d4 |  -.0831676   .0275439     -3.019   0.003      -.1371526   -.0291826
     yr_d5 |  -.0858907   .0313221     -2.742   0.006      -.1472809   -.0245005
     yr_d6 |  -.1562696   .0357535     -4.371   0.000      -.2263452   -.0861941
     yr_d7 |  -.1779206    .040891     -4.351   0.000      -.2580654   -.0977757
     yr_d8 |  -.1904555   .0447586     -4.255   0.000      -.2781808   -.1027303
     yr_d9 |  -.2091476    .048739     -4.291   0.000      -.3046743   -.1136209
    yr_d10 |  -.2285579    .052226     -4.376   0.000       -.330919   -.1261967
    yr_d11 |  -.2895014   .0566496     -5.110   0.000      -.4005326   -.1784701
    yr_d12 |  -.2767881   .0609823     -4.539   0.000      -.3963113    -.157265
    yr_d13 |  -.2519014   .0655905     -3.841   0.000      -.3804564   -.1233464
    yr_d14 |  -.2265108   .0699918     -3.236   0.001      -.3636922   -.0893293
    yr_d15 |  -.2377655   .0742488     -3.202   0.001      -.3832905   -.0922405
    yr_d16 |   -.230045   .0786345     -2.925   0.003      -.3841658   -.0759243
    yr_d17 |  -.2198849   .0828408     -2.654   0.008      -.3822499     -.05752
    yr_d18 |  -.2212806    .087632     -2.525   0.012       -.393036   -.0495251
    yr_d19 |  -.2201865   .0920761     -2.391   0.017      -.4006543   -.0397227
    yr_d20 |  -.2074495   .0948639     -2.187   0.029      -.3933794   -.0215197
     _cons |   -1.64387    .570479     -2.882   0.004      -2.761988   -.5257516
------------------------------------------------------------------------------
Note: You estimated at least as many quantities as you have observations.
```

4(B)(e)

```
. xtgls index openness p_pcgdp urbnsn debt ind_va cy_d2-cy_d35 yr_d2-yr_d20,
panels(correlated) corr(psar1)

Cross-sectional time-series FGLS regression

Coefficients:  generalized least squares
Panels:        heteroscedastic with cross-sectional correlation
Correlation:   panel-specific AR(1)

Estimated covariances      =       630          Number of obs      =       700
Estimated autocorrelations =        35          Number of groups   =        35
Estimated coefficients     =        59          No. of time periods=        20
                                                Wald chi2(43)      =  30912.60
Log likelihood             =  5283.714          Pr > chi2          =    0.0000

------------------------------------------------------------------------------
   index |      Coef.   Std. Err.       z     P>|z|       [95% Conf. Interval]
---------+--------------------------------------------------------------------
openness |  -.8721818   .0895206     -9.743   0.000      -1.047639   -.6967246
 p_pcgdp |  -.0000388   .0000136     -2.843   0.004      -.0000655    -.000012
  urbnsn |   .0440255   .0067229      6.549   0.000       .0308488    .0572021
    debt |   -.009035    .000448    -20.169   0.000       -.009913    -.008157
  ind_va |  -.0019136   .0017691     -1.082   0.279      -.0053809    .0015537
   cy_d2 |  -2.292948   .3651369     -6.280   0.000      -3.008604   -1.577293
   cy_d3 |  -1.203529   .3310639     -3.635   0.000      -1.852402   -.5546559
   cy_d4 |  (dropped)
   cy_d5 |   2.090844   .6405359      3.264   0.001       .8354172    3.346272
   cy_d6 |    5.28607   .2302202     22.961   0.000       4.834846    5.737293
   cy_d7 |  (dropped)
   cy_d8 |   .9314484   .1839475      5.064   0.000        .570918    1.291979
   cy_d9 |   2.514296   .4034588      6.232   0.000       1.723531     3.30506
  cy_d10 |  (dropped)
  cy_d11 |   .7213819   .2545974      2.833   0.005       .2223801    1.220384
  cy_d12 |  (dropped)
  cy_d13 |   1.599428   .2812843      5.686   0.000       1.048121    2.150735
  cy_d14 |   1.591681   .3322198      4.791   0.000       .9405421     2.24282
  cy_d15 |  (dropped)
  cy_d16 |  (dropped)
  cy_d17 |  (dropped)
  cy_d18 |   3.935632    .594297      6.622   0.000       2.770831    5.100433
  cy_d19 |  (dropped)
  cy_d20 |  (dropped)
  cy_d21 |  (dropped)
  cy_d22 |  -.0793576   .1453022     -0.546   0.585      -.3641447    .2054295
  cy_d23 |   2.119579   .7522545      2.818   0.005        .645187     3.59397
  cy_d24 |   3.392059   .8650987      3.921   0.000       1.696497    5.087621
  cy_d25 |  (dropped)
  cy_d26 |  (dropped)
  cy_d27 |  -.5942291   .4769172     -1.246   0.213       -1.52897    .3405114
  cy_d28 |   .0839241   .3351655      0.250   0.802      -.5729881    .7408364
  cy_d29 |   2.139057   .2777179      7.702   0.000        1.59474    2.683374
  cy_d30 |  (dropped)
  cy_d31 |   1.726137    .404482      4.268   0.000       .9333672    2.518907
  cy_d32 |   .4330158   .2159977      2.005   0.045       .0096681    .8563635
  cy_d33 |  (dropped)
  cy_d34 |  (dropped)
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  cy_d35 |   .0750569   .4825216      0.156   0.876      -.870668    1.020782
   yr_d2 |  -.0236835   .0175775     -1.347   0.178     -.0581348    .0107678
   yr_d3 |  -.0537212   .0248349     -2.163   0.031     -.1023967   -.0050457
   yr_d4 |  -.0779677   .0293721     -2.654   0.008      -.135536   -.0203994
   yr_d5 |  -.0688511   .0316715     -2.174   0.030     -.1309261    -.006776
   yr_d6 |   -.136135   .0339274     -4.013   0.000     -.2026315   -.0696385
   yr_d7 |  -.1577073   .0369992     -4.262   0.000     -.2302244   -.0851902
   yr_d8 |  -.1883074   .0386828     -4.868   0.000     -.2641243   -.1124905
   yr_d9 |  -.2226152   .0410855     -5.418   0.000     -.3031413   -.1420892
  yr_d10 |  -.2461865   .0430939     -5.713   0.000     -.3306491   -.1617239
  yr_d11 |  -.2932572   .0455008     -6.445   0.000     -.3824371   -.2040773
  yr_d12 |  -.2897921   .0480853     -6.027   0.000     -.3840375   -.1955467
  yr_d13 |  -.2851376   .0510182     -5.589   0.000     -.3851314   -.1851438
  yr_d14 |  -.2352955   .0543162     -4.332   0.000     -.3417533   -.1288376
  yr_d15 |  -.2595059   .0569903     -4.554   0.000     -.3712048   -.1478071
  yr_d16 |  -.2481012   .0601888     -4.122   0.000      -.366069   -.1301334
  yr_d17 |  -.2478201    .063411     -3.908   0.000     -.3721034   -.1235367
  yr_d18 |  -.2448457   .0666272     -3.675   0.000     -.3754326   -.1142589
  yr_d19 |   -.239393   .0700055     -3.420   0.001     -.3766013   -.1021848
  yr_d20 |  -.2277432    .072132     -3.157   0.002     -.3691192   -.0863671
   _cons |  -1.513767   .3744199     -4.043   0.000     -2.247617   -.7799178
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Note: You estimated at least as many quantities as you have observations.
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