Cole, Matthew A. (1998) Trade liberalisation, economic growth and the environment. PhD thesis, University of Nottingham.

TRADE LIBERALISATION, ECONOMIC GROWTH AND THE ENVIRONMENT

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Thesis submitted to the University of Nottingham
for the degree of Doctor of Philosophy, June 1998

Acknowledgement.

I would like to thank Prof. Tony Rayner, Mr. John Bates and Mr. Ken Ingersent for their invaluable advice and guidance throughout this research. I would also like to thank Mr. Geoff Reed and Prof. R. Kerry Turner for their helpful comments.

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Abstract.

This thesis analyses and quantifies the environmental impacts of trade liberalisation and economic growth. The history and development of the GATT/WTO's treatment of the environment is considered, together with the environmental implications of trade liberalisation in general.

The thesis then considers the relationship between economic growth and the environment, particularly since economic growth is often claimed to be an environmentally damaging feature of trade liberalisation. The manner in which economists have treated the relationship between economic growth and the environment is examined and the relationship is then subjected to an empirical investigation. The thesis estimates the reduced form relationship between per capita GDP and a wide range of environmental indicators, using cross-country panel data sets and improves on the traditional methodology for estimating environmental Kuznets curves (EKCs). Results suggest that meaningful EKCs exist only for local air pollutants whilst indicators with a more global, or indirect, impact either increase monotonically with income, or else have predicted turning points at high per capita income levels with large standard errors - unless they have been subjected to a multilateral policy initiative. Two other findings are also made; that concentrations of local pollutants in urban areas peak at a lower per capita income level than total emissions per capita; and that transport generated local air pollutants peak at a higher per capita income level than total emissions per capita.

The thesis also estimates the impact of the Uruguay Round of trade negotiations on a wide range of environmental indicators. The impact is estimated in terms of the composition effect and combined scale and technique effects associated with the Uruguay Round. Results suggest that in the developing and transition regions most indicators will increase as a

CHAPTER 1.

INTRODUCTION.

This thesis examines and quantifies the various ways in which trade liberalisation, particularly that originating from the Uruguay Round of trade negotiations, can affect the environment. In addition, the environmental impact of economic growth is analysed and quantified, including the growth which stems directly from the Uruguay Round.

The recent increase in the public awareness of environmental issues has coincided with a change in the nature of these issues. In the late 1960s and early 1970s the predominant concern was the depletion of the world's stock of non-renewable resources.[1] However, for today's environmentalists it is the earth's ability to assimilate growing levels of pollutants which is the primary concern and issues such as the depletion of the ozone layer and the build up of greenhouse gases are now high on the political agenda. This recognition that many current environmental problems have transborder features, and thus may be global in nature, has meant that global activities such as world trade have been increasingly linked to such problems - both as a possible cause of them and as a means to remedy them.

There are, however, two other factors which have brought the relationship between trade and the environment to public prominence. The first of these was the announcement by the US government in late 1990 of plans to sign a trade agreement with Mexico and Canada, since known as the North American Free Trade Agreement (NAFTA). Many environmentalists were alarmed at the possible ecological consequences of America, a country with relatively high environmental standards, trading freely with Mexico, a

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[1] The depletion of fossil fuels remains a secondary concern. The United Nations Environment Programme estimates that at current levels of utilisation, known reserves of oil will last 40 years, gas 60 years and coal 200 years (UNEP (1993)).

country with negligible standards. It was feared that an agreement of this nature would seriously hamper the ability of the US to implement environmental protection laws, as well as putting the US at a competitive disadvantage. Such alarm was heightened by Presidential candidate Ross Perot who dwelt on the possible consequences to the US workforce if fierce competition forced American firms to relocate in Mexico due to the latter's low environmental standards.

The second event responsible for raising public awareness of the links between trade and the environment was the result of a 1991 GATT dispute panel on tuna trade between Mexico and the US. In 1988, in accordance with the US Marine Mammal Protection Act, the US banned the importation of Mexican tuna which was being caught in drift nets and, as a result, killing many dolphins in the eastern Pacific Ocean. However, the GATT dispute panel judged that the US import ban inappropriately discriminated against Mexican tuna and, as a result, violated GATT's 'national treatment' provision as set out in Article III. As Dunoff (1992) states, "Article III requires a comparison between products of the exporting and importing nations, and not a comparison between different nations' production processes that have no effect on the product *qua* product." (Dunoff (1992) pp.1407-1454). These findings, as Esty (1994) points out, effectively prohibit unilateral trade actions aimed at reducing extraterritorial environmental damage and seem indicative, to many, of GATT's inability to deal with trade-environment conflicts in a balanced manner. Perhaps not surprisingly, the decision caused outrage amongst environmental groups the world over and many became convinced that GATT was inherently anti-environmental. The newly formed World Trade Organisation, which contains all those nations who accept the full Uruguay Round Agreement, at least addresses the environmental impact of trade liberalisation, something the GATT did not do.[2] However,

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[2] For example, the WTO has created a Committee on Trade and the Environment.

environmentalists still claim there to be little evidence of any real commitment in this direction.

A key objective of the liberalisation of international trade is the generation of economic growth. Indeed, most economists claim that the removal of tariff and non-tariff barriers will provide nations with greater market access which will, in turn, lead to an increase in GDP. This therefore introduces the second key theme of the thesis - the relationship between economic growth and the environment. In contrast to the study of trade liberalisation and the environment, the roots of the economic growth and the environment debate can be traced back several centuries. Indeed, many classical economists of the eighteenth and nineteenth centuries stressed the existence of possible limits to human activity.[3] This link between the environment and economic growth was generally neglected by neoclassical economics and it was not until the 'limits to growth' debates of the 1960s and 70s that the issue really caught the public imagination. Those who believed in the existence of environmental limits to economic growth stressed the possibility of natural resource exhaustion and the limited ability of the environment to assimilate pollution. Those opposed to this position pointed to our ability to overcome such limits using technological advance, changes in the composition of production and resource substitution.

In the 1980s the 'limits to growth' debate was replaced by the notion of sustainable development - a notion in which the precise relationship between economic growth and environmental well-being remains uncertain. The mainstream ('weak') interpretation of sustainable development, as provided, for example, by the Brundtland Report (WCED (1987)), still believes growth and environmental health to be complementary, thus illustrating the 'limits to growth' debate's failure to

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[3] See, for example, Thomas Malthus (1970), written in 1798, or John Stuart Mill (1871), written in 1848.

challenge the orthodoxy. Proponents point to evidence which suggests that energy use per unit of output is falling and claim that the existence of inverted U-shaped curves, which have been estimated for several local air pollutants, indicate that it is possible to 'grow out of' environmental problems.[4] Others provide a 'stronger' interpretation of sustainability which, like the anti-growth position held by many in the 1970s, posits the existence of environmental limits to growth. However, in contrast to the anti-growth position of the 1970s, the environmental limits discussed by the strong sustainability school do not arise from the exhaustion of natural resources. Rather, the relevant environmental constraints to growth stem from 'sink' limits ie. the limited ability of the biosphere to absorb and assimilate waste. Proponents of the strong sustainability hypothesis also stress the importance of the scale of the economy (e.g. Daly (1991)) and generally advocate a multi-disciplinary, or co-evolutionary, approach to sustainability issues, integrating ecology with economics.

With this background in mind, the thesis is organised as follows:

Chapter 2 examines the nature and development of the General Agreement on Tariffs and Trade, from its inception in 1948 to the creation of the World Trade Organisation at the Uruguay Round. Particular attention is paid to the development of the (limited) environmental provisions contained within the GATT, including the environmental credentials of the WTO.

Chapter 3 examines the different ways in which trade liberalisation can affect the environment, both positively and negatively. In addition, the GATT/WTO environmental provisions raised in Chapter 2 are assessed and their implications for the environment are considered. Whilst trade

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[4] Known as environmental Kuznets curves after the inverted-U shaped relationship between income and income inequality postulated by Simon Kuznets (1955). See, for example, World Bank (1992).

liberalisation may allow nations to overcome resource constraints; facilitate the transfer of environmentally clean technologies and products; and remove environmentally damaging trade distortions, it may also prove detrimental to the environment. The environmental case against free trade is reduced to four key issues; first, trade liberalisation is likely to generate economic growth (the environmental implications of which are dealt with in later chapters); second, free trade, as it is implemented through the GATT/WTO, may limit the ability to implement national and international environmental regulations; third, trade liberalisation may provide an incentive for nations to lower environmental standards; and finally, free trade may prevent the use of trade restrictions to protect the environment. The strength of each of these claims is assessed.

Chapter 4 examines the historical development of the relationship between economic growth and the environment in economics and environmental literature. Beginning with the classical economists, the chapter then progresses through the neoclassical economists and then focuses on the 'limits to growth' debates of the 1960s and 1970s. The arguments proposed by both sides of this debate are discussed. Attention then turns to the rise of sustainable development in the 1980s and 90s and a distinction is drawn between 'weak' and 'strong' forms of sustainability - the difference between the two stemming from differing opinions of the nature of the capital stock that is to be maintained. It is seen that, generally, weaker forms of sustainable development consider economic growth to be crucial if sustainability is to be achieved. Stronger forms consider economic growth to be detrimental to the objective of sustainable development. The chapter then turns to the actual implementation of sustainable development and assesses the need to develop new indicators of production and welfare. It is claimed that GNP is deficient as an indicator of production *and* welfare. Chapter 8, Policy Implications, returns to this issue.

Given the uncertainty which surrounds the theoretical relationship between economic growth and the environment, Chapter 5 attempts to estimate this relationship empirically. Specifically, this chapter estimates the reduced form relationship between per capita GDP and a wide range of environmental indicators using cross-country panel data sets. These estimated relationships are otherwise known as environmental Kuznets curves (EKCs). Several other studies have also estimated EKCs, although this chapter uses a wider range of environmental indicators and improves on the traditional estimation procedure.[5] A number of hypotheses are tested: first, it is suggested that due to the disincentives for individual nations to tackle global pollutants, pollutants with a local short-term impact (e.g. suspended particulate matter) will have estimated turning points at lower per capita income levels than those environmental indicators with a more global impact (e.g. carbon dioxide).[6] A subsidiary hypothesis is that a global air pollutant will only have an estimated turning point within the observed income range if it has been subjected to a multilateral policy initiative. Second, since for local air pollutants it would appear easier to reduce urban air concentrations than total emissions, it is suggested that turning points for concentrations will be at lower per capita income levels than turning points for emissions per capita. Third, it is suggested that due to the growth of the transport sector, emissions from that sector will prove more difficult to control than emissions in other sectors. It is therefore hypothesised that emissions per capita of transport generated local air pollutants will have turning points at higher levels of per capita income than total emissions per capita of the same pollutants. Finally, the chapter estimates the relationship between economic growth

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[5] For other studies which estimate EKCs see Seldon and Song (1994), Grossman and Krueger (1995), and Shafik (1994).

[6] Since local pollutants have a strong impact on the locale in which they are emitted, governments often feel obliged to take action to control them. In contrast, global pollutants have a much more widespread impact and, in addition, individual countries can benefit from other nations' abatement efforts.

and certain indirect indicators of environmental quality, such as energy use and traffic volumes. Even though these indicators may be responsible for serious environmental problems, it is suggested that turning points will be high or non-existent, due to the lack of incentive for government action.

Although Chapter 5 provides a framework for analysing the relationship between per capita GDP and a wide range of environmental indicators, it does not include a time trend due to several complicating factors which arise when a time trend is included. The chapter therefore fails to take into account any factors which are common to all countries or regions but which change over time, such as the level of technology. Chapter 6 therefore discusses the implications of using a time trend and re-estimates the regressions from Chapter 5 including such a time trend as a proxy for the level of technology. The hypotheses tested in the previous chapter are re-examined to assess whether the inclusion of a time trend affects their results and, finally, the chapter identifies those environmental indicators which have benefitted from technological change, and those which have not.

The results of Chapter 5 then contribute to Chapter 7's attempt to estimate the environmental impact of the Uruguay Round of trade negotiations. Specifically, this impact is estimated in terms of three mechanisms associated with trade liberalisation; namely the composition effect, the scale effect and the technique effect. The composition effect refers to the fact that the composition of industry may change, following trade liberalisation, due to changes in comparative advantage. The scale effect refers to the increase in economic activity which is likely to result as nations obtain greater market access. The technique effect states that the manner of production may change as nations have more access to environmentally clean products and technologies and also because individuals may demand a cleaner environment as per capita incomes increase. US sectoral pollution intensities from Hettige *et al.* (1994), modified by the EKC results from Chapter 5 to allow for regional differences, together with the results of Francois *et al.* (1995) who estimate the impact of the Uruguay Round on sectoral output levels, are used to estimate the composition effect. Scale and technique effects are estimated directly from Chapter 5's results, given Francois *et al.*'s estimates of the Uruguay Round's impact on regional income levels. The likely monetary cost associated with the Uruguay Round environmental impact is also provided.

Chapter 8 provides the policy implications which arise from the results and discussions of the previous chapters and distinguishes between policy implications for the WTO, implications for the creation of a World Environmental Organisation and those which relate to national environmental policy.

Chapter 9 concludes the thesis.

CHAPTER 2.

THE DEVELOPMENT OF GATT AND ITS TREATMENT OF THE ENVIRONMENT.

2.1 Introduction.

This chapter examines the General Agreement on Tariffs and Trade from its creation in 1948 to the formation of the World Trade Organisation at end of the Uruguay Round. The development of the GATT through each negotiating round is examined, with particular attention paid to the limited environmental provisions contained within the General Agreement. It will be seen that the GATT has achieved a significant degree of success regarding tariff liberalisation, although the reduction of non-tariff barriers, particularly in the agricultural sector, has been more modest. Furthermore, achievements relating to the protection of the environment have been even less substantive.

2.2 The Creation of GATT.

The principles on which the GATT is based may be seen to be a direct reaction to the economic crises of the 1920s and 30s and the high levels of protectionism associated with that period.

The impact of the First World War was to fragment the economy of Europe, thus dislocating many channels of trade and, as a result, effectively halting the development of free trade. This situation was exacerbated by the Great Depression, one of the effects of which was to sharply reduce the volume of world trade and turn the attention of governments further inward. Levels of protection now grew in virtually all industrialised nations, particularly in response to the 1930 Hawley-Smoot

Act which raised US tariffs on dutiable items to an unprecedented 52%. Trade warfare and economic nationalism became the hallmarks of the rest of the decade.

The ashes of World War Two left the Allied leaders committed to a new regime. To avoid the mistakes of the past it was essential that any new world order could "bring about the fullest collaboration between all nations in the economic field" (Atlantic Charter, 14th August 1941). The resultant Bretton Woods conference of 1944, although primarily concerned with establishing the IMF and the World Bank to deal with monetary and banking issues, did recognise the need for a comparable institution to deal with world trade matters.

In December 1945, the United States and United Kingdom produced a number of proposals which outlined the formation of an International Trade Organisation (ITO) - the purpose of which being to liberalise and oversee international trade. The ITO charter was finally agreed upon in Havana, Cuba in March 1948 (hence often referred to as the Havana Charter), but was less trade liberalising than had been initially intended. Many delegates to the ITO negotiations grew reluctant to cede sovereignty over trade issues to an international organisation and forced numerous modifications and exceptions into the charter.

However, while the ITO was pending ratification, an interim measure was developed to deal with trade issues entitled the General Agreement on Tariffs and Trade (GATT). The GATT was completed by October 1947 and many negotiators felt it should be introduced before the ITO for two reasons. Firstly, as expounded by Jackson (1990), many negotiators were concerned that the content of the supposedly secret tariff concessions would begin to 'leak' and as a result, a wait of any duration prior to implementing the new tariffs, might disrupt world trade patterns.

Secondly, US negotiators were acting on the authority of US trade legislation, under which the GATT would not have to be submitted to Congress. Since this legislation expired in mid 1948 a degree of urgency entered the proceedings.

The result was the adoption of the 'Protocol of Provisional Application', by which eight nations agreed to apply the GATT after 1st January 1948, whilst the remaining 15 members would do so in the near future. The GATT therefore came into being on 1st January 1948 with the aim of providing a temporary framework for trade liberalisation during the ITO's gestation period.

However, events did not go according to plan and despite the fact that it was the US who made the first initiative regarding the ITO, the US Congress repeatedly failed to approve the Havana Charter. In December 1950 the US State Department announced that it was withdrawing the Charter from further consideration. This effectively signalled the end for the ITO. Hudec (1975) argues that this happened because the Charter was actually facing opposition from both sides of the free trade argument. Opposition from the pro-protection lobby was expected, but what proved to be more pernicious was the lack of support from free traders, many of whom believed the charter to be too weak. More generally, Hudec suggests that there may have been a loss of faith in the post war regime as a whole, with interest waning for all international institutions, not merely the ITO. Finally, Esty (1994), emphasises the lack of support from the business community which undermined the efforts of Congress to establish a multinational trade organisation.

Nevertheless, for whatever reason, the GATT now found itself exposed and standing alone - something it was never designed to do. The new world order as envisaged by the Allied leaders and as supposedly provided by the Bretton Woods system, was now incomplete, with no institution to deal with issues of international trade. Jackson (1990), therefore claims that it is not surprising that the framework that did exist, the GATT, found its purpose changing as nations now expected it to, at least partly, fill the role of the erstwhile ITO, albeit in a different guise.[1]

As a result, the GATT was now forced to take centre stage in all international trade disputes and has survived well, despite the fact that it was only intended to be a temporary arrangement.

The precise role of GATT will now be considered, followed by an examination of GATT's provisions for agriculture and the environment.

2.3 The Role of GATT.

Having examined the historical foundations behind the GATT and the reasons for its development, the actual aims and functions of the agreement can now be analysed so as to ascertain how the GATT's supervisory role is performed.

The stated objective of the GATT is to "provide a secure and predictable international trading environment for the business community and a continuing process of trade liberalisation in which investment, job creation and trade can thrive" (GATT (1991) p.1).

The set of rules which constitute the GATT can be seen to consist of 3 distinct elements. Firstly, there is the General Agreement itself together with its 38 articles. Secondly, there are a number of associated agreements which have been added at various stages since the GATT's inception.

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[1] It became essential that the GATT did not look too much like the ITO since many of the criticisms aimed at the ITO were sharpened by its seemingly permanent institutional nature. Consequently, any talk of transforming the GATT into a more 'solid' organisation was to be avoided.

These agreements generally cover anti dumping and other non tariff issues, with membership for these being much less than for the General Agreement. Finally, there is the Multi-Fibre Arrangement which allows the clothing and textile sectors to be exempt from the normal rules of the General Agreement.

Whilst complex in appearance, the General Agreement is actually based on a number of relatively simple principles. The first such principle is trade without discrimination i.e. there must be nondiscrimination by each participating country in its trade with others. This is generally referred to as the 'most-favoured-nation' clause and is found in Article I. This clause forbids any country from granting a trade advantage, favour, privilege or immunity to another contracting party without providing it for all. In particular, tariff reductions granted to one contracting party must be extended to all GATT parties. Thus if two countries agree on a bilateral reduction in tariffs, the tariff concession should immediately be extended to all other contracting parties. This principle provides a degree of certainty to contracting parties since they know that any bargain which they strike will not be undermined by a subsequent agreement between other contracting parties which does not apply to them. Furthermore, all tariff reductions are 'bound' such that they can be reduced but not increased, thus parties can reasonably expect any tariff concession to be permanent. These features were designed to ensure stability and to end the economic warfare of the 1930s. The most-favoured-nation clause is supported by the national treatment provision which states that imported goods should be treated no less favourably than 'like' domestically produced goods, once they enter the country of importation. This provision is found in Article III.

A second basic principle is that customs tariffs should be the only means for affording protection to domestic industries. The General Agreement has always prohibited the use of quantitative restrictions on imports, even though such quotas are now far less widespread than they used to be, at least in developed countries.[2] Thus, the GATT does not prohibit the use of protection as long as it is in the form of a tariff, thereby making the extent of any protection clear and hence minimising the trade distortion caused. Due to the fact that the General Agreement allows a degree of protection, GATT claims it is misleading to be referred to as a 'free trade organisation' since its real goal is to achieve *fair* and *undistorted* competition (GATT (1991) p.8).

The final principle underlying the GATT is to afford an international forum for discussing and settling mutual problems of international trade. Hence, parties must try to settle any disputes through consultation and negotiation.

All other issues addressed by the General Agreement can be seen to support the above principles. However, in order to examine how such aims are brought to fruition, if indeed they are, it is necessary to analyse the institutional framework of the GATT.

It is important to realise that, as Dam (1970) points out, the trade policy provisions of the ITO formed the General Agreement, but were stripped of any procedural and institutional framework which the ITO may have possessed. Hence, any such framework that exists within the GATT was merely designed to facilitate the long term survival of a multi-lateral trade agreement. Nevertheless, it is still possible to talk in terms of a *framework* when dealing with the institutional nature of the GATT and certain procedural and organisational structures may be isolated. As examples of procedural factors, Dam emphasises the general provisions on consultation and 'nullification or impairment' and claims the latter constitutes the core

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[2] GATT does allow the use of quotas in the event of severe balance of payments difficulties, although they must be applied without discrimination.

of the GATT remedies section. If the General Agreement is violated by, for example, the nullification of a concession, the GATT will not actually act to punish the offender, but will instead grant the injured party the right to withdraw any concessions from which the offending party may have benefited. Dam claims that a remedy of this type illustrates how the GATT represents a balance of advantages for each party, whereby tariff concessions are made only in return for equivalent reciprocal concessions. Indeed, reciprocity is a key principle underlying the working of the GATT and is a fundamental element in multilateral trade negotiations whereby nations attempt to minimise free-riding. Essentially, the GATT is a convention of *contractual obligations* which governments agree to adhere to when applying their national regulations to international trade. Indeed, the significance of the contractual nature of the GATT is illustrated by the fact that its members are referred to as *Contracting Parties*. By early 1995 there were 128 nations acting as contracting parties and their business is carried out with the help of numerous committees, working parties and panels, with perhaps the most significant being the 'Council'. With regard to organisational factors, the GATT makes no provision for any of the usual attributes of international organisations, such as a governing body or an executive board, but does provide the opportunity for the contracting parties to act collectively in certain circumstances. So, for example, if there is uncertainty between countries regarding the interpretation of part of the agreement, a majority vote of the contracting parties could be held to provide an authoritative judgement.[3] It is provisions of this sort which allow the GATT to function effectively to settle international trade disputes, despite the fact that the agreement does not form an international organisation in the mould of the IMF or the World Bank.

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[3] As stated by Jackson (1990), majority voting is generally avoided in favour of a 'consensus' approach, with the former only being used in the case of waivers, membership and treaty amendments.

Having analysed the nature and role of the GATT, its development since 1948 will now be considered, paying particular attention to its treatment of the environment.

2.4 GATT's 1948 Stance on the Environment.

The implications of GATT with respect to the environment will be dealt with in Chapter 3, with present attention being restricted to GATT's initial provisions for environmental issues. The environment receives no explicit attention in the General Agreement, reflecting the lack of importance attached to ecological issues in the 1940s. However, Article XX provides numerous exceptions to Articles I and III (the 'most-favoured nation' clause and the national treatment provision) including provision for a degree of environmental regulation.[4] Article XX provides exemptions for normally 'illegal' actions which are designed to protect public morals or preserve national heritage, and although not mentioning the word 'environment', sections XX(b) and XX(g) allow a degree of flexibility when implementing GATT's rules, thus facilitating an element of environmental protection. XX(b) allows exception to GATT's principles for measures "necessary to protect human, animal or plant life or health", while XX(g) provides dispensation for measures "relating to the conservation of exhaustible natural resources if such measures are made effective in conjunction with restrictions on domestic production or consumption".[5] However, it should be noted that all actions taken in the name of an Article XX exemption must not "constitute a means of arbitrary or unjustifiable discrimination between countries where the same

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[4] See Appendix A.

[5] Article XX started life as Article 45 of the Havana Charter, and as Pearce points out, clause 45 originally contained an additional exception to Articles I and III, namely for measures " taken in pursuance of any intergovernmental agreement which relates solely to the conservation of fisheries resources, migratory birds or wild animals and which is subject to the requirement of paragraph 1(d) of Article 70..."

conditions prevail, or (act as) a disguised restriction on international trade".

In addition, as Esty (1994) claims, it is likely that a number of hurdles would have to be cleared before a party's claim of exemption from Articles I or II would be accepted. In particular, Pearce (1992) points out a number of ambiguities which exist within the two clauses, thus preventing ease of interpretation and hence complicating the procedure. Specifically, Pearce claims the use of the word 'exhaustible' in XX(g) is ambiguous, since all resources are exhaustible, even renewable ones if they are not managed sustainably. It is therefore unclear whether GATT has considered the distinction between renewable and non-renewable resources. Another example of ambiguity, this time in XX(b), is the use of the word 'necessary'. Measures undertaken must be 'necessary' for the protection of health; but does 'necessary' mean there is *no other choice* or is it simply referring to the most suitable measure? Furthermore, on the same point, Esty states that recent GATT cases have defined 'necessary' to mean 'least GATT-inconsistent' i.e. presumably 'least trade-restrictive'. This is a major obstacle in itself since a less GATT-inconsistent policy can almost always be conceived.

An important point concerning these provisions of Article XX, is that they are only concerned with *what* is produced and not *how* it is produced. Differential treatment is not allowed for 'like' products, and no distinction is drawn between similar goods even though they may be the result of very different production processes. Esty elucidates the obvious drawback with such a situation "... to say that a nation must accept an imported semiconductor because it physically resembles a domestically produced semiconductor is absurd if the product was made in violation of the Montreal Protocol, restricting the use of chemicals harmful to the ozone layer." (Esty (1994) p.51.). This issue was addressed, to a certain extent, by the Uruguay Round by extending the scope of the Technical Barriers to Trade Agreement.

2.5 The Development of GATT Since 1948 (With Relation to the Environment).[6]

2.5.1 1948 - 1963.

From its very inception in 1948 the GATT has allowed exceptions to its prohibition of quantitative trade restrictions. Indeed, Article XIX provides a rationale for the use of quantitative import restrictions on all goods (including agricultural goods) if rapidly growing imports are seen to jeopardise domestic production, whilst Articles XII, XIII, XIV and XV allow the use of quotas for balance of payments reasons. Most notably, Article XI which provides the general rule prohibiting the use of import quotas, grants a permanent exemption for import quotas on agricultural commodities - subject to certain qualifications. That is, import restrictions are allowed on agricultural commodities; firstly, providing domestic production or marketing of the commodity is also restricted; secondly, providing that imports are permitted the share of the domestic market which would have been theirs in the absence of any restrictions on production;[7] and finally, if the quotas are used to remove temporary domestic surpluses.

One of the first matters which had to be tackled by GATT was the use of quantitative import restrictions by many countries, under the guise of balance of payments difficulties. As Schwenger (1958) points out, it is by no means clear whether GATT rules permit greater levels of protectionism under balance of payments quotas than under agricultural quotas, but

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[6] See appendix B.

[7] Several factors must be considered when determining this share; (a) the representative historical share that imports have had, (b) changes in relative productive efficiency and (c) any other factors which may affect trade.

nevertheless such quotas went generally unchallenged. However, by 1950, many contracting parties were concerned by this use of quotas, especially since it was widely believed that many countries were no longer experiencing balance of payments problems. A report was consequently prepared documenting the extent of their usage and additionally, methods were suggested to remove such quotas as rapidly as possible.[8] In 1952, the contracting parties began annual reviews of the operation of Article XI (the Article eliminating the use of quantitative restrictions), in order to keep the use of quotas under close scrutiny.

In 1954 a review session was held specifically to appraise the performance of the GATT. One of the main outcomes concerned the use of subsidies which were still 'legal' under GATT provisions. The initial stance adopted by GATT was simply that countries applying subsidies were requested in Article XVI to notify all other contracting parties. No provision was therefore made to outlaw the use of such subsidies. Furthermore, the initial treaty made no separate provisions concerning export subsidies. In 1954 however three paragraphs were added to Article XVI which allowed the use of export subsidies for agricultural goods whilst prohibiting their usage for any other goods. GATT rules now merely stated that export subsidies for agricultural goods *should* be avoided but that if they are applied they should not result 'in a more than equitable share of world trade'. Already agriculture can be seen to be receiving differential treatment from the GATT - regarding the use of both quantitative import restrictions and subsidies.

A problem developing in the US concerned Section 22 of the US Agricultural Adjustment Act (1933). This required the use of quotas or special fees whenever "any article or articles are being or are practically certain to be imported into the United States under such conditions and in

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[8] The report was entitled *GATT, The Use of Quantitative Restrictions for Protective and Commercial Purposes.* (Geneva, July 1950).

such quantities as to render or tend to render ineffective, or materially interfere with" any US farm programme or "to reduce substantially the amount of any product" subject to such a farm programme (7 USCA s. 624 (1964) from Dam (1970) p.260). As such then, Section 22 can be seen to conflict with GATT rules, with the former requiring quotas whenever US domestic farm policy is threatened, whilst the GATT requires all agricultural import quotas to be matched by domestic restrictions. US Congress made it clear that in any actual conflict which may occur, Section 22 was to take precedence over GATT commitments.

This situation was obviously unsatisfactory as far as GATT was concerned with both the US and many European nations operating in flagrant violation of GATT rules. The US was imposing quotas on agricultural commodities with no domestic production constraints, whilst the European importers were operating balance of payments quotas without having the balance of payments difficulties to justify them. (Schwenger (1958)).

The United States was aware that the implications of such a large power acting in defiance of GATT rules, would be to seriously threaten GATT's authority. As a result, the US tried to legalise its position at the 1954-55 Review Session. The outcome was that the US was granted a waiver from GATT obligations for any action required by Section 22, subject to certain qualifications.[9] Also at the 1954-55 Review Session, the GATT granted a temporary waiver allowing parties to maintain quotas after any balance of payments difficulties have vanished, again subject to strict qualifications. This so called 'hardcore' waiver recognised that industries having received protection from balance of payments quotas may need further short term protection to ease adjustment when such quotas are suddenly removed.

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[9] Namely, as outlined by Schwenger, the US must review any quota at the request of the government of a GATT member; give notice of the consideration of, and decisions regarding, any new or modified restrictions; remove or relax restrictions as soon as circumstances permit; and provide an annual report which will act as the basis for an annual review by the contracting parties.

Zietz and Valdes (1988) believe that although such waivers may not have been of great importance quantitatively, they have been significant in a qualitative sense. By weakening the power of Article XI relating to the agricultural sector, and thus facilitating the growth of quantitative restrictions, such waivers have obviously hampered the trade liberalisation process in general. Furthermore, the granting of the Section 22 waiver illustrates the priority given to domestic interests by the US. Such actions by the architect of the trading system itself, are by no means conducive to the creation of a liberalised international trading environment. Indeed, the sixth GATT review (1961) claimed that the Section 22 waiver "...probably caused more serious damage to the fulfilment of the objectives of the General Agreement than any single factor". (Basic Instruments and Selected Documents, 3/S (1961), p.261 - Quoted in Warley (1976) p. 347).

The late 1950s saw the GATT reach an impasse. Little progress was being made in terms of the reduction of tariffs, whilst agricultural protectionism was growing steadily and the problems of the less developed countries were not being tackled. A panel of experts, consisting of four leading economists, was therefore established to address these problems, the result of which being the 1958 Habeler Report. On the basis of the report's findings three committees were set up to deal with each of the above issues. Committee I was to plan the negotiations for the reduction of tariffs; Committee II was to address the growing use of non-tariff barriers in the agricultural sector; and Committee III aimed to develop the export-earnings of the less developed countries (Kock (1969)). According to Dam (1970), Committee II's most important consultations were held with the EEC regarding the formation of the Common Agricultural Policy in 1962 and its extension in 1965 to cover new products. It would appear, however, that Committee II's achievements lacked any real substance. Warley reinforces this point when he states that "the political will" of

Committee II "to change, moderate and harmonise agricultural programmes was lacking".

Nevertheless, the period 1948-63 saw the achievement of a considerable degree of non-agriculture liberalisation, with tariff concessions on 45,000 items being agreed at the initial Geneva Round and concessions on over 58,000 individual items in existence after the Annecy (1949) and the Torquay (1951) Rounds. However, it appears that this initial momentum began to falter during the 1950s, largely as a result of the cumbersome nature of negotiations at this time, whereby concessions were granted item-by-item. In addition, as Greenaway (1983) points out, the granting of such concessions faced increased political opposition. Nations had typically granted concessions on goods which had a degree of tariff redundancy, thus minimising any adjustment required. However, as the number of concessions grew, nations found it increasingly difficult to find such goods. The implication of this being that any further tariff concessions granted necessitated a greater degree of adjustment and hence faced increased political opposition.

Warley provides a number of conclusions regarding the treatment of agriculture prior to the Kennedy Round (1963 - 67) and firstly concurs with Dam in stating that the GATT's attempts to liberalise the agricultural sector had achieved very limited success. However, Warley does not attribute this failure to the actual design of the GATT, but merely to the fact that the contracting parties were unwilling to apply the rules of the General Agreement to the agricultural sector in the same way as they had for the industrial sector. Warley points to a general lack of commitment regarding the reduction of agricultural protectionism, and although contracting parties spent much effort condemning each others' actions, very little tangible action was taken. Additionally, as previously mentioned, the poor example set by the US should be emphasised. Whilst simultaneously advocating the free trade goals of the GATT, and yet prioritising domestic agricultural objectives, US policy was clearly ambiguous and provided a confusing example for smaller nations to follow. Warley concludes that throughout this period there was generally "no strong common interest in promoting agricultural trade liberalisation in GATT under the terms of the Agreement, and few opportunities for reaching pragmatic agreements outside it to which the contracting parties could accommodate the operation of the Agreement." (Warley (1976) p.355).

2.5.2 The Kennedy Round 1963 - 67.

"The Kennedy Round is a test, with the world watching, of how this new entity of six European nations, growing and prospering rapidly and implementing with gratifying determination the great dream of European unity, will respond to the exciting call for major trade liberalisation in world commerce." (Blumenthal (1965)).

Warley (1988) echoes this sentiment and claims that the overriding goal of the Kennedy Round was to respond to the challenge of the Habeler Report by reducing the level of agricultural protectionism. However, as Greenaway (1983) points out, the Kennedy Round was more ambitious than previous Rounds, partly because of the problems it addressed, partly because of the larger number of contracting parties involved in the Round, and partly because the nature of granting tariff concessions changed, with the abolition of item-by-item negotiations and the introduction of across-the-board reductions.

With regard to the industrial sector, it can be seen that a reasonable degree of success was achieved in the reduction of tariff levels during the Kennedy Round. According to Winham (1986), when approximate general averaging procedures are used, it is likely that the major players in the Round made reductions of around 35% on non-agricultural tariff rates. Furthermore these reductions cover about 80% of total world trade. To illustrate the relative success of the Kennedy Round, the average reduction in the Dillon Round was around 10% for the US and the EEC, and the supposedly hugely successful Geneva Round in 1947 achieved average reductions for the US of only about 20%.

However, four years of negotiations achieved very little for the agricultural sector and it appeared that generally "the Community was not ready to accept external constraints on its emerging common agricultural policy". (Warley (1988) p.308). During the period covered by the Kennedy Round the extent of agricultural protectionism actually increased - not merely with the emergence of the CAP, but also in the US and Canada, with the former introducing quantitative import controls on ruminant meats in 1964, and the latter implementing its highly protectionist dairy policy in 1965. Nevertheless, Winham (1986) suggests that some progress *was* made in the agricultural sector due to the Kennedy Round. Using data compiled by Preeg (1970), Winham states that total dutiable agricultural trade (other than grain) of industrial countries amounted to $1650 million on which tariff reductions were made on $861.9 million or 52%. In addition, the average tariff reduction on dutiable imports was 20%. As Winham points out though, the extent of tariff reductions in the agricultural sector is somewhat irrelevant when the bulk of agricultural protectionism is in the form of non-tariff barriers. Such barriers received little attention in the Kennedy Round.

2.5.3 The Tokyo Round 1973 - 79.

Like the General Agreement itself, the Tokyo Round of trade negotiations arose as the result of economic crisis and the breakdown of the international trading system. Specifically, the Round was instigated largely due to the collapse of the Bretton Woods system of fixed exchange rates, the advent of 'stagflation' and the general instability of the world economy in the early 1970s. Indeed, as Warley points out, "The Tokyo Round was seen as a rededication to multilateral co-operation in stabilising the international economy, as a means of reversing the drift to protectionism, and as a vehicle for making a liberal response to the demands of the developing countries". (Warley (1988) p.309).

The scope of the Tokyo Round was to be wider than previous Rounds, with 99 contracting parties involved, and a far more ambitious agenda. Of specific concern was the growth of non-tariff barriers and, in particular, the increased use of subsidies - issues generally neglected in previous GATT Rounds. Largely in response to efforts by the US to restrain the use of subsidies, a Subsidies Code was added to the General Agreement which widened the definition of 'more than equitable share' of the world market, to cover the displacement of exports in third-country markets. However, this Code is supplementary to the General Agreement and, in fact, only approximately a quarter of GATT members have signed it. In addition, although the Subsidies Code applies as much to the industrial sector as to the agricultural sector, Zietz and Valdes (1988) point out that it has been in the latter sector that a number of disputes has arisen. As a result Zietz and Valdes claim that the Subsidies Code has been the least effective of the codes negotiated at the Tokyo Round.

With regard to tariff liberalisation in the industrial sector, Table 1 below illustrates that the Tokyo Round achieved a significant degree of success. It should be noted, however, that tariff reductions outlined in Table 1 did not apply to all industrial goods, with many (e.g. textiles, footwear, leather) receiving zero or substantially lower than average concessions. It was this fact that led many less developed countries to express dismay at the outcome of the Tokyo Round.

Table 1. Tokyo Round Tariff Changes;[10]

		Tariff averages		
		Pre-Tokyo	Post-Tokyo	% reduction
Total industrial products	W	7.2	4.9	33
	S	10.6	6.5	38
Raw materials	W	0.8	0.4	52
	S	2.6	1.7	36
Semi-manufactures	W	5.8	4.1	30
	S	9.7	6.2	36
Finished manufactures	W	10.3	6.9	33
	S	12.2	7.4	39

Negotiations concerning the agricultural sector occurred separately from the other issues in the Tokyo Round and, in addition to the Subsidies Code, two multilateral agreements and a series of individual bilateral agreements were made. A significant bilateral agreement between the US and the EC resulted in an exchange of concessions estimated at $168 million to the EC and $106 million to the US. The agreements reached following multilateral negotiations were the Bovine Meat Arrangement and the International Dairy Arrangement. Both were primarily designed to increase the exchange of information between signatories, with little economic effect on actual trade intended. (Winham (1986).

Despite these advances, Winham argues that the Tokyo Round achieved no substantial results in the area of multilateral agricultural negotiations. Indeed, "the participating nations ended the Tokyo Round about as far

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[10] Note: W = weighted (by MFN imports) average, S = simple average. Source: GATT (1979) p.120.

apart on agricultural trade policy as they were at the beginning of the negotiation". (Winham (1986) p.255).

An achievement of the Tokyo Round was the creation of the Standards Code - or the GATT's Agreement on Technical Barriers to Trade - designed to oversee the application of standards in international trade and to minimise their use as non-tariff barriers. The Code is a free-standing agreement which therefore applies only to its signatories. Such signatories are obliged to follow set guidelines in formulating and applying standards, with prior notification to other signatories required. The Code supports the idea of harmonised standards (i.e. internationally agreed), although as Pearce (1992) points out, nations may impose stricter standards than other countries, in order to protect "human, animal or plant life and the environment." The Code, therefore, does refer specifically to the environment - something Article XX does not do. However, as Pearce demonstrates, there exist many areas of confusion within the Standards Code, including whether nations are allowed to maintain lower standards than the international norm; whether a nation can insist on imports having the same standard as domestic products; and the fact that the post-Tokyo Round Standards Code, like the GATT's main articles, appears to refer only to *products* as distinct from *process and production methods.* This point, however, is by no means clear. This is illustrated by the fact that when attempting to justify its ban on hormone-fed beef from the US (1989), the EC claimed its actions were outside the scope of the GATT since the Code did not cover processes and production methods. In contrast the US claimed that it did. GATT was unable to resolve the issue.

2.5.4 The Uruguay Round 1986 - 94.

As expected the Uruguay Round was more ambitious than previous Rounds, although the number of contracting parties, at 103, was only slightly higher than at the Tokyo Round. The key objective of the Round was to address the differential treatment received by the agricultural sector, relative to the industrial sector, and to reduce the use of non-tariff barriers in both sectors. Finger and Olechowski (1987) outline the general objectives of the Uruguay Round as follows:

(1) To prohibit, or at least reduce, the use of non-tariff barriers.

Whilst the Uruguay Round also aimed to reduce the level of tariffs, it is non-tariff barriers which are deemed the most problematic by the GATT.

(2) To broaden and extend the coverage of GATT, particularly with respect to the agricultural sector, and the production and trade of services. The issues covered by the Round were to be extensive with new issues such as Trade-Related Intellectual Property Rights being considered.[11]

(3) To ensure that the developing countries participate in the Round and the more advanced of them undertake more GATT obligations than they do at present.

Specifically, GATT feels that since several 'developing' countries have now experienced a significant degree of economic development and are hence major world competitors in numerous manufactured products, greater access should be allowed to the markets of such countries.

(4) To restore respect for the GATT system.

Finger and Olechowski believe that the success of the negotiations rested on the ability of the GATT to restore its credibility, "in the public mind and in political circles".(Finger and Olechowski (1987) p.11). In particular, they believe a comprehensive review of all GATT articles, would serve to update the General Agreement, thus earning it more respect and a greater degree of observance.

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[11] See Appendix C.

The post-Tokyo Round era saw agriculture become more and more distinct in relation to other sectors as illustrated in the following tables drawn from Zietz and Valdes (1988).

Table 2. Average applied tariffs for 11 developed market economies, by product group, 1983[12]

Product Group	Tariff Application (on all imports).
Food	5.3%
Agricultural materials	0.5%
Fuels	0.6%
Chemicals	3.1%
Other manufactures	4.7%
All items	3.0%

Table 2 shows that the level of food protection was considerably higher than in other sectors. In addition, Table 3 provides evidence of the high level of non-tariff barriers in the agricultural sector, relative to the manufacturing sector and in particular, relative to one of the most protected industries within the manufacturing sector - the iron and steel industry. It can be seen that the extent of non-tariff protection in the agricultural sector was similar to that in the iron and steel industry.

As Rayner and Colman (1993) point out, this high level of agricultural protectionism was largely the result of two factors; firstly, the rapid growth of market distorting domestic agricultural programmes, and secondly the differential treatment which the agricultural sector received from the GATT, relative to the industrial sector. The inability of previous GATT rounds to reduce the level of agricultural protectionism meant that

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[12] Source: Based on data from Laird and Finger (1986).

Table 3. Percentage of industrial countries' imports subject to NTBs, by product group, 1983[13]

Country	Imports from:	Agriculture	Manuf-acturing	Iron and Steel
Australia	Developing	21.6%	28.6%	42.5%
	Developed	47.7%	22.7%	57.8%
EC	Developing	26.9%	29.9%	31.9%
	Developed	47.7%	15.2%	51.8%
Japan	Developing	53.3%	4.4%	0.0%
	Developed	36.8%	9.7%	0.0%
Norway	Developing	15.4%	20.9%	20.6%
	Developed	27.0%	3.2%	0.0%
USA	Developing	25.1%	18.6%	48.9%
	Developed	23.5%	16.5%	35.6%

agricultural trade was largely shaped by domestic policies. However, the early 1980s saw a reduction in the growth of the worldwide consumption of agricultural products. The US, in particular, found that its share of global agricultural exports fell quite considerably during the 1980s, whilst its domestic agricultural trade was suffering from increased market competition, lower farm prices and rural depression (Hillman (1994)). Consequently, the US began to place pressure on the GATT to force such issues onto the international trade agenda.[14] As a result, agricultural issues were promised a high priority in the Uruguay Round. Specifically, the negotiations aimed to address GATT's past neglect of agricultural trade and to rectify its failure to reduce the level of agricultural protectionism to the same extent as industrial protectionism.

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[13] Upper numbers refer to imports from developing countries, lower numbers to imports from developed countries. Source: Selected data from Nogues, Olechowski and Winters (1986).

[14] As Hillman (1994) notes, this represented something of a watershed since the US had always been reluctant to link its agricultural policy with its international trade policy.

Seven and a half years of complex negotiations were concluded at the Marrakesh ministerial conference on April 15th 1994, with the result being a treaty over 22,000 pages long and 170 kilos in weight. (The Times, 16th April 1994). However, despite the sheer size of the agreement, it appears that its agricultural provisions fall short of expectations - expectations which may have initially been unrealistically high due to the US's so called zero-option, whereby *all* trade distorting agricultural support and protection was to be removed within 10 years. Clearly, such a stance by the US was overly ambitious, with the result that it was implicitly dropped after the 1989 Geneva Accord. This now provided scope for agreement with the EU, whose reaction to the zero-option had been largely defensive. However, disagreements between contracting parties arose throughout the negotiations and by 1991 the talks appeared to have reached stalemate. As a result GATT Secretary-General Dunkel intervened by tabling a draft 'Final Act' which included the actual amount by which agricultural support and protection should be reduced. Whilst the US and many Cairns Group countries were prepared to accept the substance of the 'Final Act', the EU was not, and as a result Dunkel abandoned plans to conclude the Uruguay Round by 15 April 1992. This inability to agree on issues affecting agriculture would therefore appear to be largely responsible for both the duration, and the weakened results of the Round.

Nevertheless, the Uruguay Round Agricultural Agreement does contain some major contributions to the liberalisation of agricultural trade. Breakthroughs were made in all three areas of agricultural support and protection, namely, domestic support, market access and export subsidies. With reference to the first of these achievements, contracting parties from the developed world are committed to a 20% reduction in total Aggregate Measurement of Support, over 6 years, using Fixed External Reference

Prices from 1986-88.[15] A notable exception to this ruling is the case of direct payments made under production limitation programmes - such as the EU's post-Macsharry compensation payments and the deficiency payments used in the US since the 1970s.

However, perhaps the most significant achievements of the Round occurred in the area of market access requirements. The Agricultural Agreement brings the agricultural sector in line with the industrial sector by 'outlawing' all forms of protection other than tariffs. Indeed, the Agreement states that no new non-tariff barriers are to be created, whilst all existing non-tariff barriers are to be converted into tariffs. All base period tariffs (including converted NTBs) are then to be reduced by an unweighted average of 36%, over 6 years, after which time all tariffs will be bound.[16] In addition, market access is enhanced by the minimum access provisions - 3% rising to 5% of domestic consumption in the base period. This provision is operationalised via tariff quotas, whereby within-quota tariffs are set at a low level (32% of the basic tariff in the EU). As stated by Ingersent, Rayner and Hine (1995), countries do not have to ensure that the level of imports meets the minimum access level, merely that they are capable of doing so, given the required access opportunities.

A significant feature of the market access provisions is Article 5 of the Agricultural Agreement, which provides special safeguards in the event of an exceptionally high volume of imports, or an unusually large fall in import prices. Should either eventuality arise, and the volume or the price of imports reaches a 'trigger' level, then the contracting party is entitled to raise normal tariffs by an additional duty. The size of this duty is proportional in size to the difference between the volume or price of

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[15] This reduction is 13.3% of total AMS for developing countries, whilst those nations classed as 'least developed' are not required to make any reduction.

[16] In addition, a key result of the Blair House Agreement (November 1992) between the US and the EU, was to allow the EU's tariff equivalent calculations to include a 10% Community Preference margin.

imports, and the level of the trigger. However, as Ingersent, Rayner and Hine (1995) point out, the operation of this special safeguard is not equivalent to a variable import levy, since the additional duty does not *fully* compensate for the increase in volume, or the fall in price, of imports. Nevertheless, the overuse of this provision could, at least in theory, seriously hinder the tariff reduction process.

The final area of reform concerns the use of export subsidies. Article XVI of the General Agreement made the use of such subsidies 'illegal' - with the exception of the agricultural sector. However, following the Uruguay Round, agricultural export subsidies still receive differential treatment relative to other sectors, but are now to be reduced by 36% (relative to 1986-90 levels) over a 6 year period. In addition, the actual volume of subsidised exports is to be reduced by 21%.[17] As Tangermann (1994) notes, a key effect of the Agriculture Agreement on export subsidies is to redefine the term 'equitable market share', as referred to in Article XVI:3 of the GATT, as the actual market share which prevailed in the base period, 1986-90.

With regard to industrial sector tariff liberalisation, a key achievement of the Uruguay Round was a significant increase in the number of tariff bindings. Prior to the Uruguay Round developing countries had received special treatment allowing them not to offer concessions at negotiating rounds. However, the Uruguay Round aimed to limit this differential treatment and the formation of the World Trade Organisation (WTO) committed all members to submit tariff schedules. This was not required under GATT rules. Whilst the product coverage of these schedules for developing countries is not stipulated by the WTO, Table 4 below clearly

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[17] For the developing countries export subsidies are to be reduced by 24%, the volume of subsidised exports by 14%, and the transition period is 10 years. 'Least developed' nations are exempt from such commitments.

illustrates that the extent of tariff bindings increased significantly as a result of the Uruguay Round.

Table 4. Tariff bindings for industrial products (excluding petroleum) before and after the Uruguay Round.[18]

Type of economy or region	no. of lines	import value (US $bn)	% of tariff lines bound		% of imports under bound rates	
Economies:			**Pre-**	**Post-**	**Pre-**	**Post-**
developed	86,968	737.2	78	99	94	99
developing	157,805	306.2	22	72	14	59
transition	18,962	34.7	73	98	74	96
Regions:						
N.America	14,138	325.7	99	100	99	100
S.&C.America	64,136	40.4	38	100	57	100
W.Europe	57,851	239.9	79	82	98	98
C.Europe	23,565	38.1	63	98	68	97
Asia	82,545	415.4	17	67	36	70

As has already been mentioned, a notable feature of the Uruguay Round was its extension to cover three new areas; trade in services, trade-related intellectual property, and trade-related investment measures. By 1994 trade in services accounted for approximately 20% of global trade (European Commission (1994)) and hence pressure had been mounting to bring the sector under the umbrella of the GATT. The General Agreement on Trade in Services (GATS) therefore introduces the principle of non-disrimination to trade in services, through the most-favoured nation and national treatment rules. Exemptions to the most-favoured nation rule will, however, be granted in specific circumstances. In addition, Hoekman and

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[18] The data cover 26 developing economies and account for four-fifths of total merchandise imports of all developing country participants in the Uruguay Round. Source: GATT (1994).

Kostecki (1995) outline certain market access obligations which members undertake. Specifically there are limits on; the number of service suppliers allowed; the value of transactions or assets; the total quantity of service output; the number of natural persons that may be employed; the type of legal entity through which a service supplier is permitted to supply a service; and the extent of foreign shareholding. Finally, the GATS also addresses issues such as domestic regulation, transparency and the behaviour of public monopolies.

With regard to trade-related intellectual property (TRIPs), the trade in goods containing intellectual propertyhas increased substantially in recent years and so too has dissatisfaction with the existing intellectual property regulations.[19] Industrialised nations generally felt that inadequate protection of intellectual property was eroding the competitive advantage of their industry, and in particular the high-technology sector. The negotiations often proved arduous, however, as many developing nations expressed the concern that a strengthening of intellectual property rights would increase the monopoly power of multinational companies and also have the effect of raising the price of medicines and food. Nevertheless, as the European Commission (1994) point out, the Uruguay Round *will* strengthen intellectual property rights in a number of areas; there will be stronger protection of trade marks; industrial designs will receive more protection and especially the products of the textile and clothing industry; patent protection will be introduced in all countries for pharmaceutical and chemical products; and new rules will prohibit the incorrect use of geographical appellations. Finally, the establishment of a clear set of principles will ensure that intellectual property rights will be enforced through national courts.

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[19] Hoekman and Kostecki define intellectual property as "information with a market value". (Hoekman and Kostecki (1995) p. 144.)

The third and final new area which GATT rules have been extended to cover is trade-related investment measures (TRIMs). The TRIMs agreement generally aims to clarify the rules concerning such investment measures and to provide a framework for future actions. Many measures have been declared non-permissible and must be phased out over a two-to-seven year period, depending upon the stage of economic development of the country concerned.

Turning now to environmental considerations, the Uruguay Round extended the scope of the Technical Barriers to Trade (TBT) Agreement by relating it to processes and production methods. Article 2 of the TBT Agreement states that "technical regulations shall not be more trade restrictive than necessary to fulfil a legitimate objective", with one such legitimate objective being "the protection of human health or safety, animal or plant life or health, or the environment." Article 2 goes on to state that "relevant elements of consideration are .... available scientific and technical information, related processing technology or intended end-uses of products." As already stated, it appears that the post-Tokyo Round TBT Agreement applied only to the actual product, with no consideration of how it was produced. Now, such processes and production methods are covered by the agreement *providing they leave a trace in the final product.*[20] If, for example, the production of a good leaves traces of a banned chemical in the final product, the importation of this final product may be prevented even if it is not in itself made from the chemical concerned - providing it is judged that a less trade restrictive solution is not available. However, the Agreement states that all standards set must be considered to be proportional to the problem they are trying to solve.

The Uruguay Round also contains other environmental provisions. The Agreement on Agriculture allows direct payments under environmental

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[20] This point was clarified by personal correspondence with Steve Charnovitz.

programmes (subject to conditions) and makes them exempt from WTO members' commitments to reduce domestic support for agricultural production. Secondly, the Agreement on Subsidies and Countervailing Measures treats government assistance to industry, to cover up to 20% of the cost of meeting environmental legislation, as a non-actionable subsidy.

The Uruguay Round's Agreement on the Application of Sanitary and Phytosanitary Measures bears a strong resemblance to the Agreement on Technical Barriers to Trade and is specifically concerned with food safety and animal and plant health regulations. The Agreement is designed to prevent the use of such regulations as a means of covert protectionism and encourages greater transparency. In addition the use of international standards and thus harmonisation are advocated based on the recommendations of a number of international scientific organisations. Finally, the Agreement provides for the World Trade Organisation to establish a Committee on Sanitary and Phytosanitary measures to generally oversee the realisation of the above objectives.

A key achievement of the Uruguay Round was indeed the development of the World Trade Organisation. The WTO is not intended as a successor to the GATT 1947, but is a new organisation for all those prepared to accept the entire Uruguay Round Agreement. As an organisation, it therefore oversees the functioning of the General Agreement on Tariffs and Trade 1994, as it relates to trade in goods, the General Agreement on Trade in Services and the Agreement on Trade Related Intellectual Property. As the European Commission point out, the creation of the WTO should introduce more certainty into the international trading system due to the fact that to be a member of the WTO, a country must have signed the *entire* Uruguay Round Agreement, thereby making its exact obligations known. Those countries who do not accept the entire agreement will remain within the old GATT framework which will be frozen in its pre-

Uruguay Round situation. In the preamble of the Agreement Establishing the World Trade Organisation it is claimed that the WTO recognises that "relations in the field of trade and economic endeavour should be conducted with a view to raising standards of living, ensuring full employment, and a large and steadily growing volume of real income and effective demand, and expanding the production of and trade in goods and services, *while allowing for the optimal use of the world's resources in accordance with the objective of sustainable development, seeking both to protect and preserve the environment and to enhance the means for doing so in a manner consistent with their respective needs and concerns at different levels of economic development.*"

Additionally, although the main text contains no reference to a trade and environment committee, Annex III.11 of the final act states that "the first meeting of the General Council of the WTO is to establish a Committee on Trade and the Environment."[21] Appendix D provides a timetable for further WTO negotiations. The remit of the Committee will include;

- an examination of the relationship between trade measures and environmental measures in promoting sustainable development, and the need for rules to enhance that positive interaction;

- an examination of the relationship between the multilateral trading system and trade measures used for environmental purposes, including those in multilateral environmental agreements;

- an examination of the relationship between the multilateral trading system and environmental measures with significant effects on trade; and

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[21] As the European Commission (1994) states, a trade and environment committe "was resisted by developing countries worried about hidden protectionism and the lack of clarity over the form or powers of such a committee." (European Commission (1994) p.28).

- an examination of the environmental effects of trade liberalisation.

(From Anderson (1995) p.15).

The creation of the WTO sees the institution transformed into a global organisation with the same status as the World Bank or IMF. Most decision making will still result from negotiation and consensus between the Members, although the WTO has been strengthened relative to the GATT, particularly with regard to dispute settlement whereby it is now more difficult for the parties to a dispute to block the process. The WTO is headed by a Ministerial Conference of all Members which will meet at least once every two years.[22] Furthermore, it is intended that trade ministers will enjoy greater participation in the WTO's activities, thereby boosting its international standing and enhancing its credibility in domestic political arenas (Hoekman and Kostecki (1995)). The WTO is managed by the General Council in which each member can participate. This strengthened WTO may well result in a more rigorous and efficient enforcement of trade rules, perhaps hastening the process of trade liberalisation. The formation of the WTO sees the original goal of the Bretton Woods conference of 1944 come to fruition, and allows world trade matters to be dealt with in a manner as prominent and authoritative as global monetary and banking issues have been dealt with by the IMF and World Bank.

2.5.5 Post-Uruguay Round.

The Committee on Trade and the Environment (CTE) was formally established on 1st January 1995, with the implementation of the WTO Agreement. On 8th November 1995 the CTE adopted a Report which was then forwarded through the General Council to Ministers at the 1996

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[22] By early 1995 there were 128 members of the GATT/WTO. These are listed in Appendix E, together with the date of each country's accession to the GATT.

Ministerial Conference in Singapore. A number of issues are contained in the CTE's work programme, as laid out in the Report.

One issue to be addressed is the relationship between WTO provisions and trade measures contained in multilateral environmental agreements (MEAs), an issue discussed in Chapter 3. Discussions on this subject have confirmed that the WTO prefers members to tackle transboundary or global environmental problems via such multilateral agreements and that unilateral action is to be avoided. The CTE Report notes that trade measures are often not the most appropriate or the most effective policy instrument, but admits that they can play an important role. Also noted is the fact that few MEAs contain trade measures and no conflict of this nature has yet arisen under the WTO. Nevertheless, the potential is there. Several policies have been discussed to make MEA trade measures compatible with the WTO, including the creation of an 'environmental window' to allow discriminatory trade measures against non-signatories to MEAs. As yet, this proposal has not received consensus support in the CTE.

Also discussed is the appropriate dispute settlement procedure were a dispute between an MEA and the WTO to arise. The WTO states that in the first instance a dispute of this nature should attempt to be settled under the dispute settlement mechanisms contained within the MEA. If the dispute concerns a non-signatory to the MEA, then settlement would occur under the WTO.

A further issue addressed by the CTE Report relates to the export of domestically prohibited goods. Concern was expressed in the mid-1980s by developing country GATT contracting parties, that hazardous substances were being exported to them without them knowing the dangers or the implications of receiving such substances. Since then the

Basil Convention has been established to deal with trade in hazardous substances and the WTO has made it clear that it does not wish to duplicate the work of the Convention. In the CTE Report WTO members agree to support the provisions of the Basil Convention, and it is noted that the WTO may be able to pursue a role which is complementary to the Convention. This role is to be investigated by the WTO.

In May 1997 a WTO Symposium with non-governmental oganisations was held on the subject of trade, environment and sustainable development. The aim of the Symposium was to undertake constructive dialogue between representatives of WTO member governments and business, development and environmental organisations. Topics discussed were mostly quite general although specific details were discussed with regard to the relationship between WTO rules and MEAs. Some representatives proposed amending GATT Article XX, including adding the term 'the environment' to Article XX(b) or allowing exceptions for trade measures taken in accordance with MEAs. Also suggested was the reversal of the burden of proof so that a trade measure in support of an MEA was considered acceptable unless a complainant proved otherwise. The relationship between WTO rules and the Convention on Biodiversity and was also discussed and it was noted that more work was needed to understand the full linkages between the two.

Whilst the non-governmental organisations welcomed the opportunity to interact with the WTO, little constructive progress would appear to have been made, with no attempt made to summarise views or identify consensus positions, throughout the Symposium.

2.6 Conclusion.

To summarise, the GATT has achieved a considerable degree of success in its efforts to reduce the both the size and number of tariffs in international trade. This success has even been extended to the developing world as a result of the Uruguay Round. With regard to the agricultural sector, until the Uruguay Round, little progress had been made in terms of agricultural trade liberalisation, with non-tariff barriers still widely in use. However, as a result of the Uruguay Round agricultural protection is being reduced, and so too is the differential treatment received by the agricultural sector relative to the industrial sector. There is, though, a long way to go. Concerning the prospect of further agricultural trade liberalisation, this would seem to depend largely on the success achieved in reforming domestic agricultural policy. According to Ingersent, Rayner and Hine (1995), this reform should aim to replace price support with direct income support whilst at the same time decoupling this income support from the level of current production. It is extremely likely that agricultural trade reform will take a prominent role in the next round of GATT talks.

The GATT's provisions for the protection of the environment are minimal and there has been little progress since the GATT's inception. Perhaps the most significant development in this area is the fact that the new WTO at least recognises the need to preserve the environment, something the old GATT did not. Nevertheless, the creation of the WTO and the Committee on Trade and the Environment does represent a step in the right direction. However, the CTE and the Symposium with non-governmental organisations have yet to deliver any concrete results despite addressing the key issues. It therefore remains to be seen whether the new WTO will deal with the issue of the environment more effectively than the old GATT.

Chapter 3 analyses the impact of the GATT/WTO's treatment of the environment.

CHAPTER 3.

TRADE LIBERALISATION, GATT / WTO AND THE ENVIRONMENT.

3.1 Introduction.

The extent of the environmental concern arising from the formation of NAFTA, together with GATT's 'tuna-dolphin' decision, has meant that many environmentalists view proponents of free trade with deep rooted suspicion. Esty (1994) claims that the environmental case against free trade can be reduced to four essential points: Firstly, by promoting economic growth, trade may damage the environment through the unsustainable use of natural resources and pollution emissions that threaten the earth's assimilative capacity. Secondly, international environmental agreements may contain trade measures which are illegal under GATT/WTO rules, whilst the market access provisions associated with most trade agreements may, to some extent, limit the ability of nations to implement domestic environmental regulations. Thirdly, countries operating low environmental standards may have a competitive advantage over those countries with higher standards, thus creating pressure to lower standards. Finally, free trade, as it is being implemented through the GATT/WTO, may prevent nations from using trade restrictions to protect their environment.

The suspicion displayed by environmentalists towards advocates of free trade is not one-sided, however, and free traders also view the environmental lobby with distrust. Whilst pointing to the potential environmental *benefits* of free trade, free traders also stress their fears of a growth of 'green' protectionism designed to prevent environmentally harmful goods from entering a country and which can also be used as leverage to encourage other nations to comply with environmental agreements. Since environmental regulation is a potential vote-winning issue, the concern of free traders is that governments will find it politically difficult to refuse to implement such protection, and as a result, the efficiency gains from world trade will be reduced. Furthermore, it is feared that nations may shield domestic markets from the competitive force of the world economy by using protectionism in the guise of environmental measures. Advocates of free trade draw support from economic theory, and particularly the theory of optimal intervention, which suggests that it is not trade *per se* that damages the environment, but rather that the environment is harmed when trade occurs in the presence of externalities. As a result, free traders argue that the optimal solution to the problem is not to alter the global trade regime, but to tackle the externalities directly.

Clearly, the potential for future conflict between the pro-trade and the pro-environment lobbies is considerable. The arguments advanced by each side of the debate will now be analysed in more detail.

3.2 Trade and the Environment

The traditional economic approach to the trade-environment relationship states that it is not trade *per se* that damages the environment, but rather, it is when trade occurs in the presence of market and government failures, or externalities, that the environment is harmed. Although market and governmental failures are interrelated, and are exacerbated by uncertainty and lack of information, it is nevertheless useful to distinguish between them.

Market failures occur when the market fails to properly value and allocate environmental goods, with the result that prices do not cover the full social cost of production.[1] The OECD (1994) outline three causes of market failure. Firstly, if environmental costs such as pollution damage are not included in the prices of goods and services, then such costs have been *externalised* and are hence neglected by the market. Secondly, market failure can also occur if markets fail to take into account the total economic value which society places on environmental assets, where total economic value typically consists of the use value, option value and existence value associated with an asset.[2] Finally, the lack of property rights for environmental assets can also lead to market failure. If property rights cannot be defined then it is likely that the resource will be treated as if it were 'free', thus leading to the over-consumption of the asset. A common fourth cause of market failure, not discussed by the OECD, is the case where markets do not exist even when property rights *are* defined, such as the case of capital markets in less developed countries.

Government failures occur when government policy creates, exacerbates or simply fails to remove, market failures. An example would be the EU's Common Agricultural Policy, as already mentioned. The design of government policy is often heavily influenced by producer interest groups and political factors with the result that the attainment of economic efficiency is not the prime motivation behind such policy. As a result, government, or intervention, failures are prevalent.

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[1] The social costs of production consist of private costs (e.g. wages, rent etc.) plus external costs (e.g. pollution). When prices only cover the private cost, they do not cover the *full* cost of production and as a result an externality is said to exist.

[2] Use values derive from the actual use of an environmental asset, for example, the revenue obtained by selling timber grown in a forest would constitute part of the use value of that forest. Option values reflect our preference to use an environmental asset in the future. An asset may not be used at present, but it is still valued since it provides the opportunity for use at a later date. An existence value is a value which does not derive from the use of an asset. It expresses the value attached to an asset simply because that asset exists. For example, the vast majority of people do not derive any use from Antarctica, but would still value it simply for its existence. Finally, bequest value is often included in total economic value and can represent either a use or non-use value. Bequest value represents the value placed on an environmental asset as a bequest for future generations. It therefore constitutes a future use or non-use value for our descendants.

This traditional approach to the trade-environment relationship which sees environmental damage as resulting from the existence of externalities and not from trade itself, states that the 'first best' solution to environmental problems is not to alter the system of world trade but, instead, to tackle the externalities directly. Indeed, economists generally believe that such externalities should be *internalised*, that is, prices should be made to cover both private and social costs. As an example, consider the pollution produced by a coal mining company in the process of extracting coal. If the price of coal does not reflect this pollution, then society pays for these costs, for example through increased hospital bills due to pollution induced asthma. The internalisation of social costs, and the 'polluter pays' principle on which it is based, means that the producers of coal have to pay these costs, since it is they who caused them. Furthermore, if social costs are fully internalised, consumers decrease consumption of higher priced environmentally damaging goods, instead switching to cheaper, environmentally cleaner goods, thus reinforcing the principle of internalisation.

A distinction has to be drawn, however, between externalities which are global in nature and those which are merely local. Externalities which affect only the immediate environment in which they occur are known as local externalities, an example of which would be noise pollution. At the other extreme are global environmental problems, such as ozone depletion or the greenhouse effect. Externalities of this kind are generally known as global, or pervasive, externalities. This distinction between the two is of relevance to the process of internalisation. The internalisation of a local externality requires the national government to tax, for example, the emissions of the guilty firm. Since the externality is local, it should prove relatively straightforward to identify the affected parties and to estimate the level of taxation necessary to internalise the external cost of the pollution. Whilst this process can prove far more difficult in reality, this difficulty pales into insignificance compared to that encountered when trying to internalise a global externality. As Runge (1994) notes, when externalities are global in nature, their internalisation would result in extremely high implementation and enforcement costs and matters of jurisdiction and sovereignty also have to be considered. Daly (1989) asks us to consider the problems that would be encountered when trying to arrive at the level of taxation necessary to internalise the greenhouse effect. Whilst the physical effects of the build up of greenhouse gases are themselves uncertain, placing a monetary value on the associated economic losses is subject to even greater uncertainty, and would require a calculation that involves a large degree of guesswork. As Runge states, "In short, it is far easier to recommend that environmental externalities be 'internalised' than it is to implement and enforce internalisation." (Runge (1994) p.26).

3.3 How Trade Liberalisation May Help the Environment.

The perceived benefits of free trade stem from the fact that it allows individuals and nations to specialize in those sectors in which they are relatively more efficient. Adam Smith is generally seen as the originator of this viewpoint, although it is David Ricardo who is associated with the principle of comparative advantage itself. Writing in 1817, Ricardo sums up the theoretical argument for free trade;

> "Under a system of perfectly free (international) commerce, each country naturally devotes its capital and labour to such employments as are most beneficial to each. This pursuit of individual advantage is admirably connected with the universal good of the whole. By stimulating industry, by rewarding ingenuity, and by using most efficaciously the peculiar powers bestowed by nature, it distributes labour most effectively and most economically: while, by increasing the general mass of productions, it diffuses general benefit, and binds together, by one common tie of interest

> and intercourse, the universal society of nations throughout the civilised world." (Ricardo (1973) p.81).

In a fully liberalised global trade regime resources will be allocated to the least-cost and highest return production activities thus ensuring that production occurs in the most efficient manner possible. This obviously implies that natural resource use will also be efficient, thus minimising the quantity of input needed per unit of output, and thereby also keeping associated wastes to a minimum. Furthermore, as the OECD (1994) point out, if trade maximises allocative efficiency in this manner, then economic activity should be allocated in accordance with the environmental capacities and conditions of different countries, thus, theoretically, keeping environmental stress to a minimum. However, as Hudson (1992) argues, free trade will only efficiently allocate natural resources if environmental externalities are fully internalised. Clearly, this is not the case, and it is uncertain whether policy should proceed *as if* all external costs were internalised.

A related issue is the environmental impact of the *composition* effect associated with trade liberalisation. After trade liberalisation, countries will specialise to a greater extent in those sectors in which they possess a comparative advantage. As Grossman and Krueger (1993) point out, if comparative advantage arises due to differences in factor abundance and technology, each country will shift resources into sectors which make intensive use of these factors. The resultant impact on the environment is difficult to predict and will depend on whether pollution intensive activities expand in those countries with greater pollution legislation. However, if comparative advantage arises due to differences in environmental legislation, then the composition effect associated with trade liberalisation is likely to prove detrimental to the environment as countries will specialise in those sectors in which their own environmental legislation is weakest.

Liberalised trade should, however, enable nations to overcome resource constraints which may previously have limited their growth potential. As the scale of economic activity expands, then so too do the financial resources available to protect the environment. Indeed, there is evidence that increases in income are essential if the developing world is to improve the quality of the environment. Voigt (1993) states that the environmental problems currently facing Mexico can all be traced to a common source, "That source is the lack of economic resources available to adequately control the environmental effects of development in the border region." (Voigt (1993) p.329). Thus, by raising the level of national income through economic growth, trade can facilitate environmental improvements at both the level of the firm and at the level of government.

A further means by which trade liberalisation may benefit the environment is through the exchange of environmentally clean products, services and technologies. According to the OECD (1994), the worldwide market for environmental equipment and services is valued at $200 billion and growing at a rate of 5.5% per year. If trade allows this market to expand, then countries will have greater access to both ecologically cleaner products *and* resource efficient production methods, thereby ensuring that their own future production will be environmentally improved. Thus, output may not be produced in the same manner following trade liberalisation. This so-called *technique* effect may also arise as a result of the increase in incomes associated with trade liberalisation. As incomes grow and more basic needs are met, individuals may start to demand a cleaner environment. This suggestion, that the environment may be considered a luxury good, implies that governments may have to respond to these increased demands by increasing legislation and generally ensuring that output occurs in a manner which is more beneficial to the environment.

Finally, trade liberalisation will remove many trade-distorting policy measures which, themselves, have proved to be environmentally damaging. The very existence of such measures means that resources are not being allocated as efficiently as they could be, and thus both the location and intensity of technology, production and consumption are distorted. An example of protection of this nature is the EU's Common Agricultural Policy (CAP). The CAP's system of guaranteeing prices to farmers has resulted in increasingly intensive production methods and considerable overproduction of foodstuffs.[3] For example, Friends of the Earth (1992) estimated that there were 25 million tonnes of surplus cereals and over 800,000 tonnes of beef in storage in the EU in 1992. Furthermore, Friends of the Earth also state that in 1990 the EU spent nine billion pounds just disposing of and destroying this surplus production. The removal of a system of this nature would at least mean that there is no incentive to produce quantities which are considerably in excess of the market's requirements.

The above arguments are typically advanced by advocates of free trade in response to claims that the impact of trade liberalisation on the environment is likely to be of a pernicious nature. The foundation behind such claims will now be considered.

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[3] The CAP provides an incentive for farmers to produce as much as possible with the resultant environmental impact stemming from the removal of hedgerows and the increased use of artificial inputs, for example.

3.4 How Trade Liberalisation May Damage the Environment.

3.4.1 Trade Liberalisation and Economic Growth.

The prevalence of externalities, due in part to the difficulty of internalisation, means that trade liberalisation may exacerbate environmental damage. One reason for this is the *scale* effect associated with free trade. It was stated above that perfectly free trade will ensure that resources are utilized in the most efficient manner possible, thus minimising inputs per unit of output. Indeed, this is the case in a static framework. However, once we enter a dynamic framework then it is likely that liberalised trade will lead to an expansion of markets and hence economic growth. The increase in income associated with such growth may mean that nations now find themselves with greater resources to protect the environment, but the environmental impact of such an expansion in the scale of production may be considerable. This relationship between economic growth and the environment is analysed in detail in the next three chapters.

However, one way in which trade liberalisation, and the resultant increase in the volume of world trade, directly affects the environment is through increased product transportation. Madeley (1992) has estimated that the transport involved in international trade already accounts for one eighth of world oil consumption. Pearce (1992) states that this is likely to worsen since the EU's Single Market is predicted to increase transfrontier lorry traffic by 30-50%. As long as fuel prices continue to externalise most environmental costs, product transportation will continue to expand, further damaging the environment. Clearly, as international markets expand as a result of trade liberalisation, the environmental impact of the resultant increase in transportation looks set to become an issue which receives increasing attention.

3.4.2 The Ability to Implement Environmental Regulations.

An additional charge which environmentalists often level against advocates of free trade is that trade liberalisation limits the ability of nations to protect the environment, irrespective of whether the nations are operating in a unilateral or multilateral capacity. The abatement of global externalities has generally necessitated a multilateral response in the form of international agreements such as the Montreal Protocol (1987). A potential problem from the GATT/WTO point of view however, is that many agreements of this kind contain trade-based enforcement mechanisms to prevent free riders from undermining the effectiveness of the agreements.[4] For example, the Montreal Protocol, which aims to protect the ozone layer by reducing the use of CFCs, forbids its signatories from trading with nonsignatories in products containing CFCs.[5] Furthermore, as Pearce points out, the agreement also commits signatories to ban the trade of products *made with CFCs*, but not actually containing them. This is clearly a trade restriction due to the existence of a production externality and, as will be seen below, would therefore appear incompatible with GATT/WTO. It has been suggested, however, that trade restrictions to enforce compliance *are* fully justified since those nations who fail to sign the treaty would otherwise effectively obtain a competitive advantage by continuing to use CFCs rather than adopting more expensive alternatives (Esty (1994), Reinstein (1991)).

It is clear that if nations are signatories to both the GATT/WTO and the Montreal Protocol, then they are likely to be subject to conflicting

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[4] Examples of other international environmental agreements which contain the threat of trade restrictions are the Basel Convention which regulates the trade of hazardous waste, and the CITES agreement on trade in endangered species.

[5] Hudson (1992) provides the example of South Korea, which is a party to the GATT but has not signed the Montreal Protocol. For several years South Korea has been expected to challenge the Montreal Protocol as illegal under GATT rules.

obligations. The Vienna Convention on the Law of Treaties (1969) states that the obligations of whichever treaty is 'later in time' should prevail - providing the two treaties address the same subject matter, and providing that the later treaty does not specifically abrogate the earlier treaty. Whilst it could be reasonably argued that the two treaties are not concerned with the same subject matter, other potential problems arise. First, the GATT is technically not a treaty and, even if it is, it is not clear whether the creation of the World Trade Organisation makes this more recent than the Montreal Protocol. Furthermore, as Runge points out, Article 34 of the Vienna Convention states that even if the agreement is later in time it cannot bind a nonsignatory nation without their consent, unless the agreement becomes customary international law.

At the time of the Montreal Protocol's signing it was felt that the agreement was GATT-consistent, due to the headnote to GATT Article XX. This states that exceptions to the GATT's rules are allowed providing that "such measures are not applied in a manner which would constitute a means of arbitrary or unjustifiable discrimination *between countries where the same conditions prevail.....*" (GATT Article XX from Pearce (1992)). Emphasis added). It was believed at the time (1987) that conditions in nonsignatory nations were different to those of signatory nations and thus trade restrictions were allowed. However, even if this is indeed the case, Esty suggests that it is unlikely that the GATT/WTO would dispute the imposition of a trade restriction if it were in response to a widely supported international environmental agreement. This is obviously far from certain, though, and the fact remains that the use of trade restrictions in support of such an agreement is illegal under GATT/WTO rules.

As stated in Chapter 2, however, the issue of the relationship between the WTO and multilateral environmental agreements is now beginning to be discussed by the Committee on Trade and the Environment and was also addressed by the Symposium on Trade, Environment and Sustainable Development. The outcomes of these discussions remain to be seen.

This threat to international environmental agreements is another reason why environmentalists claim that trade liberalisation through the GATT/WTO is environmentally damaging. However, many also claim that the GATT/WTO limits the implementation of environmental legislation at a *national* level. In particular, it is feared that enforced market access agreements will have the effect of harmonising environmental standards at the lowest common denominator, thus preventing nations from implementing stricter standards, or from restricting the importation of environmentally harmful goods. In response, free traders fear the growth of 'green protectionism' and claim that, in actuality, the GATT/WTO does provide considerable scope for the protection of a nation's environment. Indeed, it is argued below that the existence of an externality which arises when the imported good is consumed (a consumption externality) is a legitimate reason for a trade restriction, providing certain conditions are met. However, environmentalists criticise GATT/WTO for its failure to allow trade restrictions in order to remove those externalities which arise during the production of the good in the exporting country (production externalities). This inability of nations to distinguish between 'like products', even if they have very different production methods, is very difficult to justify on environmental grounds. Indeed, environmentalists therefore claim that, by forbidding the restriction of imports in response to a product's method of production, the GATT/WTO is clearly failing to recognise the transnational nature of many of today's environmental problems.

With regard to the harmonisation of standards, the post-Uruguay Round Sanitary and Phytosanitary Code and the Technical Barriers to Trade Agreement both clearly state that nations should aim to comply with common standards.[6] Many environmentalists object to this notion of harmonisation, however, fearing a loss of sovereignty as nations lose control of their environmental regulations and standards fall to the baseline level. Interestingly, those in favour of trade liberalisation are not united in their support for harmonisation either. One claim is that harmonised standards will remove the comparative advantage that nations possess due to their high assimilative capacity (Rauscher (1994)).[7] Alternatively, Nordhaus (1994) assesses whether the harmonisation of environmental policies is compatible with the goal of economic efficiency, and distinguishes between policies aimed at global externalities, and those aimed at local environmental issues. Using standard neoclassical analysis, Nordhaus argues that by treating global environmental problems as traded goods which will display price equalisation, economic efficiency requires that nations should harmonise their environmental regulations (see Appendix F, diagram 1). The reasoning behind this assertion is that if pollution is global, then the marginal benefits of emissions reductions are equal across regions (country 1 and country 2 face the same marginal benefit curve), whilst the marginal abatement costs are likely to vary. Abatement of emissions should occur up to the point where the marginal benefit of this abatement, in each region, is equal to the marginal cost. By setting the same tax level per unit of emissions (T*), both nations can equate their marginal benefit and marginal cost - hence harmonization. It should be noted that, for Nordhaus, harmonisation refers to all nations setting the same level of taxation per unit of emission and not the use of harmonized quantitative standards which, for example, force both nations to reduce a pollutant by a given percentage.[8] Indeed, if the level of

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[6] See the Sanitary and Phytosanitary Code paragraph 9 and the Technical Barriers to Trade Agreement Article 2:4.

[7] The assimilative capacity is the ability, or capacity, of the environment to break down waste and pollution. This capacity will vary from region to region due to differences in climate, topography etc.

[8] It can be shown that emissions fees or marketable permits are both least-cost ways of achieving a given level of emissions reduction and are hence more efficient than the use of quantitative standards (Pearce and Turner (1990)).

taxation is equated both nations will reduce emissions by a different amount, but this will be the optimal amount for each nation, and is hence efficient. With regard to local externalities, Nordhaus treats them as non-traded goods and thus their prices will vary across regions (see Appendix F, diagram 2). Since both marginal benefits and marginal costs now vary, economic efficiency requires that each region sets a different level of taxation (T1 for country 1 and T2 for country 2). The intuition behind this result is that some countries, e.g. low income countries, have higher abatement costs than others, whilst having lower levels of environmental damage. In terms of efficiency, a nation of this nature should have a lower level of emissions reduction and a lower pollution tax, than other countries. Thus, to summarise Nordhaus's conclusions, environmental policies (emissions fees or marketable permits, but generally not quantitative standards) designed to address global environmental problems should be harmonised across regions. On the other hand, policies to tackle local environmental externalities should not be harmonised (emissions fees, marketable permits *or* standards).

It should be pointed out that Nordhaus's recommendations stem purely from his aim to attain economic efficiency. In reality, however, economic efficiency is just one of a number of criteria on which policy decisions are made, with the issue of equity being of great importance. It is therefore unlikely that policy recommendations made on economic efficiency grounds alone would ever come to fruition. Indeed, it could be expected that Nordhaus's recommendations would experience significant opposition, not least from lobby groups and developing country governments, if they resulted in the implementation of a global uniform carbon tax, for example. In reality, complex negotiations, particularly between developed and developing countries, are likely to be required if such a policy is to be implemented.

It is interesting to note however, that complete harmonisation of environmental standards is considered by some to be *necessary* to obtain economic efficiency. For example, Esty notes,

> "If...every nation and all their political subdivisions have complete autonomy to set their own radically different environmental standards, trade could grind to a halt. Inconsistent production, testing, labelling, packaging, and disposal requirements could become serious trade barriers, reducing the opportunities to achieve scale economies and gain market access - economic virtues that translate into broader product choice, better service and lower prices for consumers." (Esty (1994) p.173).

It does not, therefore, appear that the harmonisation of only global environmental policies is accepted by all as compatible with the goal of economic efficiency.

To summarise, it is clear that GATT/WTO based trade liberalisation has the potential to hinder the implementation of *international* environmental agreements, where such agreements include the threat of trade restrictions. With regard to *national* environmental legislation, it would appear that the Technical Barriers to Trade Agreement of the GATT/WTO seeks to harmonise *all* national environmental standards. However, as stated above, from an economic point of view Nordhaus does not believe this to be sensible. Such a policy may also be unwise from an environmental point of view, since standards aimed at local environmental issues are generally ill-suited to harmonisation and may be dealt with more effectively at a national level. This point is discussed in more detail in Chapter 8. The above clearly illustrates that, in the absence of the necessary environmental amendments to the GATT/WTO, trade liberalisation may hamper the implementation of national and international environmental legislation.

3.4.3 Will Trade Liberalisation Force Environmental Standards Downwards?

Advocates of the harmonisation of environmental standards often claim that free trade in the presence of divergent environmental standards provides the nation with the lowest standard with a competitive advantage. As a result, it is feared that there will ensue a 'race to the bottom' as nations try to undercut the environmental standards of their competitors. This claim, however, is not accepted by all.

Nordhaus (1994) dismisses the fear of a 'race to the bottom' by stating that it is not in a country's interests to lower the stringency of its environmental standards. Utilising the logic behind optimal tariff theory, Nordhaus claims that it would be optimal for a large country to *tax* its exports rather than subsidise them by lowering standards, since such a policy would turn the terms of trade in the country's favour by raising export prices.[9] As a result, Nordhaus claims that there is no economic incentive for a large country to enter a 'race to the bottom'.

Although the subsidisation of exports is against national interests as Nordhaus claims, he concedes that nations *will* often subsidise exports due to the lobbying of producer interest groups or because nations do not always operate in an economically rational manner, either through choice or ignorance.

Others have adopted a different approach by arguing not that it is economically irrational to lower standards, but that nations would not *need* to lower them. Indeed, many have argued that the loss of competitiveness

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[9] In the case of small countries who are price takers and hence cannot affect their terms of trade, Nordhaus states that environmental policies will be set in the traditional way by equating marginal costs and marginal benefits. These countries cannot engage in any race since they are not in a position to set prices which undercut their competitors.

associated with environmental regulation is in fact minimal, and hence so too is the pressure to lower standards. Dean (1991) found that abatement costs are a small proportion of a firm's total costs and hence have little impact on the firm's competitiveness. In addition, Walter (1973,1982) found that abatement costs in US export industries were only 1.75% of total costs, whilst Tobey (1990) found environmental regulation costs were under 1.85% for forty industries, and between 1.85 and 2.89% for twenty four industries. Jaffe *et al.* (1995) also found little evidence that environmental regulations have had a significant adverse affect on competitiveness. A recent study by Janicke *et al.* (1997) found no empirical evidence to support the 'pollution haven' hypothesis i.e. that firms have relocated abroad in response to stringent domestic environmental regulations, again suggesting that such regulations have little impact on competitiveness. Finally, the 'Porter hypothesis' (Porter and van der Linde (1995)), actually suggests that properly designed environmental regulations will stimulate innovation that may partially, or more than fully, offset the initial compliance cost. If this hypothesis is correct then firms may not benefit from partaking in a 'race to the bottom'.

Esty, however, claims that the interstate competition for new investment experienced by the US in the 1940s, 1950s and 1960s would suggest that competitiveness concerns associated with environmental regulation were a significant factor in where firms chose to invest. Furthermore, he provides evidence of the major role played by interstate competition in the push for the *national* harmonisation of environmental standards. Similarly Esty believes that intercountry competitiveness concerns which may provide incentives for nations to lower their environmental regulations, necessitate the *international* harmonisation of such regulations.

Revesz (1992) finds little empirical evidence of a 'race to the bottom', but states that were such a race to take place, the harmonization of environmental standards would not be the answer. Instead, this would simply have the effect of moving the downward spiral to another area of regulation. Esty, however, believes this would be a positive achievement since the environment "is more vulnerable than almost any other area of regulation to welfare-reducing market failures in the absence of government intervention." (Esty (1994) p.156).

Clearly, the impact of environmental regulation on competition is uncertain and empirical study throws little light on whether a 'race to the bottom' will occur.

3.4.4 The Use of Trade Restrictions to Protect the Environment.

The GATT/WTO's environmental provisions have already been outlined in the previous chapter, but it will here be considered whether GATT/WTO rules allow a nation to restrict the importation of a product which subjects the importing country to an externality. There are two situations in which this may occur. Firstly, the importing country may be subjected to a *consumption* externality. For example, the EU considered it was subjected to an 'externality' when it consumed US beef containing growth hormones. Alternatively, the importing country may face a *production* externality, whereby injury is caused by the actual production of a good.

With regard to consumption externalities, Pearce states that it would appear from various GATT disputes that the existence of such an externality would be a legitimate reason for a restriction under Article XX provided a number of conditions are met. Firstly, there must be evidence of the externality, and any resultant restriction must be universally applied. Secondly, the trade restriction must be justified through one of four tests which exist under GATT/WTO. The first of these is the 'necessary' test which stems from Article XX(b) and essentially states that there must be no other way in which the party could remove the externality. Article XX(g) provides a second test which assesses whether the trade restriction is 'primarily aimed at' conservation and is not simply a means of protecting the domestic market. A third test originates from the Agreement on Technical Barriers to Trade which states that a trade restriction must be shown to be 'proportional' to the benefits which result from the removal of the externality. Finally, and differing little from the 'primarily aimed at' test, Article XX states that a trade restriction must not be applied in a way that constitutes a 'disguised restriction on international trade'. As Runge (1994) points out, all of these tests effectively weigh the environmental benefits resulting from the removal of the externality with the harm that stems from the disruption to trade. Providing the disruption to trade does not exceed the resultant environmental benefits, the trade restriction will generally be justified under GATT/WTO rules.

The GATT/WTO, however, does not appear to allow trade restrictions in order to remove a production externality. Pearce suggests that the GATT/WTO has simply adopted the principle that an importing nation does not have the right to interfere with the production and processing methods of another country. Although, this principle has been criticised by environmentalists, the GATT/WTO does have its reasons for maintaining the distinction between consumption externalities and production externalities. Since the GATT's inception, the agreement has tried to limit the number of excuses that could be used to implement trade restrictions, preferring contracting parties to implement domestic policies instead. The GATT/WTO is clearly concerned that if nations are allowed to distinguish between 'like' goods which have different production methods there would be a risk of countries implementing blanket import restrictions. However, as already stated, the post-Uruguay Round Technical Barriers to Trade Agreement (TBTA) does allow trade restrictions for products whose related processes and production methods do not conform to regulations - subject to strict conditions. To be covered by the TBTA, the processes and production methods must leave a trace in the final product, so, for example, a regulation stating that all bottles must be made from recycled glass would be covered by the Agreement, but a regulation stating that tuna must not be caught in drift-nets would not be covered. Any regulations which are not covered by the TBTA are subject to the generally less restrictive regular GATT rules, which in contrast to the TBTA, do not appear to allow nations to interfere with the processes and production methods of other nations. In this sense at least, the revised TBTA would seem environmentally beneficial, although it would appear that the outcome of the 'tuna-dolphin' dispute would not have been different had the amended TBTA been in place. Although the TBTA now considers regulations which concern product related processes and production methods, GATT Article XX still fails to allow a distinction to be drawn between 'like' products which are the result of very different processes and production methods.

To summarise, GATT/WTO does appear to allow trade restrictions in order to prevent environmental damage which results from the *consumption* of a good. However, with regard to damage resulting from the *production* of a good or service, trade restrictions are generally not allowed under GATT/WTO. Whilst the Technical Barriers to Trade Agreement does allow processes and production methods to be regulated, this is only if they leave a trace in the final product. Thus, trade restrictions are not allowed in support of regulations which control those foreign production processes which are not detectable in the final product. Furthermore, GATT/WTO does not allow nations to implement trade restrictions in response to environmental damage which occurs *outside* their jurisdiction. Indeed, the US attempt to justify its ban of Mexican tuna in 1991 using GATT Article XX(b) was deemed inapplicable by GATT since this exception does not cover damage which occurs outside the jurisdiction of the trade-restricting country.[10]

As outlined in Chapter 2, the emergence of the World Trade Organisation, which encompasses all those who accept the entire Uruguay Round Agreement, would, from an environmental point of view, appear to be a (small) step in the right direction. It remains to be seen, however, whether the WTO will address some of the environmentalists' criticisms, above.

3.5 Conclusion.

An analysis of the relationship between world trade and the environment clearly shows such a relationship to be a complex one. It is possible, for example, that free trade will prove to be environmentally beneficial. Trade liberalisation in a static framework should lead to efficiency gains which reduce the amount of environmental inputs used per unit of output. Furthermore, once a dynamic framework is entered, the generation of economic growth may mean that additional resources are available with which to tackle environmental problems, whilst the demand for a cleaner environment may also increase. A liberalised global trading system should also augment the exchange of environmentally beneficial products, services and technologies. Finally, by removing trade-distorting policy measures, free trade will ensure that the location and intensity of production is not distorted.

However, trade liberalisation also contains the potential to damage the environment in the absence of appropriate (domestic) policy measures. As Esty points out, the environmental case against trade liberalisation can be reduced to four key issues. The first of these is the ability of the environment to deal with the economic growth which results from

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[10] Presumably, the TBTA also forbids trade restrictions in support of standards aimed at *extraterritorial* environmental damage.

liberalised trade, in a dynamic framework. This, in turn, is a complex issue which is dealt with in Chapters 4, 5 and 6. The internalisation of externalities would be a significant improvement but is likely to entail monumental difficulties, not the least being the fact that countries will not *unilaterally* internalise social costs, yet there is no mechanism to co-ordinate *multilateral* internalisation.[11]

The second issue is whether the GATT/WTO suppresses the implementation of environmental legislation, both at a national and international level. At present, any multilaterally accepted environmental agreements which contain the threat of trade measures to enforce compliance are illegal under WTO rules. With regard to *national* environmental legislation, the WTO aims to harmonise all environmental regulations, irrespective of whether they are aimed at local or global environmental problems. As stated above, such a policy may prove economically and environmentally damaging. In addition, the WTO does not allow nations to distinguish between 'like products' which have very different production methods. Nations have traditionally been allowed to do as they please within their own borders, but in an ecologically inter-dependent world, where production processes in one country can affect the global environment, such a notion may be out-dated.

The third environmental grievance is the issue of whether trade liberalisation provides those nations operating low environmental standards with a competitive advantage - hence offering an incentive for nations to lower standards. It was seen that the extent of any competitive

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[11] At present, very few environmental costs have been internalised in the price of goods. Warren (1995) gives the example of the EU's attempt to implement a Europe-wide tax, at ten dollars per barrel, to be levied on all energy consumption. Although most of the largest fuel using companies obtained concessions drastically reducing the impact of the tax, Warren claims that they also ran a successful lobby which resulted in the tax effectively being side-stepped. Furthermore, although some northern European countries have introduced such a tax domestically, this has generally been at a very low level and intended more to raise revenue than to change consumption habits.

advantage which results from low environmental standards is empirically uncertain, and hence so too is the strength of any pressure to lower standards.

The fourth, and final, issue is whether GATT/WTO based trade liberalisation will allow the use of trade restrictions to protect the environment. It has been argued above that the GATT/WTO will allow trade restrictions to be implemented in response to a *consumption* externality, but not to tackle a *production* externality apart from in limited instances under the Technical Barriers to Trade Agreement. Furthermore, trade restrictions are not allowed to be implemented in response to environmental damage which occurs *outside* the jurisdiction of the trade-restricting country, nor are trade restrictions to be implemented *unilaterally.*

Whilst the above are the environmentalists' four key areas of conflict with those who advocate trade liberalisation, the foundations of this conflict stem largely from a clash of cultures and ideals. Although the goal of free traders is to maximise welfare, environmentalists tend to consider efforts to liberalise trade as being fuelled by the quest for profits and jobs - in short, purely anthropocentric, materialistic goals. In contrast, environmentalists consider *their* goals to be far more worthy, largely from an ethical or moral point of view. They concern themselves with the well-being of *all* species, not just humans, together with the protection of the earth in general. As a result of these ideals, the environmental case against the GATT/WTO is more fundamental than is perhaps suggested by the analysis of the four issues above. For instance, an inherent presumption within the GATT/WTO is that the gains from trade outweigh any losses from environmental damage which may occur as a result of trade. As Pearce (1992) argues, the implication of this presumption is that all trade restrictions are wrong and hence whichever party implemented the trade restriction has to justify it. Environmentalists view this fact as evidence of the biased nature in which GATT/WTO deals with trade-environment disputes. Indeed, Friends of the Earth (1992) claim that the burden of proof should be shifted to those parties wishing to challenge the adoption of an environmental trade restriction. They argue that this would go some way towards showing that the GATT/WTO does not always put the interests of trade before those of the environment. Such a reversal in the burden of proof, however, would significantly increase the potential for countries to implement trade restrictions to protect domestic industries, under the guise of environmental protection. The GATT/WTO is clearly wary of increasing the ability of countries to distort trade patterns and reduce welfare.

An additional criticism often raised against the GATT/WTO is the fact that the Agreement itself is effectively negotiated in secret. Environmental (or health or consumer) non-governmental organisations are typically not allowed to observe or participate in GATT/WTO meetings. As Shrybman (1990) states, "As trade negotiations take place, and are concluded, in private, democratic institutions that are increasingly willing to respond to public pressure to protect the environment, are circumvented. By characterising environmental regulation as a non-tariff trade barrier, discussion can be removed to a less public forum, and one more sympathetic to the interests of those opposed to environmental regulation." (Shrybman (1990) p.32). However, as mentioned in Chapter 2, the Symposium on Trade, Environment and Sustainable Development which took place with non-governmental organisations, illustrates that the WTO is willing to listen to the views of such organisations. Furthermore, these organisations can lobby national governments thereby indirectly influencing the decisions of the GATT/WTO.

The preceding analysis would seem to suggest that the GATT/WTO has the potential to have a major influence on the scale and character of international natural resource use and pollution. Chapter 8 discusses the numerous policy implications which arise from this discussion of the GATT/WTO's treatment of the environment.

CHAPTER 4.

ECONOMIC GROWTH AND THE ENVIRONMENT.

4.1 Introduction.

This chapter examines the historical treatment of the relationship between the economy and the environment in economics and the environmental literature. It will be seen that the classical economists of the eighteenth and nineteenth centuries possessed an awareness of social and environmental limits to economic growth, although the rise of neoclassical economics generally neglected such factors. The 'limits to growth' debate of the 1960s and 1970s brought the issue to the fore and questioned whether continued economic growth was feasible and whether it was actually beneficial to society and the environment. It will be seen that the potential environmental limits to growth are twofold; firstly they originate from the possibility of natural resource exhaustion; and secondly, they stem from the limited capacity of the environment to assimilate pollution. There is much uncertainty surrounding both limits. The social limits to growth question the welfare which is derived from economic growth and suggest that an increase in the growth rate of GNP is not in fact synonymous with an increase in welfare. Despite the ferocity of the debate, the views of the political mainstream remained intact - technological advance will ensure that environmental limits are not reached and as such, economic growth unequivocally increases the welfare of society.

The notion of sustainable development, which arose during the 1980s, will then be examined and, in particular, its treatment of the economy-environment relationship. A common theme in most definitions of sustainability is intergenerational equity, which is to be achieved by maintaining the capital stock over time. A distinction will be drawn between 'weak' and 'strong' forms of sustainable development, the difference between the two stemming from differing opinions of the nature of the capital stock that is to be maintained. It is claimed that, typically, weaker forms of sustainable development take economic growth to be complementary to the environment, whilst stronger forms posit the existence of environmental limits to growth. The chapter then moves on to consider the adjustments necessary for the transition to sustainable development and, in particular, the modifications needed to transform GNP into a more successful indicator of welfare and production.

4.2 The Classical Economists and Growth. An Awareness of Both Social and Environmental Limits.

T.R. Malthus's *Essay on the Principle of Population* (1798) contains the central theme that the potential capacity for population growth is greater than the capacity for increased food production. As Malthus states; "...the power of population is indefinitely greater than the power in the earth to produce subsistence for man.", (Malthus (1970) p. 71).

Such a claim stems from Malthus's belief that population, as long as it is not restricted by a scarcity of resources, will increase geometrically, whilst agricultural production necessarily increases arithmetically.[1] He therefore concludes that the fundamental cause of poverty is the pressure which population growth places on resources. The unsavoury implication of Malthus's *Essay* is that since poverty is the consequence of the natural laws governing the growth of food and population, any attempts by the government or the people to remove such poverty will be futile. It is this fact which the critics of Malthus found most unpalatable. Marx, for one,

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[1] In later editions of the *Essay* the arithmetic nature of increases in food production was replaced (or accompanied) by the law of diminishing returns on land.

claimed that by blaming poverty on natural processes Malthus effectively exonerated social injustice and private ownership of any responsibility.

Whilst the writings of Malthus clearly relate more to the growth of the population than to the growth of the actual economy, Malthus's importance stems from his recognition of the possible existence of natural constraints to human activity and his discussion of the relationship between natural resources and human welfare (poverty).

A commentary on the social impact of rapid economic expansion is provided by the Swiss economist Sismondi who witnessed the effect of unrestrained economic activity during the British industrial revolution. As Wall (1994) points out, Sismondi was highly critical of the anti-human elements of such expansion. In 1819 he wrote;

> "In this astonishing country, which seems to be submitted to a great experiment for the instruction of the rest of the world, I have seen production increasing whilst enjoyments were diminishing. The mass of the nation here, no less than philosophers, seems to forget that the increase of wealth is not the end in political economy, but its instrument in procuring the happiness of all. I sought for this happiness in every class, and I could nowhere find it...." (Sismondi (1847) p.205 (written in 1819)).

However, of the classical economists, the work of John Stuart Mill is perhaps the most relevant to the economic growth debate. Indeed, in tackling the social and environmental implications of continued industrial expansion, Mill echoes many sentiments expressed today.

> "I confess I am not charmed with the ideal of life held out by those who think that the normal state of human beings is that of struggling to get on; that the trampling, crushing, elbowing and treading on each other's heels which form the existing type of social life, are the most desirable lot of

> human kind, or anything but the disagreeable symptoms of one of the phases of industrial progress." (Mill (1871) p.328 (written in 1848)).

Mill is critical of the continual quest to increase production and accumulation and questions why such activity "excites the congratulations of ordinary politicians".

> "I know not why it should be a matter of congratulation that persons who are already richer than anyone needs to be, should have doubled their means of consuming things which give little or no pleasure except as representative of wealth....It is only in the backward countries of the world that increased production is still an important object: in the most advanced, what is economically needed is a better distribution..." (ibid., p.330).

However, Mill's concern goes beyond the social effects of growth and the implications for the environment are duly considered.

> "Nor is there much satisfaction in contemplating the world with nothing left to the spontaneous activity of nature; with every rood of land brought into cultivation, which is capable of growing food for human beings; every flowery waste or natural pasture ploughed up, all quadrupeds or birds which are not domesticated for man's use exterminated as his rivals for food, every hedgerow or superfluous tree rooted out, and scarcely a place left where a wild shrub or flower could grow without being eradicated as a weed in the name of improved agriculture." (*ibid.*, p. 331).

Whilst such a concern for the environment was rare in the mid-nineteenth century, in general, the classical economists, like the French physiocrats before them, stressed the importance of nature to the economic process. The advent of neoclassical economics generally neglected this link between nature and the economy, albeit with several notable exceptions.[2]

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[2] Alfred Marshall was, however, aware of nature's positive contribution. "In a sense, there are only two agents of production, nature and man....But on the other hand, man is

One such exception was A.C. Pigou who, in 1920, became the first to analyse the impact of pollution on the economy. In his analysis, Pigou distinguished between the private costs of production (i.e. wages, raw materials etc.) and what he called the *social* costs. The social costs are the *full* costs faced by society and consist of private costs plus external costs, or externalities, which arise from pollution. In later years, Pigou widened his analysis, and considered external costs to encompass far more than pollution. As Kapp (1950) points out, Pigou lists the following as examples of external costs, "the destruction of the amenities and lighting of neighbouring sites by the construction of a factory in residential districts,...the wearing out of the surfaces of roads by motor cars...and the increase in expenditures for police and prisons made necessary by the production and sale of intoxicants." (Kapp (1950) p.38). Although Pigou's analysis of social costs is clearly far-reaching, for Kapp, the fact that it takes place, not within the main body of value and price, but in the sub-discipline of welfare economics, illustrates that in neoclassical economics, "the phenomenon of social costs is still regarded as the exception rather than the rule." (ibid., p.8).

An additional exception to the neoclassical neglect of the environment was H. Hotelling, who, in 1931, provided an analysis of non-renewable resource use. Hotelling's main contribution was to show that, in certain circumstances, the rent on a resource (the price of the resource net of extraction costs) would increase over time at a percentage rate equal to the resource owner's discount rate. Indeed, this relationship has since become a fundamental principle of non-renewable resource use known as the Hotelling rule.

The relative neglect of environmental issues within neoclassical economics, despite the above exceptions, meant that the implications of

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himself largely formed by his surroundings in which nature plays a great part." (Marshall (1920) p.116).

economic growth for the environment were largely ignored for many years. The 'Keynesian Revolution' of the 1930s did little to change this.

4.3 The Environmental Limits to Growth.

Public awareness of the relationship between the economy and the environment increased considerably during the 1960s, due not least to the publication of Rachel Carson's *Silent Spring* in 1962. Carson examined the impact of man's indiscriminate use of chemicals, in the form of pesticides and insecticides, and predicted catastrophe if practices remained unchanged.

In 1966, Kenneth Boulding produced his seminal article *The Economics of the Coming Spaceship Earth,* in which he examined the relationship between production, resource depletion and environmental degradation. Boulding highlighted the danger of steadily increasing production levels, both in terms of reducing finite resource stocks and in terms of environmental pollution. As a means to illustrate this danger, he refers to the current open economy as the 'cowboy economy' and believes it to be characterised by reckless and exploitative economic activity - activity undertaken as if the earth's resources were in limitless supply. The lifetime of this cowboy economy is limited, however, and will be replaced by the 'spaceman economy' of the future;

> "...in which the earth has become a single spaceship, without unlimited reservoirs of anything, either for extraction or pollution, and in which therefore, man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form..." (Boulding (1966)).

The volume of production, or more accurately the throughput from factors of production (a proportion of which are from the finite stock of non-renewable resources) to output (and waste and pollution) is the cowboy economy's measure of success, and should be maximised accordingly. In contrast, such throughput is to be minimised in the spaceman economy and hence the existence of economic growth is no longer indicative of a successful economy. Furthermore, in this economy of the future, it is the actual nature of the capital stock which is of importance, and in particular its quality, extent and complexity, including the state of human bodies and minds.

It is also interesting to note that Boulding does not believe it will be very long before the cowboy economy is replaced by its new incarnation; "The shadow of the future spaceship, indeed, is already falling over our spendthrift merriment." He also notes that, surprisingly "...it seems to be in pollution rather than in exhaustion that the problem is first becoming salient." (*ibid.*).

With these concerns in mind, Donella and Dennis Meadows and a team from the Massachusetts Institute of Technology produced a report for the Club of Rome's Project for the Predicament of Mankind entitled *The Limits to Growth*. A world model was constructed to estimate the future impact of continuous exponential growth under a number of different assumptions. The 'standard' world model assumed that the physical, economic, or social relationships that have historically governed the development of the world system would remain effectively unchanged. Additionally this model assumed that population and industrial capital would continue to grow exponentially, leading to a similar growth in pollution and in demand for food and non-renewable resources. The supply of both food and non-renewable resources was assumed to be fixed. Perhaps not surprisingly given these assumptions, this model predicted collapse due to non-renewable resource depletion. The continual exponential growth of industrial capital necessitates an ever increasing supply of resources. However, as resources rise in price and stocks become depleted, more and more capital is needed to *obtain* resources and hence less is available to invest for future growth. The result is the collapse of the industrial base and with it, the dependent service and agricultural sectors. Finally, population will fall due to the lack of food and medical services. Whilst Meadows *et al.* stress that the model is not capable of making exact predictions concerning time scale, indications are that growth would come to a halt before the year 2100.[3]

The report claims that the credibility of such grave conclusions is strengthened by the fact that efforts were made "to make the most optimistic estimate of unknown quantities" and thus in actuality "the model is biased to allow growth to continue longer than it probably can continue in the real world." (Meadows *et al.* (1972) p.126). Furthermore, the nature of exponential growth meant that the finite limits placed on food and non-renewable resources could be quadrupled without changing the conclusions of the model. Meadows *et al.* were aware that a weakness of the model is its preoccupation with the physical aspects of man's activities at the expense of changes in social factors such as attitudes concerning family size or tastes in goods. It is due to this weakness that Meadows *et al.* emphasise the model's inability to make predictions. This, however, was not the object of the exercise which was simply to show the outcome of exponential economic growth under the assumption of no change in the present system, or under the assumption of any number of technical changes in the system.

The radical nature of the report attracted much attention, not only in academic circles, but also in society at large. As a result, *The Limits to Growth* fuelled a debate which continued throughout the 1970s. As Ekins (1993) points out, a major critique of the report came from Cole *et al.*

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[3] The 'standard' model was also run under the assumption of a number of technological changes. In each case the final outcome was the same - exponential growth of capital and population, followed by collapse.

(1973) who were based at Sussex University's Science Policy Research Unit. Their criticism firstly concerned the model's preoccupation with purely physical factors. As stated above, Meadows *et al.* recognised this weakness, but due to the uncertainty surrounding the emergence of new forms of societal behaviour, and in particular the exact nature of any new behaviour, felt unable to include such factors in their model. Secondly, Cole *et al.* questioned the model's assumptions, particularly the assumption of finite limits to non-renewable resource stocks. Indeed, Cole *et al.* re-ran the model with the assumption of continual exponential increases in resource stocks, through new discoveries and recycling, and produced altogether different results.

The fundamental difference between the viewpoint of the *Limits to Growth* team and that of Cole *et al.* stems from their differing opinions concerning three factors: the rate of technical progress; future changes in composition of output and the possibilities of substitution (Lecomber (1975)). "If these three effects add up to a shift away from the limiting resource or pollutant equal to or greater than the rate of growth, then the limits to growth are put back indefinitely." (Ekins (1993) p.271). However, for Lecomber ((1975) p.42) the point to be stressed is that "this establishes the *logical* conceivability, not the certainty, probability or even the possibility in practice, of growth continuing indefinitely." He goes on to distinguish between resource optimists and pessimists;

> "The optimists believe in the power of human inventiveness to solve whatever problems are thrown in its way, as apparently it has done in the past. The pessimist questions the success of these past technological solutions and fears that future problems may be more intractable." (Lecomber (1975) p.45).

An argument clearly originating from the 'optimist' camp comes from Wilfred Beckerman (1974) who, after expressing his faith in future technological advance, then raises an additional defence of economic growth. Beckerman claims it to be important that we distinguish between the issue of how consumption is spread over time (i.e. growth) and the issue of how resources should be spent at one point in time. A misallocation of resources does not necessarily mean that the growth rate is inappropriate. Indeed, if externalities exist at one point in time due to the misallocation of resources, any resultant environmental damage could not be prevented by changing the rate of growth of consumption. However, as Ekins (1993) stresses, if externalities do persist, their impact will be greater in a large economy than in a small one.[4] He continues, "Given that failures to remedy externalities are common, due not least to the power of the vested interests that are causing them, opposition to the economic growth that amplifies them would not seem an irrational position on the part of those adversely affected." (Ekins (1993) p.271).

A different perspective on the growth debate is provided by considering the Second Law of Thermodynamics, also known as the entropy law.[5] Georgescu-Roegen (1973) is primarily associated with work of this nature and utilised the Second Law to emphasise the physical limits to the economy. Rees (1990) clarifies the meaning of the Second Law; "The Second Law states that in any closed isolated system, available energy and matter are continuously and irrevocably degraded to the unavailable state." Furthermore, "Since the global economy operates within an essentially closed system, the Second Law is actually the ultimate regulator of economic activity." (Rees (1990) p.19). As Daly (1973) states, entropy may be considered to be a measure of the unavailable energy within a

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[4] If a good is produced such that its price is less than the marginal social cost of its production (i.e. there exists a positive marginal external cost) then the more of that good that is produced, the greater will be the total external cost.

[5] The First Law of Thermodynamics states that energy can neither be created nor destroyed, thereby implying that economic activity is not damaging to energy stocks. However, the Second Law clarifies the point by stating that, whilst energy cannot undergo a *quantitative* change, it can change *qualitatively*. Economic activity transforms *free*, or available, energy into *bound*, or unavailable, energy.

closed thermodynamic system. To use Georgescu-Roegen's (1973) example, a piece of coal contains available, or free, energy and therefore has low entropy. However, once that coal is burned the energy is no longer available, but has become dissipated in the form of smoke, heat and ashes. The energy is now bound and hence has high entropy i.e. the coal has now become waste.

As Georgescu-Roegen states, man has access to two sources of free energy (low entropy). Firstly, there is the terrestrial stock of mineral deposits and secondly the flow of solar energy which allows the 'production' of renewable resources. An economy fuelled by solar energy is constrained only by the limited flow of that energy, hence it is the fixed nature of the terrestrial stock which is the ultimate regulator of economic activity. Furthermore, "Growth in physical production and throughput that is not based on solar energy must increase entropy and make environmental problems worse, implying an eventual limit to such growth." (Ekins (1993) p.272). Attempts to increase the efficiency of energy use simply have the effect of reducing the amount of energy used per unit of output ie they economise on low entropy. Whilst this is clearly necessary, it is not sufficient. As Georgescu-Roegen (1976) points out, an unwelcome implication of the entropy law is that *all* of man's activities *must* result in the dissipation of energy, with less low entropy available after the activity than before it. "If there were not this entropic deficit we would be able to convert work into heat, and, by reversing the process, to recuperate the entire initial amount of work." (Georgescu-Roegen (1976) p.10).[6]

The physical constraints imposed on economic activity by the entropy law are an integral part of the writings of Herman Daly. However, Daly's (1973, 1993) critique of economic growth is not restricted to purely

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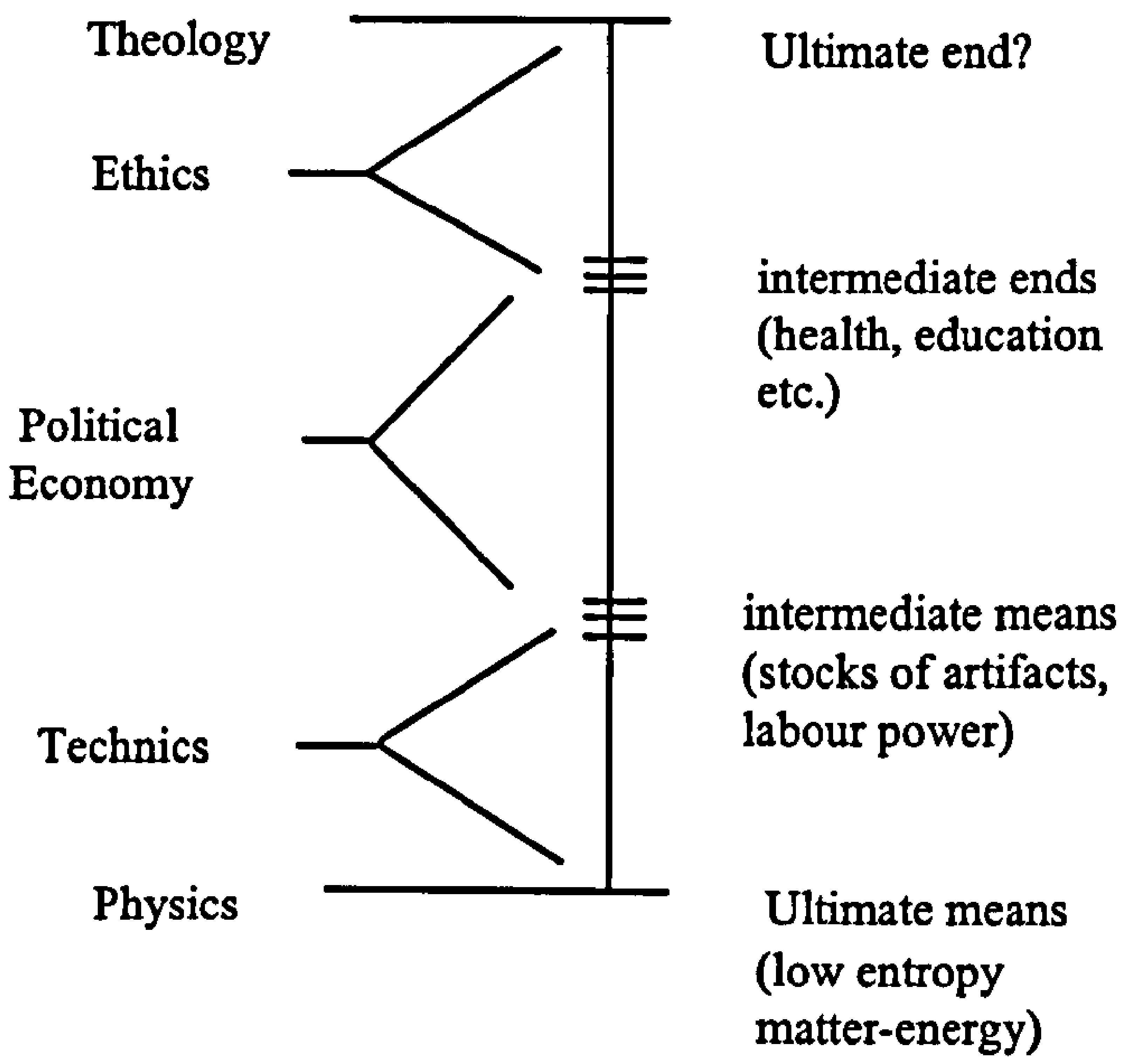
[6] As a result, Georgescu-Roegen claims that the entropy law is the root cause of economic scarcity; "Were it not for this law, we could use the energy of a piece of coal over and over again..." (ibid., p.9).

physical considerations and growth is also analysed from an ethical or moral viewpoint.

Daly begins his critique with reference to the ultimate means and the ultimate end of society and describes the ends-means spectrum which faces mankind (see Diagram 1).

Diagram 1. The Ends-Means Spectrum.



Daly explains the importance attached to growth in traditional economics in terms of an incomplete view of the total ends-means spectrum. For Daly, "humanity's ultimate economic problem is to use ultimate means wisely in the service of the Ultimate End." (Daly and Townsend (1993) p.20). "The ultimate end is that with reference to which intermediate ends are directed. It is that which is good in itself and does not derive its goodness from any instrumental relation to any other end." (Daly (1973) p.7). Daly is conscious that our perception of the ultimate end is vague but nevertheless believes such a perception to be essential since without this

"...it would be impossible to order intermediate ends and to speak of priorities." (ibid., p.8). At the opposite end of the spectrum is the ultimate means which consists of low entropy matter-energy. All intermediate categories are means with respect to the ultimate end, or ends with respect to the ultimate means.

On the left of the diagram lies the traditional disciplines which cover each portion of the spectrum. Daly believes that the central segment occupied by economics is highly significant;

> "In looking only at the middle range, economics has naturally not dealt with ultimates or absolutes, which are found only at the extremes, and has falsely assumed that the middle-range pluralities, relativities and substitutabilities among competing ends and scarce means were representative of the whole spectrum. Absolute limits are absent from the economists' paradigm because absolutes are encountered only in confrontation with the ultimate poles of the spectrum, which have been excluded from the focus of our attention." (Daly and Townsend (1993) p.21).

For Daly, any critique of economic growth should originate from both poles of the ends-means spectrum, thus encompassing ends-based (moral) and means-based (biophysical) considerations;

> "To crack the nut of growthmania, it is not enough to hammer from above with moral arguments, because there is sufficient 'give' underneath for optimistic biophysical assumptions to cushion the blow...Hammering only from below with biophysical arguments leaves too much room for elastic morality to absorb the blow (The interest rate automatically looks after the future; growth itself is the Ultimate End...etc.) Growth chestnuts have to be placed on the unyielding anvil of biophysical realities and then crushed with the hammer of moral argument. The entropy law and ecology provide the biophysical anvil. Concern for future generations and subhuman life and inequities in current wealth distribution provide the moral hammer." (Daly and Townsend (1993) p.22-23).

In place of 'growthmania', Daly's advocates the establishment of a steady (or stationary) state, defined as "a constant stock of physical wealth (capital), and a constant stock of people (population)." (Daly (1973) p.15). For both stocks to remain constant, the rate of inflow must be equal to the rate of outflow i.e. the birth rate must equal the death rate and the level of depreciation must equal the rate of production. For a number of reasons, Daly believes that this throughput should be minimised. Firstly, if population throughput is low (i.e. a low birth rate and a similarly low death rate) then this necessarily implies that life expectancy is high. Secondly, if capital throughput is low (i.e. a low rate of production and an equally low rate of depreciation or consumption) then clearly goods are more durable and thus less time will be sacrificed to production. In addition, since by the First Law of Thermodynamics energy cannot be created or destroyed, all natural inputs in the production process must be returned to the environment in the form of waste. Therefore, a lower rate of throughput will lead to less resource depletion and less pollution.

The economic and environmental implications of a steady state economy are likely to be numerous and far reaching. Daly claims that one such implication is that a steady state economy is likely to be more equitable than a growth-orientated economy for the simple reason that, in the former, the issue of income distribution can not be avoided. The existence of economic growth facilitates the neglect of *relative* shares in society by continually promising to increase *absolute* shares. Douthwaite (1992) takes up this argument, "The promise of jam for all tomorrow has eased our consciences about the unequal division of bread today." (Douthwaite (1992) p.3). Both Daly and Douthwaite claim that in an economy where the stock of capital is constant, and thus issues relating to absolute wealth are no longer of such relevance, greater emphasis is likely to be placed on the relative shares within society.

The term 'stationary state' (steady state) is borrowed by Daly from the classical economists, who generally believed it to be the state of affairs to which the world is evolving.[7] However, it is John Stuart Mill who expressed a sentiment closest to Daly's, stating that a stationary state of capital and wealth "would be, on the whole, a very considerable improvement on our present condition." (Mill (1871) p.328). However, both Mill and Daly emphasise what is *not* constant in a steady state. Mill, for one, feels that;

> "It is scarcely necessary to remark that a stationary condition of capital and population implies no stationary state of human improvement. There would be as much scope as ever for all kinds of mental culture, and moral and social progress; as much room for improving the Art of Living, and much more likelihood of its being improved, when minds ceased to be engrossed by the art of getting on." (ibid., p.332).

Similarly, Daly stresses that a steady state does not hold constant knowledge, technology, the distribution of income or the allocation of resources. He claims that in a steady state the economy will develop qualitatively rather than quantitatively ie. development will occur without an increase in the size of the economy.

Daly's contribution to the economic growth debate is notable for two reasons. Firstly, he subjects growth to criticism using both ecological and social arguments. Daly therefore not only assesses the *feasibility* of growth, but also considers its *desirability*. As such, he concludes that sustained exponential growth is neither feasible nor desirable. Secondly, the fact that Daly goes some way to suggesting an alternative to what he refers to as 'growthmania' - the steady state economy - makes his contribution more valuable than a mere critique.

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[7] Daly is careful to distinguish this interpretation of the stationary state from that used by neoclassical economists in which tastes and techniques are constant.

However, it will now be seen that, as valuable as Herman Daly's work is, he is not the only economist to point out the social impacts of economic growth.

4.4 The Social Limits to Growth.

In his defence of economic growth, Wilfred Beckerman (1974) asserted that growth was needed the world over. Very simply, he believed that for the third world, economic growth is essential in order to win the fight against poverty and deprivation. Moreover, in the first world, economic growth will continue to raise wealth and net welfare. As Ekins points out, with regard to the third world, it remains uncertain whether "economic growth *per se* is what poor people in poor countries need to improve their life prospects." He continues "...entitlements such as ensured access to resources and capabilities to use those resources, neither of which are the automatic results of economic growth, may be even more important. Where these lead to more secure, but non-market subsistence, they will not even show up as economic growth." (Ekins (1993) p.273). However, it is Beckerman's claim that growth will increase net welfare in the developed world which has proved to be the most contentious.

E.J. Mishan is perhaps the most well known of those who have contested the positive link between economic growth and human welfare. For Mishan, economic growth, and the scientific advance and technological progress on which it depends, have far reaching implications for society. Indeed, "despite the abundance of man-made goods produced by continued economic growth, its net effect on human health and happiness could be adverse and possibly disastrous." (Mishan (1977) p.9). In addition to ecological considerations, of which he is well aware, Mishan argues that the impact of continued growth has been to reduce the aesthetic quality of many of the world's cities and to dramatically increase traffic congestion and associated noise levels - factors which all act to the detriment of society. Furthermore, according to Mishan, man's preoccupation with expansion has contributed to social disintegration, notably in the form of divorce, suicide, crime and violence, all of which have increased markedly throughout the post-war period.

An additional consequence of growth Mishan refers to as 'the growing menace of obsolescence'. He describes its impact on society as follows; "Skills painstakingly acquired over many years may become obsolete in as many months. And it is not earnings alone that matter to a man. High unemployment pay and re-training opportunities do not suffice to compensate him for losing his position in the hierarchy of his chosen occupation, for seeing his hard earned skill and experience thrown on the mounting scrap-heap of obsolete tools." Furthermore, "...everyone of us, manager, workman or scientist, lives closer to the brink of obsolescence...and...feels menaced in some degree by the push of new developments." (Mishan (1969) p.115). One implication of continued product innovation is the need for ever intensive advertising campaigns. Indeed, the perceived necessity of growth and the hence ubiquitous nature of advertising, constantly draws man's attention to the material "...by hinting continually that the big prizes in life are the things that only money can buy...leaves a man restless and discontented with his lot." (*ibid.*, p.116). Moreover, tastes are also threatened by obsolescence "leaving fashion alone as the arbiter of moral behaviour." (ibid., p.116).

Mishan expresses grave concerns about the direction in which Western civilization is heading, and mourns the loss of a social community - the result, he believes, of economic growth and continued technological advance.

Like Mishan, Hirsch (1976) stresses the social implications of growth. For Hirsch, the effects of growth are twofold: Firstly, growth is associated with the increasing importance of positional goods and secondly, economic growth leads to the systematic erosion of individual morality. With regard to the former, Hirsch asserts that a major determinant of consumer demand is scarcity, not scarcity of a physical nature, but social scarcity. For reasons expressed below, he believes that most individuals derive more utility from a scarce good or service than from one which is relatively common. As a result, any increase in the availability of such goods or services will cause a given amount of use to yield less satisfaction. Hirsch believes that such a situation is comparable to a limitation on absolute supply of a good, and hence refers to social scarcity as a social limit. 'Pure' social scarcity therefore refers to the situation where satisfaction is derived from the scarcity of the good itself. Hirsch argues "This social limitation may be derived, most directly and most familiarly, from psychological motives of various kinds, notably envy, emulation, or pride. Satisfaction is derived from relative position alone, of being in front, or from others being behind" (Hirsch (1976) p.20). However, not all social scarcity is 'pure'. Indeed, an individual's utility may be *indirectly* affected by the consumption of others due to congestion or crowding. This notion of an individual's satisfaction being impeded by the similar activity of others, does not merely refer to *physical* congestion, as experienced in cities for example, but also to congestion of a social nature. Hirsch gives the example of leadership positions "both in work relationships and in political or civic roles. Shared leadership neither fulfils the same function nor yields the same satisfaction as individual leadership." He continues, "...top positions are regarded here...as valued primarily for their intrinsic attractions. Social scarcity in this case is primarily incidental, the outcome of social congestion" (*ibid.*, p.22).

Hirsch assesses the implications of social scarcity in terms of the positional economy. For Hirsch, the positional economy "relates to all aspects of goods, services, work positions, and other social relationships that are either (1) scarce in some absolute or socially imposed sense or (2) subject to congestion or crowding through more extensive use" (*ibid.*, p.27). As the material economy grows and incomes rise, Hirsch believes that the demand for positional goods increases. Ekins summarises the impact of this increase in demand; "...with fixed or very inelastic supply, the goods are either rationed through price (e.g. desirable resort properties) or criteria of eligibility (e.g. more stringent examinations) or their quality is degraded through overcrowding (e.g. roads). The effect is either to reduce growth, or the welfare to be derived from it or both" (Ekins (1993) p.274). The impact of social scarcity is that economic growth fails to live up to its promises - "...economic growth in advanced societies carries some elements of built-in frustration" (Hirsch (1976) p.175).

Hirsch's second social limit originates from the depletion of individual morality which occurs in a growing capitalist economy. As he points out, "...the pursuit of private and essentially individualistic economic goals by enterprises, consumers and workers in their market choices - the distinctive capitalistic values that give the system its drive - must be girded at key points by strict social morality which the system erodes rather than sustains" (*ibid.*, p.117). Hirsch asserts that an individualistic contractual economy relies on certain social virtues such as truth, trust and acceptance. However, these very virtues are undermined by the individualistic ethos of the growth process. As such, "Economic growth undermines its social foundation" (*ibid.*, p.175).

4.5 The Rise of Sustainable Development.

The advent of the 1980s saw attention turn from the limits to growth arguments of the 1970s towards the notion of sustainable development. The term 'sustainable development' appears to have been first advanced in 1980 by the International Union for the Conservation of Nature and Natural Resources (Ruttan (1994)) although it was the Brundtland Commission Report (World Commission on Environment and Development, 1987) which brought the concept to the top of the agenda of institutions like the United Nations and the World Bank. Since the Brundtland Report the goal of sustainability has been adopted by an ever increasing number of organisations and bodies. Indeed, the preamble to the agreement establishing the World Trade Organisation specifically states that its intentions will comply with the goal of sustainable development.

The popularity of sustainable development would seem to belie, or is perhaps indicative of, the vagueness of the term. Pretty (1995) claims there have been over seventy definitions of sustainable development since the Brundtland Report, and comments "The implicit assumption is that it is possible to come up with a single correct definition," (Pretty (1995) p.11). Pretty clearly believes such a task to be impossible and quotes Campbell (1994) as stating "attempts to define sustainability miss the point that, like beauty, sustainability is in the eye of the beholder..." (ibid., p.11). The amorphous nature of the concept means that it is impossible to state the precise relationship between sustainable development and economic growth although, as shall be seen below, certain general viewpoints may be defined. In addition, opponents of sustainable development use its ambiguity as ammunition, claiming such a vague concept to be meaningless. Wilfred Beckerman, continuing his pro-growth stance adopted in the 1970s, clearly holds such a view and believes sustainable development to be "devoid of operational value" (Beckerman (1992) p.491).

Despite the countless definitions, Pearce argues that a key characteristic of virtually all versions of sustainable development is the principle of equity. Such a notion of equity includes not only providing for the needs of the least advantaged in *today's* society (intragenerational equity), but also extends to the needs of the next generation (intergenerational equity).[8] Indeed, this is clearly in line with perhaps the most well-known definition of sustainable development, "...development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED (1987) p.43) - the definition which emanated from the Brundtland Report. As Pearce points out, it is generally agreed that the most appropriate mechanism for ensuring the well-being of future generations is to ensure that the next generation has access to a stock of capital at least as large as the current stock. There is, however, disagreement surrounding the precise nature of the capital stock which is to be maintained. Such disagreement has resulted in Pearce (1993) distinguishing between 'weak' and 'strong' forms of sustainability. In line with Pearce, it is here suggested that the different forms of sustainable development can be categorised as being 'weak' or 'strong'. The features of each will now be analysed, with particular reference to the stance taken regarding economic growth.

4.5.1 Weak Sustainable Development.

As argued above, intergenerational equity requires the maintenance of the capital stock. The capital stock is comprised of man-made capital (such as

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[8] As Pearce notes, the two objectives of intragenerational and intergenerational equity are not necessarily compatible, "If the best way to help the poor is to industrialise rapidly using 'dirty' technology then that objective may conflict with the concern to improve the global atmospheric conditions for future generations." (Pearce (1993) p.10).

the means of production, the infrastructure, human capital etc.) together with natural capital (such as fossil fuels, habitat, clean water etc.). Weak sustainability simply requires that it is the *aggregate* capital stock which is to be maintained for the next generation, and thus any fall in the stock of natural capital can be compensated by an appropriate increase in man-made capital. Proponents of this form of sustainability therefore assume that the two forms of capital are fully substitutable for each other, an assumption which will be appraised when considering strong sustainability.

Batie (1989) also distinguishes between two versions of sustainability which loosely conform to Pearce's weak and strong forms. The weak form of sustainable development she refers to as the constrained economic growth position, which advocates the pursuit of economic growth subject to certain environmental constraints. Such an approach has two stages: "first, the establishment of some contractual arrangement, incorporating ecological principles and environmental ethics to establish the 'rules' applicable to the development policy. Second, within those rules, the utilitarian stance of economic maximisation can be adopted" (Batie (1989) p.1084). It is clear therefore that the weaker forms of sustainable development do not see an inherent conflict between environmental health and economic growth. Indeed, by this definition the recommendations of the Brundtland Report would fall into the weak sustainability category due to its perceived complementarity between growth and the environment. The Report itself actually called for "more rapid economic growth in both industrial and developing countries" (WCED (1987) p.89). Whilst this growth must be forceful in nature, Mrs. Brundtland did realise that it must be "at the same time socially and environmentally sustainable" (*ibid.*, p.xii). As will shortly be seen, the very concept of 'sustainable growth' is considered to be a contradiction in terms by those who favour a more ecocentric approach to sustainable development.

As Ekins (1993) argues, a key difference between the limits to growth debate of the 1970s and the post-Brundtland sustainable development debate is the involvement of the business community. Whilst abstaining from the debate in the 1970s, generally due to its failure to recognise an environmental problem, business in the late 1980s and 90s has been keen to embrace the concept of sustainability, albeit weak sustainability. Ekins highlights two international business initiatives, the 'Business Charter for Sustainable Development' and the 'Business Council for Sustainable Development' which were designed to give advice from a business perspective to the International Chamber of Commerce, and to the 1992 UN Conference on Environment and Development, respectively. It is interesting to note that both initiatives posit that economic growth is compatible with a healthy environment, with the former initiative stating "Economic growth provides the conditions in which protection of the environment can best be achieved, and environmental protection, in balance with other human goals, is necessary to achieve growth that is sustainable" (ICC, 1990, from Ekins (1993) p.275).

Advocates of weak sustainability therefore typically argue that economic growth does not necessarily imply environmental degradation. Whilst Pearce (1992) claims that it is likely that growth *will* prove costly to the environment, he argues that it does not have to be so; "If energy inputs per unit of economic activity decline over time, as they have done in industrialised countries, then an expansion of output need not increase energy consumption." (Pearce (1992) p.7). The World Bank Development Report (1992) also claims that increasing the efficiency of energy usage means that economic growth can be decoupled from environmental damage. Similarly, Turner, Pearce and Bateman (1994) provide evidence of the falling level of energy use per unit of output in industrialised countries since the early 1970s, despite substantial increases in economic growth in this period. They and the World Bank both conclude that economic activity can, in theory, be increased indefinitely without further harming the environment and thus the economy need not produce *less*, provided that it produces *differently*.[9]

Jacobs (1991) echoes this sentiment by arguing that GNP growth does not itself damage the environment: rather it is the 'environmental impact coefficient' (EIC) of that growth that is of relevance. Thus, as long as the EIC falls faster than GNP grows the overall environmental impact falls.

It is interesting to note that the latest report to the Club of Rome (Von Weizsacker *et al.* (1997)) argues that technological advance has the ability to significantly reduce the environmental impact of production, whilst significantly increasing productivity. This is a notable change of position from the Club of Rome report which arguably triggered the 'limits to growth' debate of the 1970s (Meadows *et al.* (1972)), and which rejected technological advance as the answer to our environmental problems.

Bernstam (1991) also expresses faith in man's potential to decouple growth from the environment. For Bernstam, it is only when a nation's economy *first* starts growing that a negative relationship between growth and environmental health exists. Indeed, as the economy develops and growth continues, a positive relationship forms due to the increased efficiency of resource use and the corresponding fall in waste. He therefore argues that the pollution produced by the South, (for whom there exists a negative relationship between growth and the environment) must be offset by a reduction in pollution in the North. Thus, the upshot of Bernstam's argument is that the North *must* continue growing since only

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[9] However, as Turner, Pearce and Bateman note, for there to be true decoupling, economic growth must occur without increasing the *total* amount of energy inputs and not merely the energy inputs *per unit of output*. This is obviously a far more demanding task.

with prolonged growth will pollution levels fall. Furthermore he argues that the rate of growth in the South depends on the rate of growth in the North, thus the more the North grows, the quicker the South will move beyond the peak level of pollution. This inverted-U relationship is known as the environmental Kuznets curve, and is examined in depth in Chapters 5 and 6.

The ability to decouple growth from the depletion of environmental assets is not accepted by all, however. As will be seen below, proponents of strong sustainability would question the extent of possible decoupling and would reject the notion that it will allow indefinite exponential growth.

4.5.2 Strong Sustainable Development.

Before considering the stance adopted by strong sustainability advocates regarding decoupling, their position concerning intergenerational equity will firstly be analysed.

In contrast to the weak sustainability school, the strong sustainability interpretation questions the substitutability between natural and man-made capital and hence believes it insufficient to simply maintain the *aggregate* capital stock, whereby a fall in natural capital can be compensated by an appropriate increase in man-made capital. Daly, for one, is critical of the claim that man-made capital and natural capital are indeed *substitutes,* instead believing them to be *complements.* He asks,

> "Do extra sawmills substitute for diminishing forests? Do more refineries substitute for depleted oil wells? Do larger nets substitute for declining fish populations? On the contrary, the productivity of sawmills, refineries and fishing nets (man-made capital) will decline with the decline in forests, oil deposits and fish. Natural capital as a provider of raw material and energy is complementary to man-made capital. Natural capital as absorber of waste

> products is also complementary to the man-made capital which generates those wastes." (Daly (1990) p.3).

Those who doubt man's ability to substitute man-made capital for natural capital therefore propose that intergenerational equity will only be achieved by maintaining a non-decreasing stock of *natural*. The aggregate capital stock should also be maintained, but only by individually maintaining the levels of natural and man-made capital. This position is therefore in contrast to the weak sustainability hypothesis which advocates the maintenance of the aggregate stock, irrespective of the relative size of its constituents. An additional factor which supports the strong sustainability viewpoint is the problem of irreversibility associated with the destruction of natural capital assets. As Pearce (1993 p.17) notes, "Once lost, such assets are lost forever. By contrast, man-made capital can be run down and then recreated...". Rees (1990) argues that the extensive use of natural resources which has occurred since the industrial revolution implies that much of our wealth has simply been an illusion. Whilst man-made capital has been growing, it has done so at the expense of natural capital. "We have simply drawn down one account (the biosphere) to add to another (material wealth) ... In short, the global economy is cannibalising the biosphere." (Rees (1990) p.20). Batie (1989) also equates a stronger form of sustainability with a constant stock of natural resources. For her, such resource maintenance "is a minimisation concept that implies minimising the use of the natural environment" (Batie (1989) p.1085). Strong sustainability therefore implies the existence of limits to economic growth.

Both schools of sustainability are in agreement concerning the need for reductions in the scale of materials and energy throughput. However, a key difference between the two positions is that those in favour of strong sustainability believe that such reductions in throughput will only arise if the scale of economic output (i.e. in economic growth) is reduced. By questioning whether energy throughput can be substantially reduced in a growing economy, the strong sustainability school is clearly sceptical of the potential for decoupling. Daly and Cobb (1989) argue that the evidence suggesting that energy efficiency has improved in recent years by no means implies that economic growth can continue without impairing the environment. They point out that measurements of improvements in energy efficiency may be very misleading since they ignore the indirect energy costs of the technology used to increase energy efficiency. Gever *et al.* (1987) clarify this point; "In agriculture, for example, the amount of fuel used *directly* on a cornfield to grow a kilogram of corn fell 14.6% between 1959 and 1970. However, when the calculation includes the fuel used elsewhere in the economy to build the tractors, make the fertilisers and pesticides, and so on, it turns out that the total energy cost of a kilogram of corn actually *rose* by 3% during that period." (Gever *et al.* (1987) p.102-3). Whilst the precise extent to which gains in energy efficiency will be offset by indirect costs is unclear, Daly and Cobb conclude that "In the economy as a whole ... net energy efficiency improvements (combining direct and indirect energy costs) are likely to be minimal." (Daly and Cobb (1989) p.409).[10] The World Bank (1992) provides evidence of a reduction of certain air pollutants, particularly lead and suspended particulate matter, between 1970 and 1988, despite substantial economic growth in this period. However, there is little evidence that decoupling has occurred for some pollutants such as carbon dioxide. Furthermore, as Ekins (1992) points out, energy use per unit of GDP actually rose for the US and several European countries in 1987 and 1988. Given this conflicting evidence, Bernstam's (1991) claim that the environment only improves beyond a certain level of wealth is subjected to extensive empirical analysis in Chapters 5 and 6.

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[10] Furthermore, the law of entropy means that production necessarily entails the consumption of *some* energy, and thus there is a limit to the extent of efficiency gains. Once this limit is reached, any further expansion of the scale of production will unequivocally mean an increase in resource depletion and associated waste.

In contrast to Bernstam, Hueting (1992) believes that any relationship between economic growth and environmental well-being is likely to be negative. After arguing that production growth in the economy is largely the result of increases in labour productivity, Hueting claims that between one-quarter and one-third of the activities making up national income (notably state consumption) do not contribute to its growth, since, by definition, no increases in labour productivity can result from them. Thus, a moderate growth rate of GNP will only be achieved by a much *higher* growth rate in the growth conducive activities. What this effectively means is that 70% of GNP growth is generated by 30% of the activities making up GNP.[11] The reason that growth has typically been detrimental to the environment is because this 30% represents the most environmentally intensive industries in the economy i.e. oil, petrochemical, mining etc. For decoupling to be successful, any reductions in the energy intensity of such industries will therefore have to be at least as large as the (high) rate of production growth. Hueting (1992) claims that such a task will be extremely difficult and states that, typically, technological improvements have provided little benefit to the environment as the growth of the activity has simply offset the effect of the advance.

An additional point is that, even if substantial improvements in energy efficiency could be attained, to claim that such energy efficiency decouples economic growth from the environment assumes that resource depletion and pollution are the only environmental costs associated with increasing output. It therefore neglects other environmental costs such as the continued encroachment of industry into the countryside, and the exacerbation of noise pollution and congestion which is likely to result from increased product transportation.

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[11] Hueting has updated this analysis to 1986 with the same result.

The belief that sustainable development should recognise the existence of strict limits to material growth, and should therefore require output levels to be constrained accordingly, is held by William Rees (1990). For Rees, as sustainable development has been increasingly adopted by the political mainstream, its meaning has moved ever further from its true goal of achieving ecological sustainability. Indeed, Rees is critical of the interpretation of sustainability which is provided by the Brundtland Report. He comments, "To those who regard present levels of industrial activity as the root cause of global environmental decline, the Commission's appeal for a 'revitalisation' of economic growth ... seems paradoxical at best." (Rees (1990) p.18). Continuing the work of Georgescu-Roegen from the 1970s, Rees analyses the economic process in terms of the laws of thermodynamics and considers the implications of present levels of production, not merely for the depletion of resources, but also for the assimilative capacity of the environment. He states that the impact of exceeding *current* limits is to damage the capacity of the biosphere to assimilate waste, thus reducing *future* limits to growth. Rees therefore concludes that sustainable development must be "development that minimises resource use and the increase in global net entropy."(*ibid.*, p.19).

However, having described the forms that sustainable development may take, the question of how to implement such sustainability must be raised. It has been suggested that making society pay the true costs of production would contribute to the attainment of sustainable development - a claim clearly stemming from Pigou's analysis of the divergence between private and social costs. If this analysis is accepted, then it follows that the correct price to charge would be one that covers the full social cost (i.e. includes external environmental costs). A comprehensive adoption of the 'Polluter Pays Principle', via taxation or otherwise, would be one means of making producers charge this social cost, thus aiding the implementation of sustainable development.

An additional factor which may aid the implementation of sustainable development is the development of new indicators of economic success to replace the current reliance on GNP.

4.5.3 Developing New Indicators of Production and Welfare.

The use of GNP as an indicator of economic success is widespread. Governments throughout the world gear their policies towards increasing the growth rate of their GNP, whilst the development policies of the World Bank and the International Monetary Fund are often only deemed successful if they too result in a similar outcome. However, many economists question the use of GNP as such a measure of success. Criticism is levelled at the use of GNP for two reasons; firstly its proficiency as an indicator of economic production is disputed, and secondly the ability of GNP growth to represent an increase in welfare is questioned. As a result, suggested reform measures have taken two forms; firstly, an adjustment of existing GNP to include environmental factors, thus in effect creating an indicator of sustainable income; and secondly to replace the use of GNP as an indicator of welfare with an indicator created specifically for this purpose.

The deficiency of GNP as a measure of production (or income) stems, in part, from its failure to treat natural capital in the same way as man-made capital. In the system of national accounts, net national product is calculated from GNP by deducting that portion of output which is used up in the production process i.e. that level of man-made capital which is lost through 'wear and tear'. However, no similar calculation is made for natural capital. As Schmidheiny points out, "When a forest is felled for timber, GNP includes the income earned, but no loss of future productive capacity is recorded. If countries were run like businesses, there would be an accounting for depletion of valuable assets such as forests, oil, topsoil, and water." (Schmidheiny (1992) pp.30-31). Indeed, as Schmidheiny notes, Repetto (1989) has shown that when depreciation for oil, timber, and topsoil were taken into account in the Malaysian economy, economic growth between 1971 and 1984 was only 4%, as opposed to the official 7%.

An additional deficiency of GNP concerns its treatment of defensive expenditures - the expenses incurred to protect society from the side effects of production, such as pollution control. Presently, and somewhat paradoxically, these expenses are not treated as intermediate costs, but are instead classed as final expenditures and hence included as an *addition* to GNP, therefore supposedly representing an addition to welfare. Thus as Daly (1973) notes, "We count the real costs as benefits..."(Daly (1973) p.150.) It is often argued (e.g. Pearce (1993)) that since this expenditure is not undertaken to enhance well-being, it should not be included in sustainable income

Pearce (1993) consequently defines a measure of 'green' NNP in the following way;

$$\text{'green' NNP} = \text{GNP} - D_M - D_N - \text{Destr}_N$$

Where; D_M = Depreciation of man-made capital

D_N = Depreciation of natural capital (or the costs of replacing such depreciation with renewable substitutes)

Destr_N = Destruction of natural capital

This is broadly compatible with Daly's (1989) measure of 'green' NNP, although instead of the destruction of natural capital, Daly includes the level of defensive expenditures. The advantage of using defensive expenditures as a measure of environmental damage is the fact that there exist observable data which are already expressed in monetary terms. However, the danger is that most environmental damage is *not* restored and thus such defensive expenditure will vastly underestimate the extent of actual destruction. It may therefore prove necessary to include an additional variable to take account of residual environmental damage.

In line with the definition of income provided by Hicks, the measure of 'green' NNP, above, can be interpreted as a *sustainable* measure of income or production.[12] It indicates the level of income that a nation can afford to consume without running down its overall capital stock i.e. the income that it could produce indefinitely. As Ekins points out, if GNP was comprehensively adjusted in the manner suggested above, "then much of the context of the 'limits to growth' debate would disappear because the new adjusted GNP simply would not grow in an economy that was fast depleting natural capital or generating social and environmental externalities." (Ekins (1993) p.285). However, a constant or increasing level of 'green' NNP does not mean that an economy is environmentally sustainable. First, although 'green' NNP outlines the amount of expenditure needed to maintain environmental quality, it does not, of course, mean that this expenditure will actually be made. Second, 'green' NNP can actually grow even if environmental degradation worsens. As long as the growth rate of GNP is greater than the growth rate of natural capital depreciation, *ceteris parabus*, 'green' NNP will increase. Thus,

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[12] In Value and Capital, Hicks wrote "The purpose of income calculations in practical affairs is to give people an indication of the amount which they can consume without impoverishing themselves. Following out this idea, it would seem that we ought to define a man's income as the maximum value which he can consume during a week, and still expect to be as well off at the end of the week as he was at the beginning. Thus, when a person saves he plans to be better off in the future; when he lives beyond his income he plans to be worse off. Remembering that the practical purpose of income is to serve as a guide for prudent conduct, I think it is fairly clear that this is what the central meaning must be." (Hicks (1948), p.172). This measure of 'green' NNP outlined by Pearce and Daly clearly conforms, at a national level, to Hicks's principle.

'green' NNP improves on some of the failings of GNP, but cannot be considered to be an indicator of environmental quality.

Given the above possible amendments to GNP a sustainability test, or 'savings rule', would be to assess whether an economy is saving at least as much as the sum of the depreciation of man-made capital, the depreciation of natural capital and the value of environmental degradation (or the level of defensive expenditures). If the resultant level of adjusted net savings, or genuine savings, is positive it indicates that the economy is developing sustainably. This is only a test for 'weak' sustainability, however, since it effectively states that the value of the depreciation of natural capital is of little consequence as long as this value is re-invested in other forms of income-generating assets. Hamilton *et al.* (1997) outline how technological change, human resources, resource discoveries and critical natural capital can be incorporated into the concept of 'genuine' saving. The inclusion of criticial natural capital thereby provides a measure of 'strong' sustainability by recognising that such capital and man-made capital are not substitutes.

The above methods of adjusting the existing stock of monetary accounts are not accepted by all, however. Tisdell (1994) questions the policy value of these adjustments, and argues that their sole purpose would be to warn that environmental conditions are deteriorating, or natural stocks are falling. Furthermore, "...by the time this becomes apparent from aggregate *ex post* figures damage is likely to have been irreversibly done." (Tisdell (1994) p.143). He therefore suggests that it may be more beneficial to concentrate on improving the *physical* measurement of environmental factors, particularly in the light of the difficulties associated with valuing natural resources and given the weaknesses of 'green' NNP as an indicator of environmental sustainability. Indeed, Norway has experimented with the use of physical accounts, whereby certain natural resources are accounted in physical terms thus allowing an examination of their development over time. Whilst such an approach avoids the problems of adjusting the monetary accounts, as mentioned above, the use of physical accounts does suffer from the lack of a common unit of measurement and the inability to gauge the importance of different accounts relative to each other. However, to an extent this does not matter. Only by studying individual national accounts will policy makers be aware of whether the economy is operating in an environmentally sustainable manner and be able to gear policies towards those indicators which are deteriorating. Accounts of this nature would therefore appear to be essential if sustainability is to be achieved. Chapter 8 advocates the implementation of a system of physical accounts, which are common to all countries, thereby facilitating sustainable development at the global level.

Attention will now be turned to the second criticism levelled against GNP - its inability to represent social welfare. The limits to growth arguments of the 1970s took economic growth and growth in GNP to be synonymous, and disputed the claim that an increase in growth (GNP) directly raised social welfare. However, a more recent development has seen the link between economic growth and production growth challenged. Both Ekins and Max-Neef (1992) and Hueting (1992) argue that the purpose of the economy is to provide welfare, and consequently an increase in economic growth should represent an increase in welfare. An increase in the scale of production, however, is simply one of many factors which may affect social welfare. Hueting (1992) outlines eight factors which play a role in determining the level of welfare, of which the level of production is just one. The other seven are the number of environmental goods, leisure time, income distribution, working conditions, employment, health, and the safety of the future. Thus, according to advocates of this argument, growth in GNP does not necessarily mean economic growth (welfare growth).

The perceived failure of GNP to represent social welfare has led to a number of attempts to construct an alternative indicator of welfare to replace the use of GNP in this role. Nordhaus and Tobin (1972) were arguably the first to create such an index (entitled the Measure of Economic Welfare (MEW)), although their attempt would now appear to be of only limited use due to their failure to consider environmental issues. Personal consumption, leisure and nonmarket work were major components of the index, with deductions made for necessary expenditures such as national defence, sanitation services, costs of commuting to work and 'urban disamenities' which were judged to be compulsory rather than contributing to welfare. The results of the MEW are considered below. Zolotas (1981) proposed the Index of the Economic Aspects of Welfare, which although similar to Nordhaus and Tobin's index, extended it to consider environmental factors. Personal consumption, leisure and household services again form the bulk of Zolotas's index, whilst private pollution control costs and resource depletion are deducted. The results of both Zolotas and Nordhaus and Tobin show that for the period 1947 (1950 for Zolotas) to 1965 their indices of welfare increased by less than one-third of the growth of per capita GNP which rose by 2.2% per annum between 1947 to 1965. In addition, Zolotas's index remained much the same for the period 1965 to 1977. Whilst both indices indicate that welfare increased by a smaller proportion than GNP, both still show a positive correlation between GNP growth and welfare, thus implying that GNP growth is likely to be beneficial. However, as Daly and Cobb (1989) point out, both indices omit a number of social and ecological indicators which appear to be adversely affected by the growth of GNP.

Daly and Cobb (1989) therefore attempted to provide a more comprehensive welfare index which they named the Index of Sustainable Economic Welfare (ISEW). The ISEW consists of personal consumption, weighted by distributional inequality and adjusted upwards for: services from household labour, consumer durables, and streets and highways, public current expenditures on health and education, net capital growth and the change in net international position. Downward adjustments were made for: water, air and noise pollution, loss of wetlands and farmlands, depletion of non-renewable resources, long term environmental damage, road accidents, urbanisation, commuting, advertising expenditure, defensive private expenditure on health and education, and expenditures on consumer durables.

Although the ISEW increased consistently throughout the 1950s and 1960s, there has been a downward trend since the mid 1970s, despite GNP growth throughout this period. Whilst the accuracy of a study of this nature is indeed contentious, and Daly and Cobb themselves are aware of the limitations of any attempt to estimate economic welfare over time, the ISEW is at least useful in illustrating the growing divergence between the traditional measure of welfare, GNP, and an alternative indicator of this type.

The apparent existence of falling welfare, in the face of GNP growth would be further evidence to substantiate the claims of the anti-growth lobby. However, the 'heroic' assumptions admittedly made by Daly and Cobb in the compilation of the ISEW clearly weaken its results and, as Ekins and Max-Neef point out, cast doubt on a welfare index of this kind ever gaining enough support to be officially adopted. Indeed, Atkinson (1995) also criticises the ISEW by claiming that available data are not sufficient to perform this task, resulting in the use of a number of *ad hoc* methods.

The development of alternative indicators of welfare does illustrate though that, like the limits to growth arguments of the 1970s and the sustainable development debate in general, there remains little consensus over the precise relationship between economic growth (GNP growth) and the environment.

4.6 Conclusion.

An analysis of the 'limits to growth' debate of the 1970s illustrates that the arguments raised against economic growth generally fall into three categories: the existence of natural resource scarcity; the ability of the biosphere to absorb waste; and the development of social externalities. The social arguments against growth appear to have attracted little attention. However, the arguments relating to natural resource scarcity and waste absorption have proved to be contentious. Indeed, it has become apparent that many of the catastrophic claims made by the Club of Rome, for example, have proved to be wide of the mark. It appears that, by overstating their case, some of those in opposition to unlimited exponential growth may have effectively discredited what was in fact a credible stance, if stated in a milder form. This failure to convince society at large of the need to replace economic growth as the number one policy objective is illustrated by the fact that the Brundtland Report still interpreted growth as being compatible, even complementary, to environmental well-being. Indeed, this viewpoint is held by all mainstream advocates of sustainable development.

The two sides of the economic growth debate can invariably be classified as technological 'optimists' or 'pessimists'. Placing great emphasis on the power of human intelligence, the former argue that the development of new technology will eliminate any future resource constraints that may arise, as has been the case in the past. In contrast, the 'technological pessimists' do not place such faith in future technological advance, and would argue that it is very dangerous to assume that because mankind has not faced any real resource constraints in the past, we will not do so in the future. However, as Costanza (1989) points out, "Ultimately, no one knows. Both sides argue as if they were certain but the most insidious form of ignorance is misplaced certainty." (Costanza (1989) p.3).

The inaccuracy of many of the claims made by 'limits to growth' advocates, and the ambiguous nature of sustainable development in general, would also seem to illustrate the uncertainty which exists and the lack of knowledge we have concerning the impact of the economy on the environment. Given this uncertainty, Chapters 5 and 6 estimate the historical relationship between per capita GDP and a wide range of environmental indicators in an attempt to clarify the economy-environment relationship.

CHAPTER 5.

ECONOMIC GROWTH AND THE ENVIRONMENT - AN EMPIRICAL ANALYSIS.

5.1 Introduction.

The previous chapter has examined, from a predominantly theoretical point of view, the relationship between economic growth and the environment and has illustrated that this relationship is still subject to much uncertainty. It would therefore appear that this debate cannot be settled by theoretical arguments alone but must instead be subjected to empirical analysis, with the estimation of environmental Kuznets curves (EKCs). This chapter is based on Cole *et al.* (1997).

The environmental Kuznets curve hypothesis is that there is an inverted-U relationship between economic growth and environmental damage (Stern *et al.* (1996)). Factors such as changes in the composition of output, the introduction of cleaner production technology and greater public demand for stricter controls on emissions (Grossman and Krueger (1996)) can lead to a declining, and eventually a negative, marginal change in pollution being associated with rising per capita incomes. A number of studies have estimated EKCs from cross-country panel data sets relating emissions per capita (Selden and Song (1994), Holtz-Eakin and Selden (1992)) or concentrations of pollutants (Grossman and Krueger (1993, 1995), Shafik (1994)) to per capita income for certain air and water pollutants. As emphasised by Grossman and Krueger (1996), Arrow *et al.* (1995) and Stern *et al.* (1996), these estimated regressions are reduced form relationships; they reflect correlation rather than a causal mechanism by which the growth process affects the environment. Nevertheless, these studies provide evidence that, for at least those pollutants involving local short-term health hazards, market and institutional mechanisms have eventually brought about a reduction in environmental damage during the course of economic growth.

This chapter extends the previous empirical analysis of EKCs in a number of ways. First, it is more extensive in that it investigates a wider range of environmental indicators and it employs more recent data, thereby serving as a check on earlier results. The environmental indicators used in this analysis are: carbon dioxide, CFCs and halons, methane, nitrogen dioxide, sulphur dioxide, suspended particulate matter, carbon monoxide, nitrates, phosphorous, municipal waste, energy consumption and traffic volumes. In addition, emissions of nitrogen dioxide, sulphur dioxide and suspended particulate matter from the transport sector and energy use by the transport sector, are considered separately. Second, it utilises a generalised least squares estimation procedure to correct for heteroscedasticity and autocorrelation so giving more efficient estimations in contrast to many earlier studies which rely on ordinary least squares. Third, standard errors at the estimated turning point level of income are calculated to indicate the accuracy of the estimates. Of the other studies, only Grossman and Krueger (1993, 1995) also do this. Fourth, the possibility of contemporaneous feedback from environmental degradation to economic growth, which would lead to simultaneity bias in the estimation of EKCs, has been examined by testing the null of exogeneity of the income variables. Results indicate that simultaneity is not present. These refinements of earlier studies go some way towards meeting the strictures of Stern *et al.* (1996) regarding the problems surrounding the estimation of EKCs.

The employment of a reasonably comprehensive data set permits the examination of a number of hypotheses relating to the association between economic growth and the environment. First, that pollutants with a local short-term impact (e.g. suspended particulate matter) will have estimated turning points at lower per capita income levels than those environmental indicators whose impact is more global in nature (e.g. carbon dioxide). Grossman (1994) suggests that this distinction is due to the fact that individuals demand that governments address *local* pollutants due to their obvious anti-social effects. In contrast, governments have little incentive to unilaterally reduce *global* pollutants, since their impact is far more widespread. Indeed, Arrow *et al.* (1995) suggest that global pollutants may even increase monotonically with income. Thus, a subsidiary hypothesis is that a global pollutant will only have an estimated turning point within the observed income range if it has been subjected to a multilateral policy initiative. The second hypothesis is that, for local air borne pollutants, turning points for concentrations in urban areas will be at lower per capita income levels than for total emissions per capita. Seldon and Song (1994) suggest several reasons why this may be the case, including the point that it is more difficult to reduce total emissions than urban concentrations, since the latter could be reduced by simply building taller chimneys. The third hypothesis is that emissions per capita of transport-generated local air pollutants will have turning points at higher levels of per capita income than total emissions per capita of the same local air pollutants. The rapid growth of the transport sector in recent years, together with the reluctance of many governments to regulate its environmental impact, suggests that air pollution from transport will prove more stubborn to control than in other sectors.

In order to throw further light on the relationship between economic growth and environmental quality, this chapter examines several environmental indicators which have only an *indirect* impact on the environment, namely per capita values of total energy use, energy use from transport, municipal waste and traffic volumes. Even though these indicators may be responsible for serious environmental problems, it is hypothesised that they will exhibit a relationship with per capita income similar to that hypothesised for the global air pollutants - due to the lack of incentive for government action.

5.2 The Environmental Indicators.

Any study of this nature is constrained by the availability of environmental data. However, in recent years this availability has improved considerably, and data now exist for a wide range of environmental quality measures. Table 1 provides details of the data used.

Table 1. Data Information.[1]

Environmental Indicator	Time Period	No.Countries/ Regions	Unit	Source
Carbon Dioxide	1960-91	7 regions	tonnes of carbon	Marland,Andres, Boden (1994)
CFCs and Halons	1986, 1990	38 countries ('86) 39 countries ('90)	tonnes	UNEP (1993)
Methane	late 1980s	88 countries	tonnes	UNEP (1993)
Nitrogen Dioxide	1970-92	10 countries	tonnes	OECD (1993,95)
Sulphur Dioxide	1970-92	11 countries	tonnes	OECD (1993,95)
SPM[2]	1970-92	7 countries	tonnes	OECD (1993,95)
Carbon Monoxide	1970-92	7 countries	tonnes	OECD (1993,95)
Nitrogen Dioxide from Transport	1970-92	9 countries	tonnes	OECD (1993,95)
Sulphur Dioxide from Transport	1970-92	9 countries	tonnes	OECD (1993,95)
SPM from Transport	1970-92	7 countries	tonnes	OECD (1993,95)
Nitrates	1975-90	30 rivers in 15 countries	mgN/litre	OECD (1993,95)
Phosphorous	1975-90	28 rivers in 16 countries	mgP/litre	OECD (1993,95)
Municipal Waste	1975-90	13 countries	tonnes	OECD (1993,95)
Total Energy Use	1980-92	22 countries	MTOE[3]	OECD (1993,95)
Energy Use from Transport	1970-90	24 countries	MTOE	OECD (1993,95)
Traffic Volumes	1970-92	22 countries	kilometres	OECD (1993,95)

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[1] The Data Appendix contains a sample of these data - namely, those for carbon dioxide, a key indicator in this thesis, and for nitrogen dioxide, as an example of the OECD data. Per capita income data are also included.

[2] Suspended particulate matter.

[3] Million tonnes of oil equivalent.

5.2.1 Indicators with a DIRECT Local Environmental Impact.

(i) Nitrogen Dioxide.

Man-made emissions of nitrogen dioxide stem mainly from the burning of fossil fuel, with motor vehicles responsible for a significant proportion of total emissions. The atmospheric deposition of nitrogen dioxide has resulted in the acidification of lakes, rivers and forests, particularly in northern Europe and eastern North America. Exposure to relatively low levels of nitrogen dioxide is believed to result in respiratory irritation and breathing problems and in animals has been shown to reduce resistance to bacterial and viral infection. Furthermore, vegetation growth may be suppressed and textile fibres, rubber products and polyurethanes can be degraded by exposure to nitrogen dioxide.

(ii) Sulphur Dioxide.

Like nitrogen dioxide, sulphur dioxide results from the burning of fossil fuel, particularly in electricity generation and home heating, and contributes to acid deposition in lakes, rivers and forests. Short term exposure to sulphur dioxide also affects the respiratory tract, causes coughing and deterioration of lung functions particularly amongst children, the elderly and asthmatics. Although both nitrogen dioxide and sulphur dioxide are responsible for transboundary acid deposition, they also pose serious health risks in the heavily populated urban areas in which they are emitted in high concentrations. Overall then, their impact is far more localised than that of carbon dioxide, thereby justifying the distinction which has been drawn between local and global pollutants.

(iii) Suspended Particulate Matter.

Suspended particulate matter is composed of solid or liquid particles which remain airborne once emitted and which originate from industrial activity and fossil fuel use, particularly the burning of coal. It is often the most obvious kind of air pollution since its existence results in loss of visibility and the soiling of buildings, clothing etc. Exposure to high levels of suspended particulate matter results in respiratory problems, the irritation of mucous membranes, the aggravation of existing lung and heart disease and even death in severe cases, such as those which occurred in London in the 1950s and early 1960s. Furthermore, the combination of suspended particulate matter and sulphur dioxide exacerbates the health effects associated with each.

(iv) Carbon Monoxide.

Carbon monoxide is generated predominantly by motor vehicles and has become a significant health hazard in many of the world's larger cities. The adverse effects on health associated with carbon monoxide stem from its ability to interfere with the absorption of oxygen by red blood cells.

(v) Emissions of Local Air Pollutants From Transport.

Carbon monoxide, however, is not the only pollutant generated in large quantities by the transport sector. In 1991, for example, the transport sector was responsible for almost 20% of carbon dioxide emissions from energy use (OECD (1993)). It has also been estimated that transport is responsible for 29-32% of world-wide anthropogenic emissions of nitrogen dioxide, 10-20% of suspended particulate matter, and 2-6% of sulphur dioxide (Faiz *et al.* (1992)). For each of the above local air pollutants, the relationship between income and the level of emissions resulting from the transport sector is examined.[4]

Data for all the local air pollutants are constructed from estimates of fuel use which are then applied to country and year specific estimates of emissions per unit of fuel used.

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[4] Note that carbon monoxide from the transport sector is not considered separately to *total* carbon monoxide since there is very little difference between the two. For example, in 1993, carbon monoxide emissions from the transport sector accounted for 82% of total emissions in the USA and 92% in the UK (OECD 1995).

Water Pollution.

(vi) Nitrates.

With regard to water pollution, this study considers the relationship between income and the level of nitrates in rivers. The concentration of nitrates in surface and groundwaters has been a source of concern for some years and nitrate concentrations beyond the World Health Organisation's drinking water guideline are widespread in European and North American aquifers (UNEP (1993)). High concentrations of nitrates are suspected of causing methaemoglobinaemia in bottle-fed infants. The presence of nitrates in rivers and lakes appears to be a direct consequence of the use of nitrogen fertilizers on nearby land.

(vii) Phosphorous

The second indicator of water quality is the level of phosphorous detected in rivers. Phosphorous in river water is often the result of detergents entering the river networks and is also associated with the use of phosphate fertilisers on agricultural land. If river water contains high concentrations of nutrients such as nitrates and phosphates, the result will be a proliferation of algal growth. Decaying algae will then consume oxygen, at the expense of fish and other aquatic life.

Nitrate and phosphorous data are given in terms of annual mean concentrations of nitrates and phosphorous, measured at the mouth or downstream frontiers of the rivers.

Freshwater pollutants absent from this analysis would include the level of dissolved oxygen, the concentration of fecal coliform, and the concentrations of heavy metals.

5.2.2 Indicators with NO DIRECT Local Environmental Impact.

(i) Carbon Dioxide.

Carbon dioxide is a global pollutant for which a comprehensive set of data exists. Estimated emissions derive from fossil fuel burning, cement production and gas flaring. The data on fossil fuel emissions are created by applying carbon dioxide emissions coefficients to the United Nations fossil fuel consumption data series; cement emissions data stem from cement manufacturing data compiled by the US Bureau of Mines; gas flaring emissions stem from the United Nations and the US Department of Energy's Energy Information.

(ii) Total Energy Use.

In the 1970s the primary environmental concern was the finite nature of our supply of fossil fuels. In the 1990s this is a secondary concern, with the attention of environmentalists now turned to a different energy problem - how to deal with the waste which is generated when energy is consumed. Indeed, global warming and increased acid rain both stem from greater resource use and clearly, the more energy consumed, the more pressing these problems become. This study therefore also examines the relationship between economic growth and total energy consumption. Total energy use data refer to the energy used "by the different end-use sectors (i.e. industry, transport, agriculture, commerce, public services and residential uses, as well as non-energy uses of gas, coal, oil and oil products). It includes consumption of solid fuels (mainly coal), oil, gas, electricity and heat" (OECD (1993) p.204).

(iii) CFCs and Halons and Methane.

Other global pollutants considered in this paper are chlorofluorocarbons (CFCs) and halons, and methane. CFCs and halons were, until recently, commonly found in refrigeration units and aerosols, whilst halons, in particular, have been widely used as fire extinguishants. Data on the consumption of CFCs and halons are based on official reports submitted to the Ozone Secretariat, UNEP, under the terms of the Montreal Protocol. Note that the trade and consumption of black market CFCs are unlikely to be included in these data. Methane is emitted from a variety of sources including, landfills, wet rice cultivation, energy production and use, biomass burning, and livestock. Due to a lack of time series data these environmental indicators are subjected to OLS cross-section analysis.

Carbon dioxide, CFCs and halons, and methane are all 'greenhouse gases' which are believed to contribute to global warming.[5] The term 'greenhouse gas' refers to certain pollutants which are released by human economic activity and which have the effect of preventing heat from escaping into the upper atmosphere.[6] It is therefore widely believed that any increase in the concentration of these gases will cause the earth's surface and lower atmosphere to get warmer - hence the 'greenhouse effect'. Although there is uncertainty surrounding the extent and timescale of any climate change, the scientific consensus, as represented by the Intergovernmental Panel on Climate Change (IPCC), predicts significant global warming by the middle of the next century if current practices remain unchanged. This would clearly have widespread ecological and economic implications.

A global pollutant missing from this analysis is nitrous oxide, another greenhouse gas. Its omission is due to the limited nature of nitrous oxide emissions data.

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[5] The Intergovernmental Panel on Climate Change (1990) estimates that carbon dioxide is responsible for two-thirds of the greenhouse effect, with methane responsible for 15 percent, CFCs approximately 24 percent and nitrous oxide 6 percent. As Cline (1992) points out though, subsequent findings would indicate that CFCs have a smaller impact than the IPCC believed.

[6] The greenhouse gases are transparent to short wave radiation from the sun and allow about half to reach the earth's surface, but are relatively opaque to the long wave radiation emitted from the earth, trapping about 80 to 90 percent. (Cline 1992).

(iv) Municipal Waste.

Municipal waste data measure waste from households, small commercial and industrial enterprises, office buildings, institutions such as schools and government buildings and market and garden residuals which are collected by and for the municipalities.[7] Two-thirds of OECD waste is disposed of in landfill sites, with the result that new sites are constantly being sought.[8] Local opposition to proposed sites is often strong due to the associated disruption to the countryside and the increase in freight traffic. In addition, in 1991, solid waste was responsible for 16% of total anthropogenic methane emissions, thereby providing a contribution to global warming.[9]

(v) Energy Use from Transport.

The transport sector also contributes significantly to global total energy consumption. Indeed, in 1991, the transport sector was responsible for 30.8% of total energy consumption in the OECD (OECD (1993)). As a result, the relationship between economic growth and energy consumption from the transport sector is examined. Energy consumption by the transport sector refers to the energy used by air, road and rail transport. It should be noted, however, that the transport sector does not only directly use energy in the operation of vehicles. As Transnet (1990) point out, the demand for transport also results in a demand for the manufacture of vehicles and vehicle components; a demand for associated raw material manufacture; a demand for the maintenance of vehicles; a demand for transport infrastructure; and a demand for the generation of energy. These indirect energy requirements are not considered in this analysis, thereby

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[7] It should be noted that the municipal waste data simply records how much waste is collected, and provides no information concerning how much of that waste is then recycled. Recycling rates are rising steadily within the OECD, with the recycling of glass standing at 66% in the Netherlands in 1990, for example. However, even for the Netherlands, recycled waste represented only 4% of total waste collected in 1990. This compares with 3.6% in France, 3.4% in Japan and a relatively high 14% in the USA. (OECD (1993)).

[8] OECD (1993). Calculation is made for 1990, or for late 1980s where 1990 data were not available.

[9] World Resources Institute (1994)

perhaps underestimating the true environmental impact of the transport sector.

(vi) Traffic Volumes.

Road traffic volumes are expressed in kilometres travelled by all road vehicles. The average number of kilometres travelled each year by road vehicles is multiplied by the number of motor vehicles in use. Changes in traffic volumes are a major factor in explaining the impact of transport on the environment, in terms of air pollution, noise pollution, increased congestion, and the ever growing pressure for the construction of new roads.

The income, population and trade intensity data for the period 1960-92 originate from the Penn. Mark 5.6 World Tables, in Summers and Heston (1991). The income variable used is real per capita GDP, measured in purchasing power parity terms and in 1985 US dollars (variable RGDPCH) which allows comparison of income levels between countries and over time. The measure of trade intensity is the trade openness variable which is the ratio of the sum of exports and imports to GDP.

5.3 Framework.

To estimate the relationship between income and environmental quality reduced form equations are used which relate the environmental indicators to per capita income, for each region or country. The environmental indicators are also in per capita form, except for the two measures of water pollution, nitrates and phosphorous.[10]

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[10] Note that due to data constraints a panel analysis is not possible for CFCs and halons, and methane therefore a simple OLS cross-section analysis is adopted.

Why a Reduced Form?

Shafik (1994) argues that there are four key determinants of environmental quality: (i) natural endowments such as climate and location, (ii) per capita incomes which reflect industrial composition and urbanisation, (iii) environmental policies and (iv) exogenous factors such as the level of technology, trade intensity and population density. Environmental quality could clearly be modelled using structural equations which include the above as variables, but such an approach would require extensive data which, for the most part, either do not exist or, as Grossman and Krueger (1995) point out, are of questionable validity. An alternative is to model environmental quality using a reduced form approach, as practised by Grossman and Krueger (1995), Shafik (1994), Selden and Song (1994) and Holtz-Eakin and Selden (1992). Natural endowment is accommodated in reduced form equations by the inclusion of fixed effects which allow each country or region to have its own intercept. The inclusion of per capita income in the reduced form is intended to capture both the *direct* and the *indirect* consequences of economic growth. Therefore, explanatory variables which themselves are generated by economic development i.e. the endogenous effects of growth such as the composition of output and the growth of urbanisation, are not explicitly considered. With regard to environmental policy, although not lending itself to direct inclusion in a reduced form approach, it is likely that there is a relationship between such policy and the level of per capita income across countries. The level of technology, if exogenous, may be reflected in a time trend which is linear in nature. However, the inclusion of a time trend raises a number of complicating issues. As a result, a model containing a time trend is considered separately in Chapter 6, with the time trend (i.e. the level of technology) being omitted for the purposes of this present chapter.[11] Trade

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[11] Whilst, for the most part, the reduced form can accommodate the key determinants of environmental quality (with the possible exception of environmental policy), the influence on environmental quality of other factors such as the oil price changes in the 1970s and 80s will generally not be accommodated.

intensity (the ratio of the sum of imports and exports to GDP) is included as an independent variable to test the hypothesis that the more trade-oriented a country is, the more degraded is its environment. The relationship between trade liberalisation and environmental degradation is discussed in Chapter 3. Population density is also tested as an independent variable following Selden and Song (1994) who suspect this variable to have an inverse relationship with pollution. Their reasons for such a suspicion are that if a country has low population density, the government may not be too concerned with reducing per capita pollution emissions. Secondly, a less concentrated population may require more transportation thus raising transport generated pollution. Finally, the *rate* of economic growth is tested as an independent variable. Typically, it is the level of income rather than its rate of change which is believed to affect environmental quality. Panayotou (1998), however, claims that a high rate of income growth could reduce environmental quality if the rapid accumulation of stock pollutants exceeds the assimilative capacity of the environment. Although increased pollution abatement could perhaps offset this accumulation of pollutants, as Panayotou points out, there is no reason to assume that a faster rate of economic growth will result in more pollution abatement than that corresponding to each level of per capita income.

Given the above, and in the absence of the level of technology, environmental quality could be expressed as follows;

$$EQ = f(n, Y, p, X)$$

where, EQ = environmental quality

n = natural endowment. This is accommodated using fixed effects.

Y = per capita income. This is intended to also capture the endogenous effects of economic growth.

p = environmental policy. This is likely to be a function of income.

X = exogenous factors such as trade intensity, population density and the rate of income growth.

Specifically, two reduced form equations are estimated;[12]

(1) Quadratic in levels;

$$E_{it} = (\alpha + \mu_i F_i) + \beta Y_{it} + \gamma Y^2_{it} + \varphi X_{it} + e_{it}$$

(2) Quadratic in logs;

$$\ln E_{it} = (\lambda + \kappa_i F_i) + \eta \ln(Y_{it}) + \theta(\ln Y_{it})^2 + \omega X_{it} + e_{it}$$

where, E = the environmental indicator in per capita form

Y = per capita income

F = region or country-specific fixed effects

X= exogenous factors

i = 1 .....n regions

t = 1.......T years

A priori, the quadratic logs function would seem to provide a more realistic income / environmental quality path than the quadratic levels function due to the symmetrical nature of the latter.[13] With regard to pollution for example, this symmetry implies that, firstly, pollution levels will fall at the same rate as they increased, and secondly, these pollution levels will become negative, possibly in a very short space of time. Two

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[12] A cubic function was also estimated, but the fact that every cubic relationship necessarily goes to plus or minus infinity was deemed to be unrealistic. As a result, the study concentrates on quadratic relationships, although linear and log linear relationships are also considered for two environmental indicators.

[13] Appendix G contains the proof that a quadratic levels function with a positive income term and a negative income squared term will be symmetrical around the maximum turning point, whilst a quadratic logs function will not be.

examples of quadratic functions, one in logs the other in levels, which both give the same turning point, will illustrate this point:

If the two quadratic functions are;

$$\ln e = 3\ln y - 0.5(\ln y)^2 \qquad \text{...(a)}$$

$$e = -10 + 10y - 0.25y^2 \qquad \text{...(b)}$$

The first order differentiation of (a) and (b), respectively, gives;

$$\frac{d\ln e}{d\ln y} = 3 - \ln y$$

$$\text{if } 3 - \ln y = 0$$

$$\text{then } 3 = \ln y$$

$$\text{and } y = 20$$

$$\frac{de}{dy} = 10 - 0.5y$$

$$\text{if } 10 - 0.5y = 0$$

$$\text{then } 10 = 0.5y$$

$$\frac{10}{0.5} = y$$

$$\text{and } y = 20$$

substituting $\ln y = 3$ into (a);

$$\ln e = 3\ (3) - 0.5\ (3)^2$$

$$\ln e = 9 - 4.5$$

$$\ln e = 4.5$$

$$e = 90.0$$

substituting $y = 20$ into (b);

$$e = -10 + 10\ (20) - 0.25\ (20)^2$$

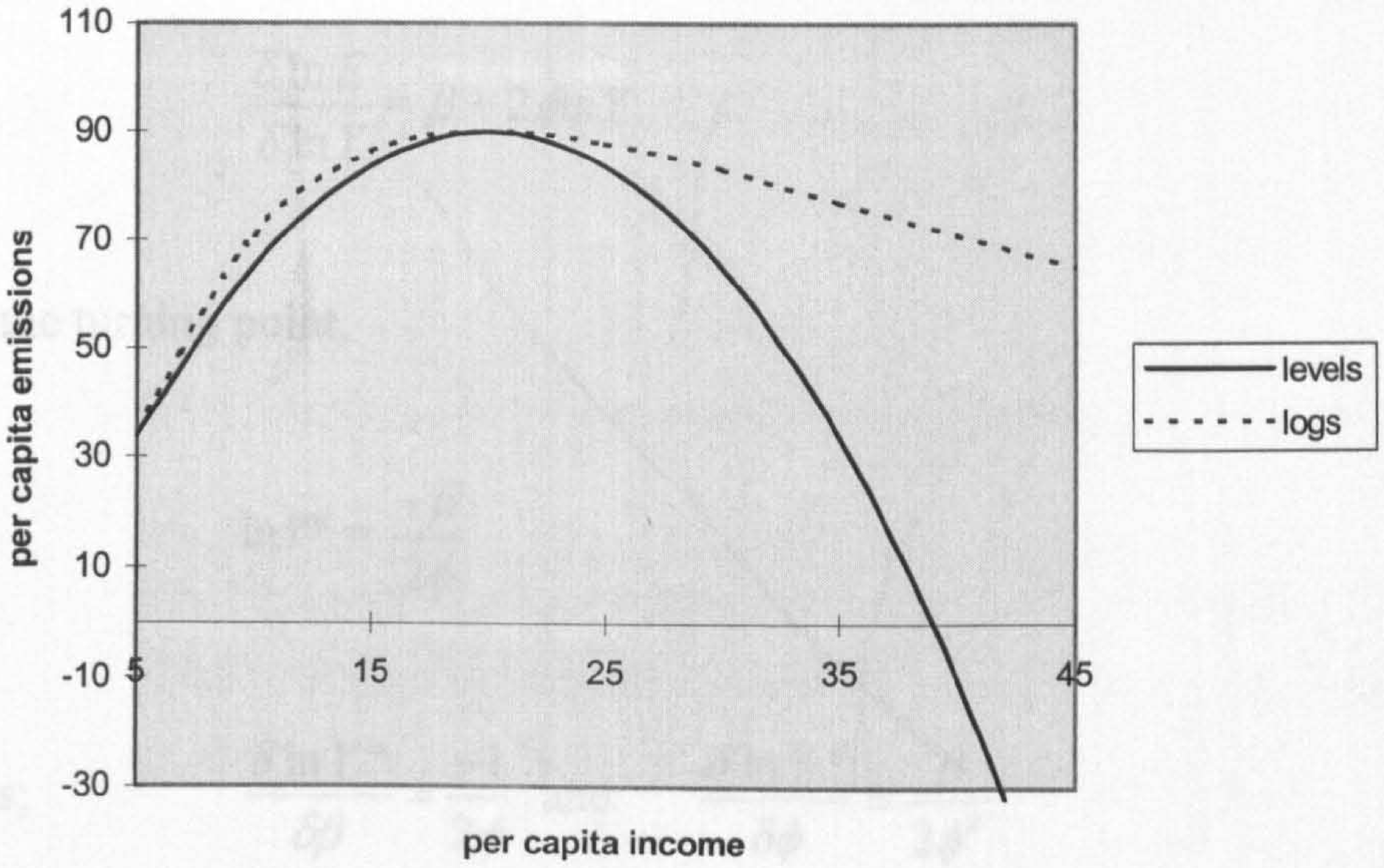
$$e = -10 + 200 - 100$$

$$e = 90$$

Turning points for both functions occur at (20, 90). Furthermore, second order differentials are negative, thereby confirming that these are *maximum* turning points.

Diagram 1, below, illustrates the two functions. The quadratic levels function can be seen to be symmetrical around the turning point. In contrast, once the quadratic logs function passes the turning point it falls away only gradually, as the curve asymptotically approaches zero. Those pollutants that have experienced falling emissions would seem to have followed a path closer to the quadratic logs function than the quadratic levels function, with pollution levels stabilising and then falling only gradually. Therefore, of the two functional forms, the quadratic logs function would seem to provide a more realistic basis with which to model the relationship between income and environmental quality.

Diagram 1.



With regard to the actual estimation procedure, an analysis of ordinary least squares residuals, for all estimations, indicates the existence of autocorrelation, that is the error terms are correlated over time, as well as heteroscedasticity, i.e. the variance of the error terms is not equal.[14] Due to the existence of these features, a generalised least squares approach is adopted following Kmenta (1986), which corrects for both autocorrelation and heteroscedasticity.[15]

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[14] For all estimations Box-Pierce and Durbin-Watson tests were used to indicate the existence of autocorrelation. Breusch-Pagan-Godfrey, Harvey, and Glejser tests were also used to indicate heteroscedasticity.

[15] See Appendix H for an outline of Kmenta's (1986) GLS process.

The Standard Errors of the Turning Points - The Delta Method.

To assess the reliability of estimated turning points, the standard error associated with each turning point is calculated and reported in Table 2, below. The Delta method is used to calculate the errors, following Greene (1993). For the logged quadratic function, for example, it takes the following form:

$$\text{If } \ln E = \alpha + \beta \ln Y + \phi(\ln \mathrm{Y})^2$$

$$\frac{\delta \ln E}{\delta \ln Y} = \beta + 2\phi \ln Y$$

At the turning point,

$$\ln Y^* = \frac{-\beta}{2\phi}$$

thus; $$\frac{\delta \ln Y^*}{\delta \beta} = \frac{-1}{2\phi} \quad \text{and} \quad \frac{\delta \ln Y^*}{\delta \phi} = \frac{\beta}{2\phi^2}$$

The Delta method states that, given the above, the variance of income at the turning point is as follows;

$$\mathrm{Var}\, Y^* = (-1/2\phi \quad \beta/2\phi^2) \begin{pmatrix} \mathrm{Var}\,\beta & \mathrm{Cov} \\ \mathrm{Cov} & \mathrm{Var}\phi \end{pmatrix} \begin{pmatrix} -1/2\phi \\ \beta/2\phi^2 \end{pmatrix}$$

The standard error of Y^* is then = $\sqrt{\mathrm{var}\, Y^*}$

Simultaneity Bias.

A Hausman specification test was employed to test the null of exogeneity of current income in the EKC. Lagged income was used as the instrumental variable. The test statistic is a Wald statistic, which is then referred to a chi-squared distribution, with appropriate degrees of freedom (see Greene (1993)), of the form;

$$W = (\hat{b} - \hat{b}_{IV})' [V_1 - V_0]^{-1} (\hat{b} - \hat{b}_{IV})$$

where $\hat{b}$ = the GLS estimators using current income

$\hat{b}_{IV}$ = the GLS estimators using lagged income (the instrumental variable)

V_1 = the variance-covariance matrix for the estimation using lagged income

V_0 = the variance-covariance matrix for the estimation using current income, divided by the variance of the current income estimation and multiplied by the variance of the lagged income estimation.

This test has been performed for all of the key pollutants - namely carbon dioxide and all four local air pollutants. The null of exogeneity was accepted in all cases, indicating that simultaneity is unlikely to be present. The test results are included in the next section.[16]

Fixed or Random Effects?

A random effects specification was also used for the local air pollutants and carbon dioxide (i.e. for the key pollutants), even though it was felt that

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[16] Note that this test is similar to the Holtz-Eakin, Newey and Rosen test used by Holtz-Eakin and Selden (1992). Note also that the Holtz-Eakin, Newey and Rosen test and the test used in this chapter have low power to reject the null.

this specification is more appropriate for studies which use site-specific data such as Grossman and Krueger (1993, 1995). A Hausman test was used to ascertain whether fixed or random effects estimation was preferred by determining whether the random effects are correlated with the income terms. Only in the absence of such correlation is random effects estimation consistent and efficient. Again, the test statistic is based on the Wald criterion, of the form;

$$W = [\hat{b} - \hat{B}]' \Sigma^{-1} [\hat{b} - \hat{B}]$$

Where $\hat{b}$ = the GLS estimator using fixed effects

$\hat{B}$ = the GLS estimator using random effects

$\Sigma = \mathrm{Var}[\hat{b}] - \mathrm{Var}[\hat{B}]$

In all instances the test statistics indicate that the random effects *are* correlated with the income variables, and hence the fixed effects estimation is favoured. The test results are included in the next section, whilst the random effects regression results are reported in Appendix I.

5.4 Results.

The tables below present the results from Kmenta's (1986) generalised least squares approach for the favoured quadratic logs functional form, using fixed effects estimation.[17] Appendix I contains GLS quadratic levels results as well as GLS linear results (where appropriate), all OLS results and all random effects results. The dummy variables form the difference in intercept between the relevant country or region, and that of the country or region which forms the constant. The figures in parentheses are the 't' statistics. Buse R^2 is a goodness of fit measure for generalised least

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[17] For CFCs and halons, and methane OLS results are reported.

squares, which is calculated using weighted variables following Buse (1973). It is analogous to the definition of R^2 used with ordinary least squares, and provides a measure of the proportion of the generalised sum of squares of the dependent variable which is attributable to the influence of the explanatory variables. D.W. and B.P. refer to Durbin-Watson and Box-Pierce tests - both of which test for the existence of autocorrelation in the OLS estimations. B.P.G., Harvey, and Glejser refer to the Breusch-Pagan-Godfrey, Harvey and Glejser tests, which test the OLS estimations for heteroscedasticity. An asterisk (*) indicates those tests which suggest that autocorrelation or heteroscedasticity is present, with a 95% confidence interval. Hausman test results for simultaneity and fixed versus random effects are also reported, with degrees of freedom in parentheses.

Choice of Country in the Diagrams:

For each environmental indicator, the estimated GLS quadratic logs relationship between per capita income and environmental quality is shown for one of the sample countries or regions.[18] Countries with relatively low levels of per capita income have been chosen in the diagrams, where possible, if the estimated turning point is at a relatively low level of income. This is to illustrate as much of the estimated income/environmental quality relationship as possible, and to ensure that the turning point is included. If the sample only contains nations with similar per capita income levels, the UK has been chosen. The diagrams show the likely future path of the income/environmental quality relationship, given their previous relationship.

Table 2 indicates the estimated percentage change in *total* emissions/energy use/traffic volumes over the period 1990-2000 for all environmental indicators. Calculations are made for the UK, or Western

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[18] The diagram for CFCs and halons stems from an OLS regression.

Europe in the case of carbon dioxide. Again, the quadratic logs functional form is used together with a two per cent per capita income growth rate.[19]

Table 2. Percentage Change of Total Environmental Indicators in the UK 1990-2000.

Environ. Indicator	% Change	Environ. Indicator	% Change
Sulphur Dioxide	-35.8	Phosphorous	-32.4
Sulphur Dioxide - Tran.	-15.6	Carbon Dioxide	+ 14.2
SPM	-36.2	Total Energy Use	+10.9
SPM - Transport	+7.7	CFCs and Halons 1990	-1.4
Carbon Monoxide	-20.0	Transport Energy Use	+27.7
Nitrogen Dioxide	+3.7	Municipal Waste	+27.3
Nitrogen Dioxide - Tran.	+11.6	Traffic Volumes	+25.1
Nitrates	+15.1		

Table 2 illustrates that many of the local air pollutants are expected to fall considerably between 1990 and 2000, but also makes clear the distinction between *total* local air pollution emissions and *transport generated* local air pollution. Also clear is the extent of the expected increase of the more indirect environmental indicators such as municipal waste, energy use and traffic volumes. These issues are discussed below.

The trade intensity variable was estimated as negative throughout, thereby suggesting that an increase in trade intensity is associated with a fall in pollution / environmental damage. The variable, however, was not statistically significant for any of the environmental indicators. The results, below, therefore stem from regressions from which trade intensity was omitted. Grossman and Krueger (1993) also found the trade intensity

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[19] According to the Penn. World Tables the UK had a per capita income level of $13,217 in 1990 and W.Europe $11,540. Total emissions are calculated simply by multiplying estimated per capita emissions by population. Population in 2000 is estimated using United Nations projected growth rates (UNEP 1993).

variable to be negative, whilst it was statistically significant for only one of the three pollutants considered in their analysis.

The population density variable appears to be acting as a linear time trend, and is statistically significant and insignificant, positive and negative for the same variables as the time trend. As a result, where data allowed, cross-section analyses were undertaken for individual years to assess whether population density is a determinant of environmental quality, in the absence of the time effect. The variable was statistically insignificant on all occasions. Due to this fact, and since the link between population density and environmental quality is tenuous at best, the results below are from regressions which do not include population density as an independent variable.

The rate of economic growth was also statistically insignificant throughout, and did not have a uniform sign across indicators. The results below therefore stem from regressions from which the rate of economic growth was omitted. In contrast, Panayotou (1998) considers sulphur dioxide concentrations and finds the rate of income growth to be statistically significant and positive, implying that a higher growth rate results in higher sulphur dioxide concentrations.

Tables 3 and 13, below, present the estimates of the turning point levels of income (in 1985 US dollars) for the favoured quadratic logs functional form, for those environmental indicators for which turning points were estimated, and provides a comparison with the results of other studies.[20] As a point of reference, in 1992, per capita income (in 1985 US dollars) was $17,945 in the USA, $12,724 in the UK, $1,282 in India and a mere $408 in Chad (Summers and Heston (1991)). The standard errors for these

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[20] Note that estimated turning points should be treated with caution and, in reality, provide only an approximate indication of the income level at which emissions may begin to fall.

turning points are reported in parentheses, and were calculated using the Delta method. The letter 'F' denotes turning points that are higher than the maximum observed income in the data set; for the environmental indicators with these projected turning points, per capita emissions / environmental damage are increasing, at a declining rate, throughout the observed income range. Note that no turning points are estimated to be below the minimum income level in each sample.

5.4.1 Indicators with a DIRECT Local Environmental Impact.

Table 3. Estimated Turning Points (1985 US$).

	This Study:	**Other Studies:**[21]		
	Emissions per capita	**Urban Concentrations**		**Emissions per capita**
ENVIRON. INDICATOR	**Quad. Logs**	**G&K**[22]	**Shafik**[23]	**S&S**[24]
Sulphur Dioxide	$6,900 (563)	$4,053	$3,670	$8,916
Sulphur Dioxide - Transport	$9,800 (586)			
SPM	$7,300 (264)	$6,151	$3,280	$9,811
SPM - Transport	$18,000 (2,709)			

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[21] Where, G&K refers to Grossman and Krueger (1995), Shafik refers to Shafik (1994), S&S refers to Selden and Song (1994) and H-E&S refers to Holtz-Eakin and Selden (1992). All estimated turning points are in 1985 US dollars.

[22] Estimates result from a quadratic levels functional form. Suspended particulate matter data were split into two categories by Grossman and Krueger - smoke and heavy particles. This turning point is for smoke. The relationship between heavy particles and income was estimated to be monotonically decreasing. Figures in parentheses are the standard errors at the turning point, calculated by the Delta method. Grossman and Krueger used GEMS data published by the World Health Organisation, together with unpublished data from the US Environment Protection Agency.

[23] Estimates are from a logged quadratic functional form. Data stem from the Monitoring and Assessment Research Centre (1991).

[24] Estimates are from Selden and Songs' fixed effects quadratic levels functional form, without population density. Data were from the World Resources Institute (1991).

Table 3 (Continued).

	This Study:	**Other Studies:**		
	Emissions per capita	**Urban Concentrations**		**Emissions per capita**
ENVIRON. INDICATOR	**Quad. Logs**	**G&K**	**Shafik**	**S&S**
Nitrogen Dioxide	\$14,700 (587)			\$12,041
Nitrogen Dioxide - Transport	\$17,600 (1,579)			
Carbon Monoxide	\$9,900 (353)			\$6,241
Nitrates	\$25,000 F (6,779)	\$10,524		
Phosphorous	\$6,600 (500)			

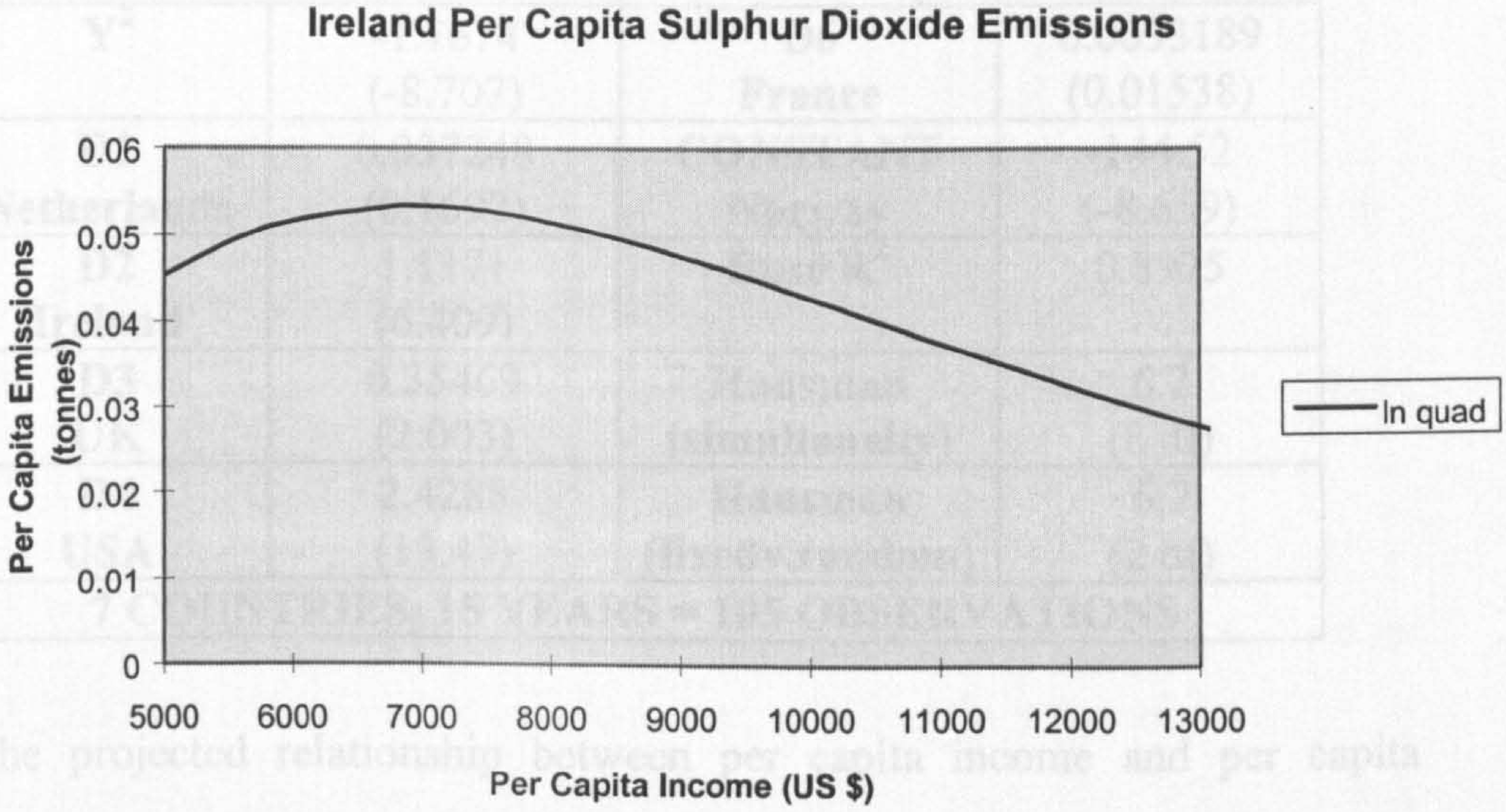
(i) Sulphur Dioxide.

Table 4.

SULPHUR DIOXIDE - GLS LOGS QUADRATIC			
Y	28.43 (5.399)	**D7** **France**	0.0472 (0.2295)
Y^2	-1.6084 (-5.649)	**D8** **Canada**	2.0527 (10.99)
D1 **W.Germany**	-0.014414 (-0.05387)	**D9** **Denmark**	0.66156 (4.423)
D2 **Netherlands**	-0.43054 (-1.973)	**D10** **Italy**	0.072181 (0.4995)
D3 **Norway**	-0.29282 (-1.576)	**CONSTANT** **Ireland**	-128.56 (-5.29)
D4 **UK**	0.75158 (4.321)	**Buse R^2**	0.7451
D5 **USA**	1.7372 (8.738)	**Hausman (simultaneity)**	5.3 (12 df)
D6 **Finland**	0.76627 (4.652)	**Hausman (fixedv.random)**	9.2 (2 df)
11 COUNTRIES, 15 YEARS = 165 OBSERVATIONS			

The GLS projection contained in diagram 2 shows that per capita income and per capita sulphur dioxide emissions have an estimated turning point at a per capita income level of approximately $6,800. As Table 3 illustrates, Grossman and Krueger (1995) and Shafik (1994) estimated turning points in urban sulphur dioxide *concentrations* at per capita income levels of $4,053 and $3,670, respectively, whilst Selden and Song (1994) estimated a turning point in sulphur dioxide *emissions* at $8,916. The fact that turning points for aggregate emissions are significantly higher than those for urban air concentrations was expected by Selden and Song, as mentioned previously. However, the results of this study, whilst still being notably *higher* than those of Grossman and Krueger and Shafik, are also notably *lower* than the estimates of Selden and Song, thereby weakening their argument.

Diagram 2.



Nevertheless, the fact that all estimated turning points are at relatively low levels of income illustrates just how successful efforts have been to reduce sulphur dioxide emissions. In 1985, the Convention on Long-Range Transboundary Air Pollution was formed which contained the Sulphur Protocol committing signatories to reduce emissions by 30% from 1980 levels to 1993. Most nations achieved this goal and even non-signatories have reduced their emissions. Total sulphur dioxide emissions in Europe fell from approximately 55 million metric tonnes in 1980 to approximately 40 million in 1991 (World Resources Institute (1994)). In the developed world, a change from domestic coal burning to electricity and natural gas for cooking and heating has been responsible for a large proportion of this reduction in sulphur dioxide (UNEP (1993)). However, many developing countries have not made this switch and are now suffering from high levels of sulphur dioxide emissions.

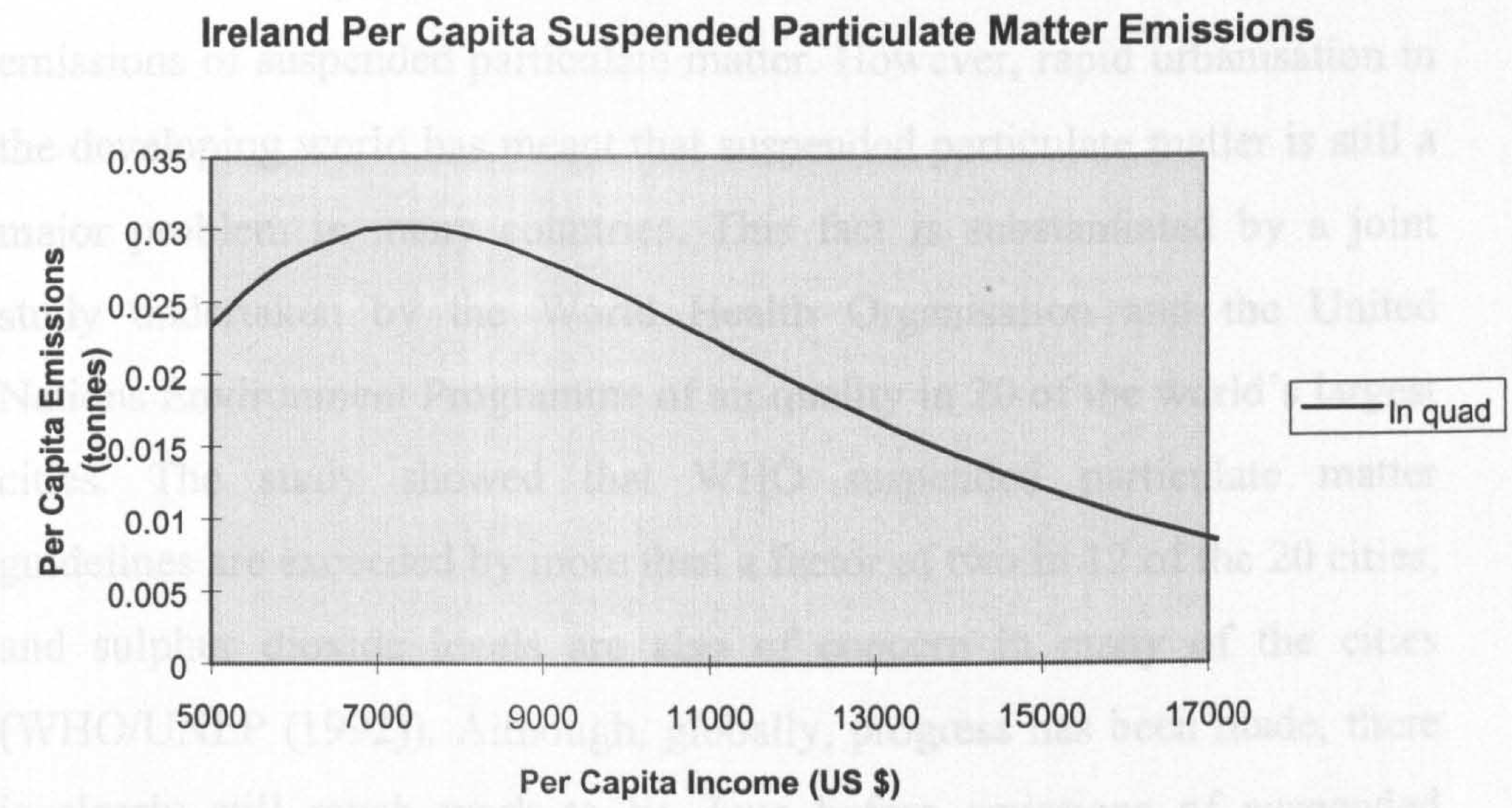
(ii) Suspended Particulate Matter.

Table 5.

SUSPENDED PARTICULATE MATTER - GLS LOGS QUADRATIC			
Y	31.449 (8.538)	**D5 W.Germany**	0.48937 (2.939)
Y^2	-1.7674 (-8.707)	**D6 France**	0.0033189 (0.01538)
D1 Netherlands	0.037248 (0.1692)	**CONSTANT Norway**	-144.52 (-8.659)
D2 Ireland	1.1171 (6.409)	**Buse R^2**	0.8975
D3 UK	0.35469 (2.003)	**Hausman (simultaneity)**	6.2 (8 df)
D4 USA	2.4288 (13.47)	**Hausman (fixedv.random)**	6.7 (2 df)
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

The projected relationship between per capita income and per capita emissions of suspended particulate matter is illustrated in diagram 3, below. As with sulphur dioxide, the turning point occurs at a relatively low per capita income level - approximately $7,300. Grossman and Krueger (1995) and Shafik (1994) estimated turning points for suspended particulate matter *concentrations* at per capita income levels of $6,151 and $3,280, respectively, whilst Selden and Song (1994) estimated a turning point for suspended particulate matter emissions at $9,811. Clearly, this disparity between estimated turning points for urban air concentrations and those for aggregate emissions supported the hypothesis of Selden and Song.

Diagram 3.



However, again, the results of this study are lower than those of Selden and Song whilst being higher than the estimates of Grossman and Krueger and Shafik. This chapter therefore does support the argument that turning points for aggregate emissions *are* higher than those for urban air concentrations, although the difference would not appear to be as large as Selden and Song believed. Compared to Selden and Song, this study uses far longer time series for each country, resulting in a greater number of observations and hence degrees of freedom.[25] However, although this chapter's observations for both sulphur dioxide and suspended particulate matter do fall on both the upward and downward sloping portions of the estimated curves, Selden and Song include more low income countries in their sample, and have a wider spread of income and better representation on the upward sloping portion. It is therefore difficult to say which results are preferable.

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[25] Selden and Song's time series consists of averages for the periods 1973-75, 1979-81 and 1982-84.

Like sulphur dioxide, all estimated turning points for suspended particulate matter are at relatively low levels of per capita income. In the developed world the shift from coal and oil for heating and cooking, which led to the reductions in sulphur dioxide emissions, has also substantially reduced emissions of suspended particulate matter. However, rapid urbanisation in the developing world has meant that suspended particulate matter is still a major problem in many countries. This fact is substantiated by a joint study undertaken by the World Health Organisation and the United Nations Environment Programme of air quality in 20 of the world's largest cities. The study showed that WHO suspended particulate matter guidelines are exceeded by more than a factor of two in 12 of the 20 cities, and sulphur dioxide levels are also of concern in many of the cities (WHO/UNEP (1992)). Although, globally, progress has been made, there is clearly still much work to be done before emissions of suspended particulate matter and sulphur dioxide cease to be a problem.

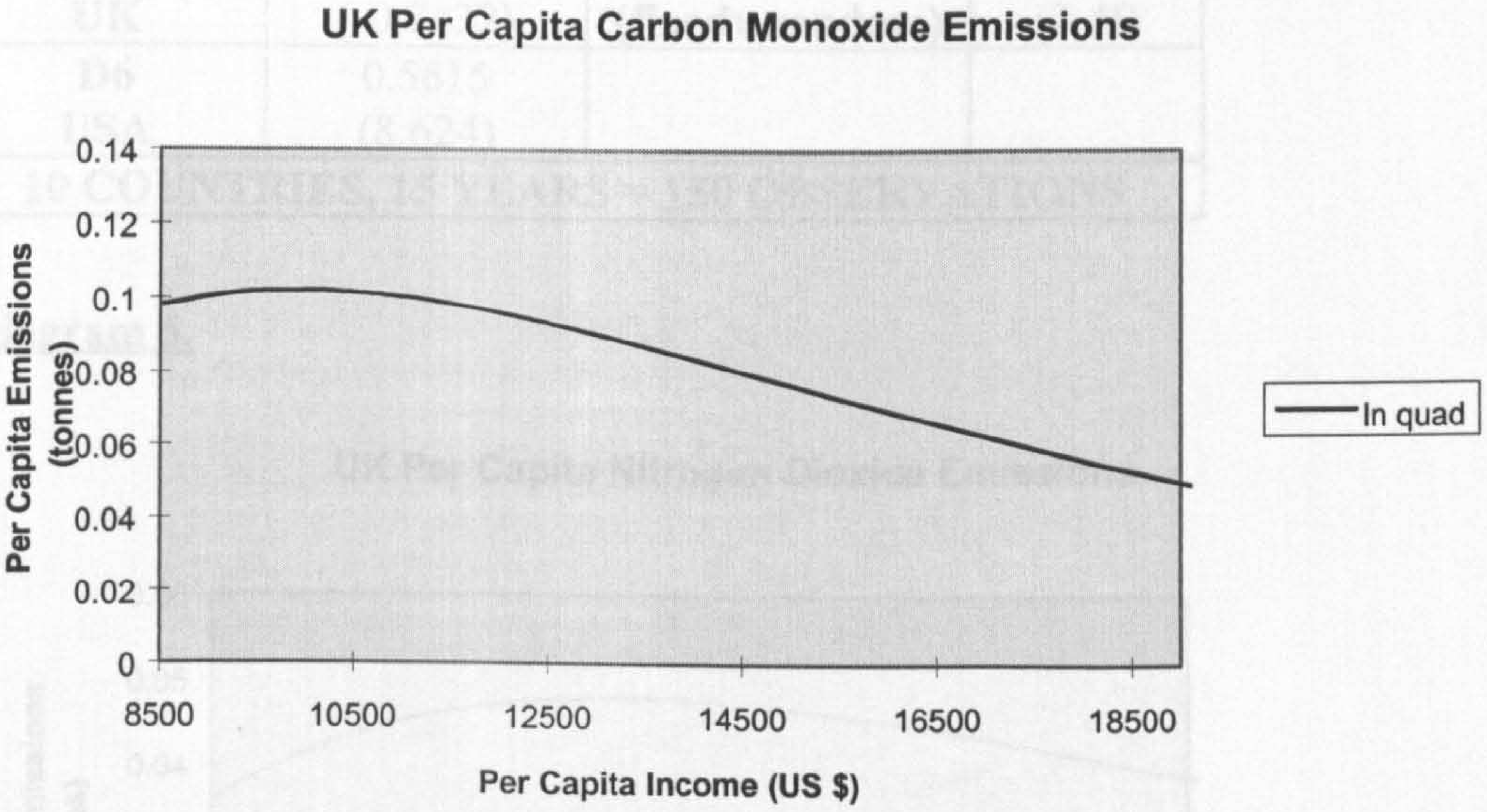
(iii) Carbon Monoxide.

Table 6.

CARBON MONOXIDE - GLS LOGS QUADRATIC			
Y	31.084 (6.845)	**D5** **USA**	1.8054 (13.33)
Y^2	-1.6885 (-6.974)	**D6** **France**	0.49938 (3.572)
D1 **W. Germany**	0.52967 (2.634)	**CONSTANT** **UK**	-145.34 (-6.827)
D2 **Netherlands**	-0.0043304 (-0.02093)	**Buse R^2**	0.8749
D3 **Norway**	0.87769 (5.289)	**Hausman** **(simultaneity)**	9.7 (8 df)
D4 **Denmark**	0.3382 (1.788)	**Hausman** **(fixedv.random)**	10.9 (2 df)
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

Diagram 4 below illustrates the GLS relationship between per capita income and per capita emissions of carbon monoxide. The turning point is estimated at approximately $9,900. This turning point is notably higher than that estimated by Selden and Song (1995) at $6,241. Nevertheless, the relatively low nature of all of these turning points indicates that per capita emissions of carbon monoxide are falling in the majority of the developed world, despite the continued growth of the transport sector. This success can largely be attributed to the fitting of catalytic converters to cars - even the earliest form of which, the oxidation catalyst, tackled carbon monoxide - and cleaner, more energy efficient engines.

Diagram 4.



(iv) Nitrogen Dioxide.

Table 7.

NITROGEN DIOXIDE - GLS LOGS QUADRATIC			
Y	18.538 (5.702)	**D7** **Finland**	0.10424 (1.008)
Y^2	-0.96586 (-5.613)	**D8** **France**	-0.56677 (-5.342)
D1 **W.Germany**	-0.16695 (-1.578)	**D9** **Canada**	0.41381 (6.364)
D2 **Netherlands**	-0.20622 (3.051)	**CONSTANT** **Denmark**	-91.932 (-5.986)
D3 **Norway**	0.031121 (0.3569)	**Buse R^2**	0.9148
D4 **Sweden**	-0.22393 (-3.245)	**Hausman** **(simultaneity)**	11.1 (11 df)
D5 **UK**	-0.056081 (-0.7432)	**Hausman** **(fixedv.random)**	12.0 (2 df)
D6 **USA**	0.5615 (8.624)		
10 COUNTRIES, 15 YEARS = 150 OBSERVATIONS			

Diagram 5.

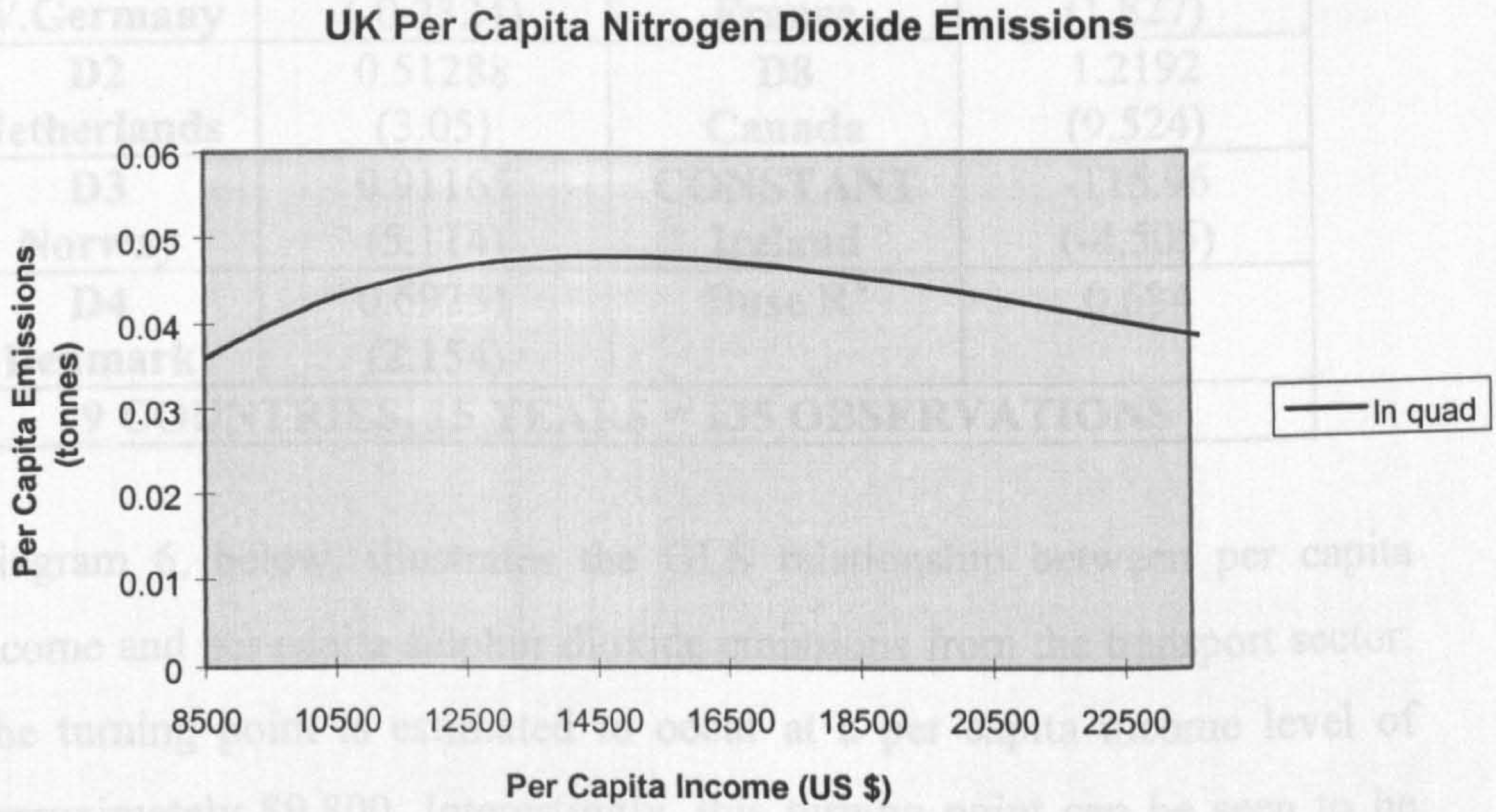


Diagram 5 contains the GLS projections of the relationships between per capita income and per capita nitrogen dioxide emissions, for the two functional forms. The diagram uses the UK's estimated intercept. Turning points occur at a per capita income level of approximately $14,700. This compares with Selden and Song's estimated turning point of $12,041, from Table 3. Whilst the income levels associated with these turning points are clearly substantially lower than those estimated for carbon dioxide, they are still relatively high compared with the other two local air pollutants, sulphur dioxide and suspended particulate matter. The main reason for this finding would seem to be the large contribution of the ever-growing transport sector to total nitrogen dioxide emissions.

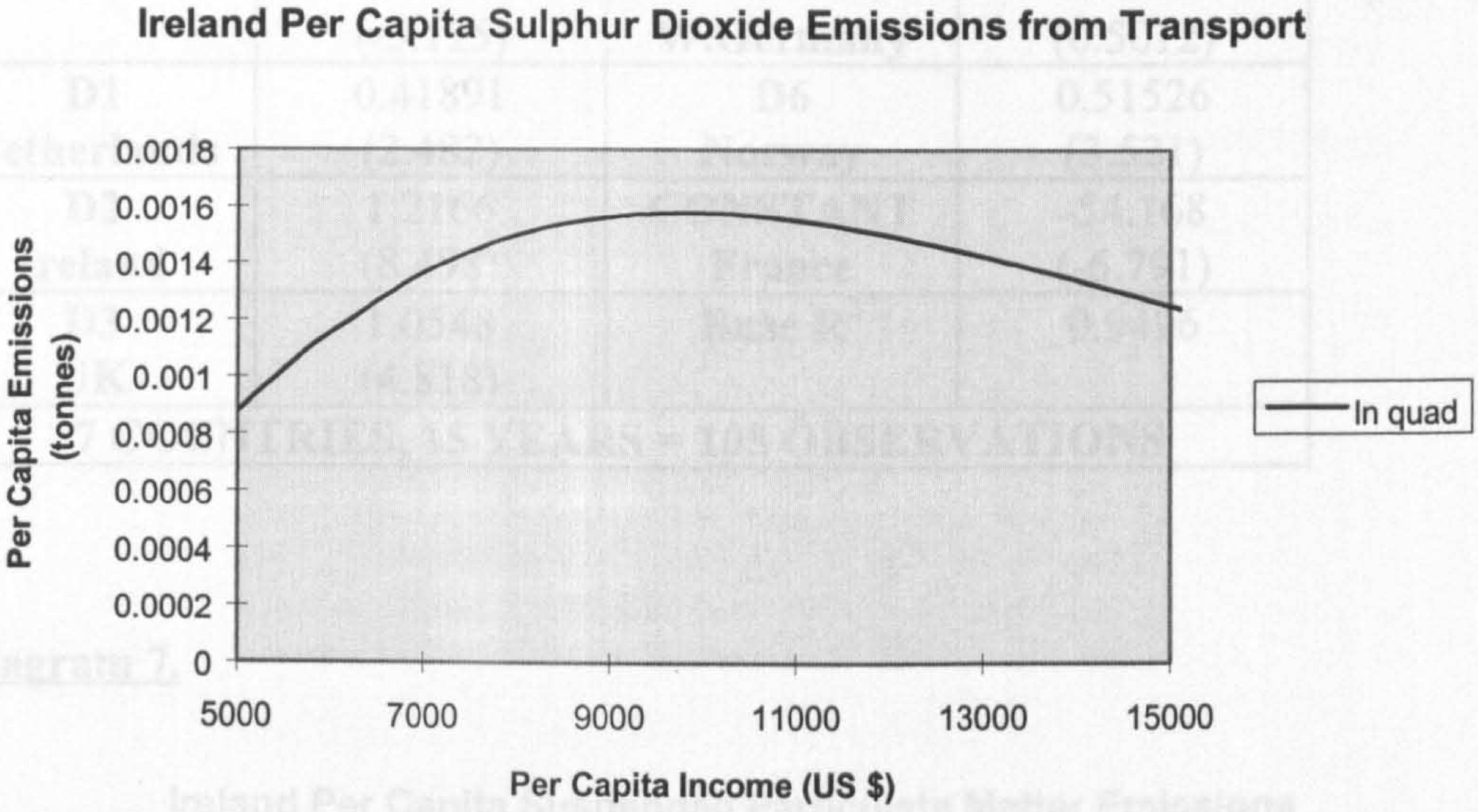
(v) Sulphur Dioxide from Transport.

Table 8.

SULPHUR DIOXIDE TRANSPORT - GLS LOGS QUADRATIC			
Y	23.829 (4.291)	**D5** UK	0.38715 (2.604)
Y^2	-1.2963 (-4.334)	**D6 Finland**	-0.071094 (-0.3177)
D1 W.Germany	-0.054051 (-0.2324)	**D7 France**	0.33148 (1.827)
D2 Netherlands	0.51288 (3.05)	**D8 Canada**	1.2192 (9.524)
D3 Norway	0.91165 (5.114)	CONSTANT **Ireland**	-115.96 (-4.505)
D4 Denmark	0.69231 (2.154)	**Buse R^2**	0.684
9 COUNTRIES, 15 YEARS = 135 OBSERVATIONS			

Diagram 6, below, illustrates the GLS relationship between per capita income and per capita sulphur dioxide emissions from the transport sector. The turning point is estimated to occur at a per capita income level of approximately $9,800. Interestingly, this turning point can be seen to be notably higher than those estimated for *total* sulphur dioxide emissions. The USA is omitted from this estimation as its inclusion led to imprecise results. This can be explained by the fact that, in contrast to the other sample countries, the USA does not appear to have reached a turning point for sulphur dioxide emissions from transport, with emissions rising steadily throughout the late 1980s and early 1990s. The omission of the USA clearly weakens the results, however.

Diagram 6.



Although the transport sector is not a major contributor to total sulphur dioxide emissions, it can be seen that the reduction of sulphur dioxide emissions from the transport sector has proven more difficult than the reduction of non-transport sulphur dioxide emissions.

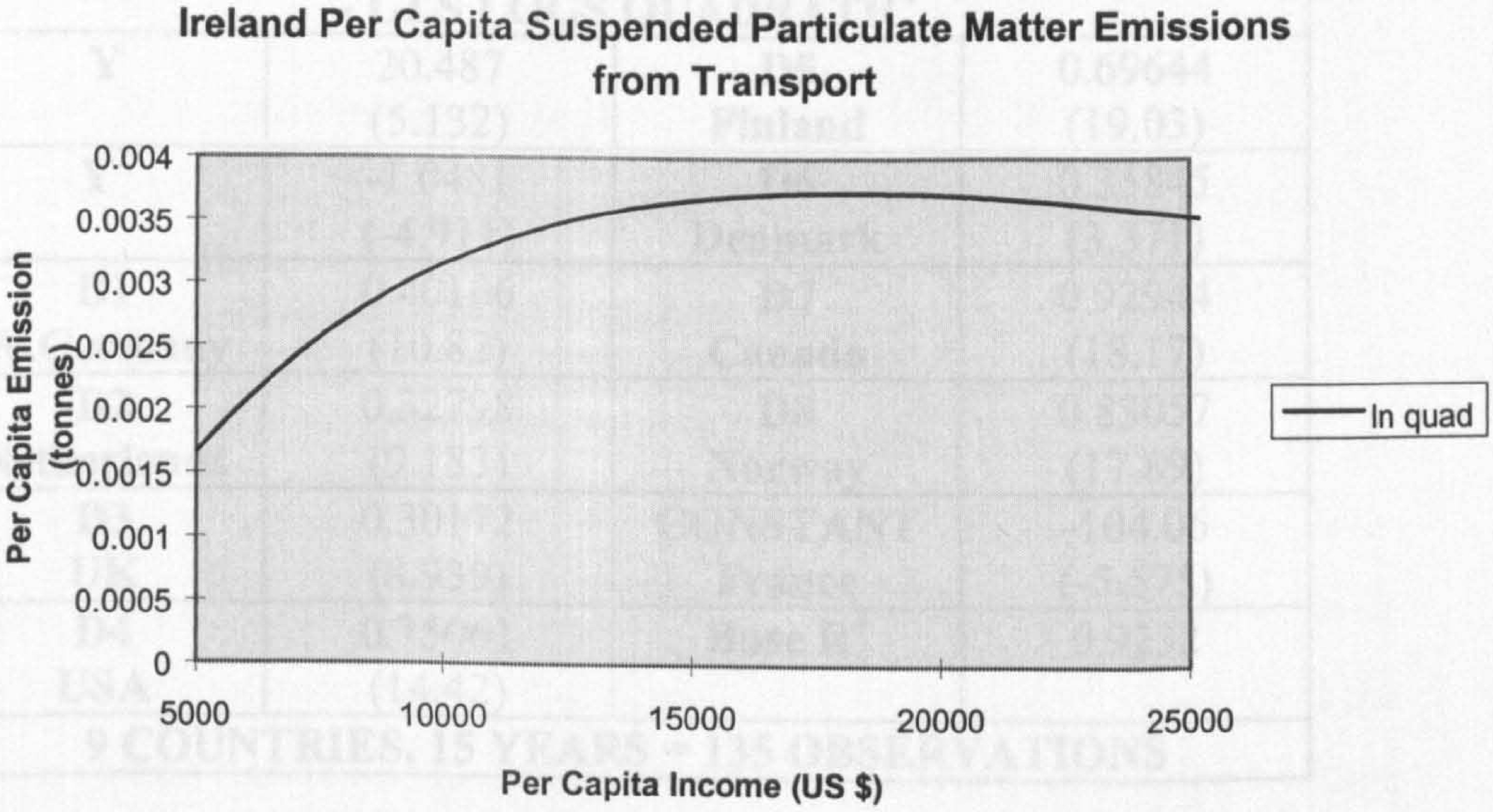
(vi) Suspended Particulate Matter from Transport.

The results contained in Table 9 are for the estimated relationships between per capita income and per capita suspended particulate matter from transport. This relationship is illustrated in diagram 7. The turning point is estimated to occur at a per capita income level of approximately $18,000. This can be seen to be considerably higher than those estimated for *total* suspended particulate matter emissions and illustrates the fact that particulate emissions from the transport sector are increasing in all sample countries throughout the time series.

Table 9.

SPM TRANSPORT - GLS LOGS QUADRATIC			
Y	9.6647 (5.517)	**D4** **USA**	1.6822 (11.59)
Y^2	-0.49306 (-5.125)	**D5** **W.Germany**	0.07412 (0.5012)
D1 **Netherlands**	0.41891 (2.482)	**D6** **Norway**	0.51526 (3.521)
D2 **Ireland**	1.2166 (8.498)	**CONSTANT** **France**	-54.168 (-6.791)
D3 **UK**	1.0548 (4.818)	**Buse R^2**	0.9496
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

Diagram 7.



Suspended particulate matter from the transport sector is released predominantly by diesel-fuelled vehicles and the wear and tear of brake linings. The wider use of catalytic trap oxidisers, which are primarily designed to reduce particulate emissions from diesel engines, should see particulate emissions from transport at least begin to stabilise, unless goods vehicle traffic volumes increase significantly.

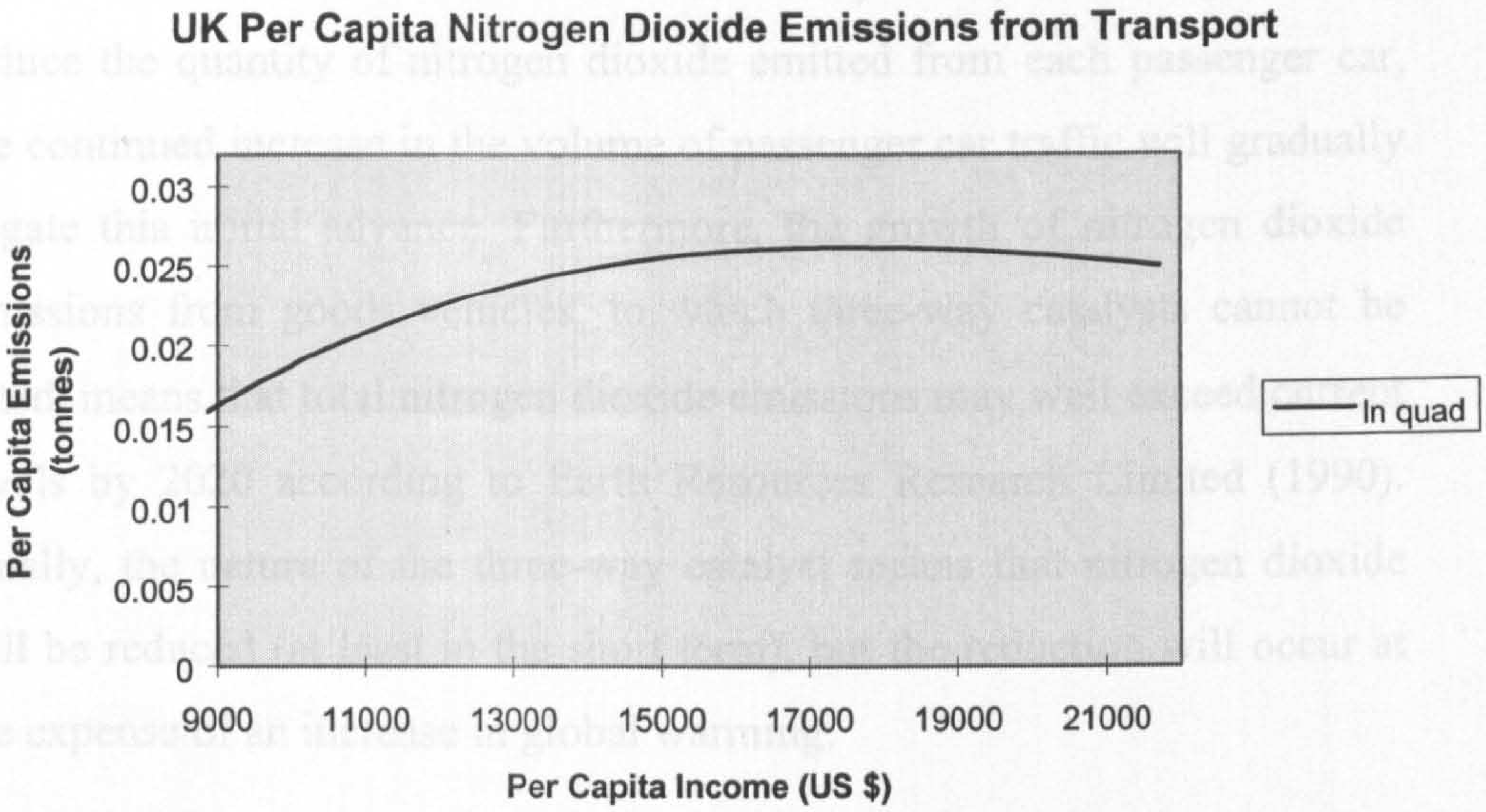
(vii) Nitrogen Dioxide from Transport.

The estimated relationship between per capita income and per capita nitrogen dioxide emissions from the transport sector is illustrated in diagram 8, below. The turning point is estimated at a per capita income level of approximately $17,500. The relatively high nature of this turning point indicates that nitrogen dioxide emissions from transport have proved to be difficult to reduce. This difficulty arises largely from the fact that traffic volumes are increasing steadily (as illustrated in diagram 16) negating any minor fuel efficiency achievements.

Table 10.

<table>
<tr><th colspan="4">NITROGEN DIOXIDE TRANSPORT
- GLS LOGS QUADRATIC</th></tr>
<tr><td>Y</td><td>20.487
(5.132)</td><td>D5
Finland</td><td>0.69644
(19.03)</td></tr>
<tr><td>Y^2</td><td>-1.0481
(-4.911)</td><td>D6
Denmark</td><td>0.35845
(3.371)</td></tr>
<tr><td>D1
W.Germany</td><td>0.40106
(10.82)</td><td>D7
Canada</td><td>0.92944
(18.17)</td></tr>
<tr><td>D2
Netherlands</td><td>0.32798
(9.183)</td><td>D8
Norway</td><td>0.83057
(17.89)</td></tr>
<tr><td>D3
UK</td><td>0.30172
(8.939)</td><td>CONSTANT
France</td><td>-104.06
(-5.575)</td></tr>
<tr><td>D4
USA</td><td>0.75061
(14.42)</td><td>Buse R^2</td><td>0.9232</td></tr>
<tr><td colspan="4">9 COUNTRIES, 15 YEARS = 135 OBSERVATIONS</td></tr>
</table>

Diagram 8.



The introduction of three-way catalytic converters in many OECD countries should, however, lead to a marked drop in nitrogen dioxide emissions (as well as carbon monoxide and hydrocarbons) in the near future. Unfortunately, the three-way catalyst is not without its drawbacks. Firstly, it is incompatible with diesel engined vehicles and thus will not reduce emissions from goods vehicles. Secondly, in the oxidation of nitrogen dioxide, carbon monoxide and hydrocarbons, the catalyst emits carbon dioxide, thereby reducing local air pollution, but contributing to global warming. Thirdly, the use of three-way catalysts may reduce the fuel efficiency of the vehicle to which it is fitted. The OECD (1987) quotes eight different references which state that three-way catalysts will increase fuel use by between 1 and 10%. Clearly, the more fuel which is used the more carbon dioxide will be emitted. A fourth problem associated with the use of catalytic converters is that they are now believed to increase emissions of nitrous oxide, another greenhouse gas. Dasch (1992) states that emissions from non-catalyst cars in the USA averaged 3.6mg of nitrous oxide per mile whereas emissions from vehicles fitted with three-way catalysts increased to 45mg of nitrous oxide per mile.

Whilst there is little doubt that the three-way catalyst will significantly reduce the quantity of nitrogen dioxide emitted from each passenger car, the continued increase in the volume of passenger car traffic will gradually negate this initial advance. Furthermore, the growth of nitrogen dioxide emissions from goods vehicles, to which three-way catalysts cannot be fitted, means that total nitrogen dioxide emissions may well exceed current levels by 2020 according to Earth Resources Research Limited (1990). Finally, the nature of the three-way catalyst means that nitrogen dioxide will be reduced (at least in the short term), but the reduction will occur at the expense of an increase in global warming.

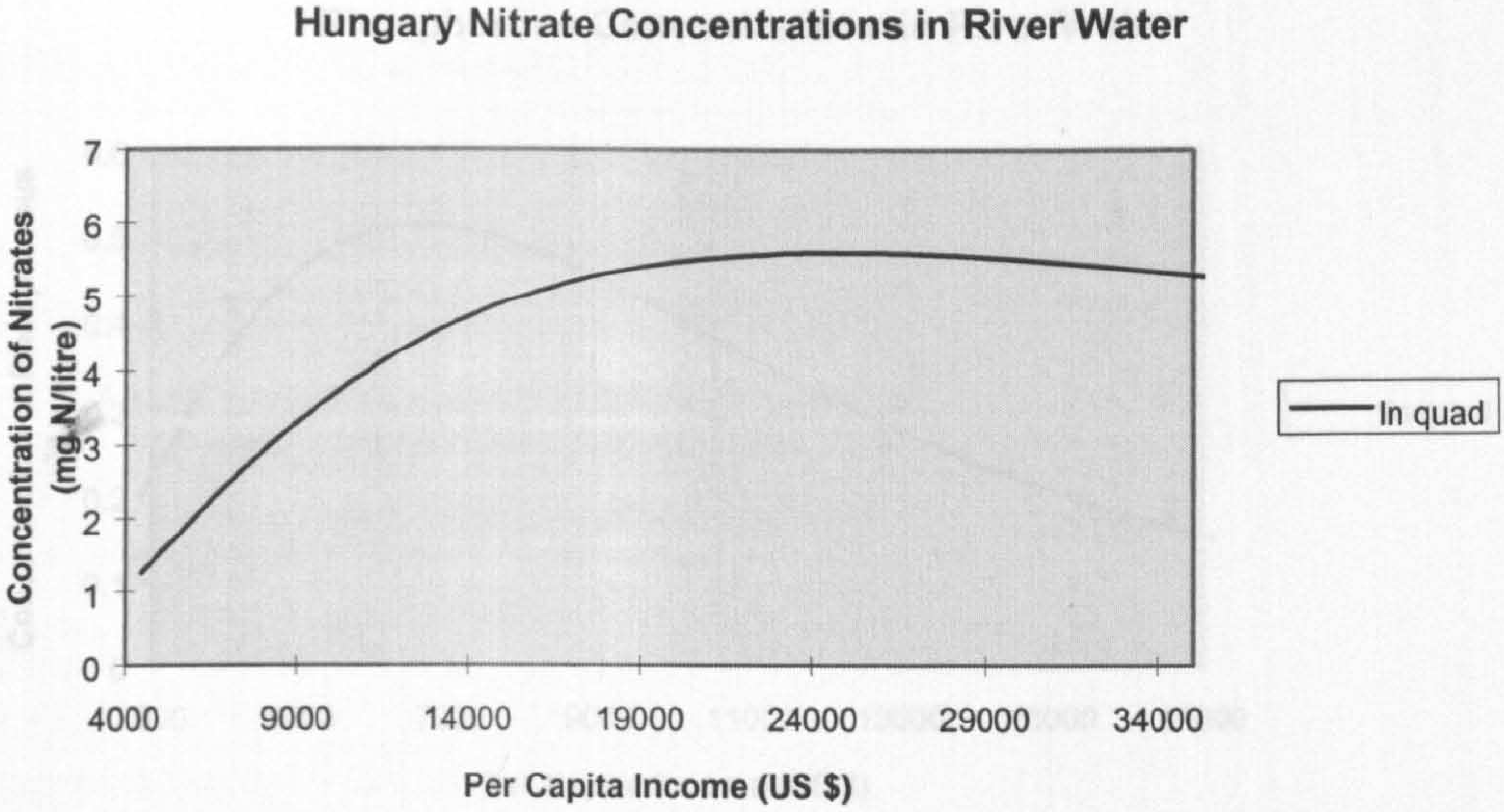
Water Pollution.

(viii) Nitrates.

Table 11.

NITRATES - GLS LOGS QUADRATIC			
Y	10.224 (3.849)	**D8 Denmark**	2.8616 (4.753)
Y^2	-0.50483 (-3.525)	**D9 Finland**	1.0863 (4.429)
D1 Spain	2.4047 (6.163)	**D10 Greece**	2.7068 (12.37)
D2 W.Germany	2.7231 (9.425)	**D11 Netherlands**	3.1715 (16.33)
D3 Norway	0.64021 (2.78)	**D12 Czech.**	4.672 (15.96)
D4 Switzerland	1.9435 (5.21)	**D13 Hungary**	3.2228 (8.966)
D5 UK	3.6047 (12.53)	**D14 Belgium**	2.8542 (12.67)
D6 USA	1.793 (8.54)	**CONSTANT Canada**	-53.267 (-4.321)
D7 Italy	2.5304 (13.27)	**Buse R^2**	0.8696
30 RIVERS, 4 YEARS = 120 OBSERVATIONS			

Diagram 9.


Hungary Nitrate Concentrations in River Water

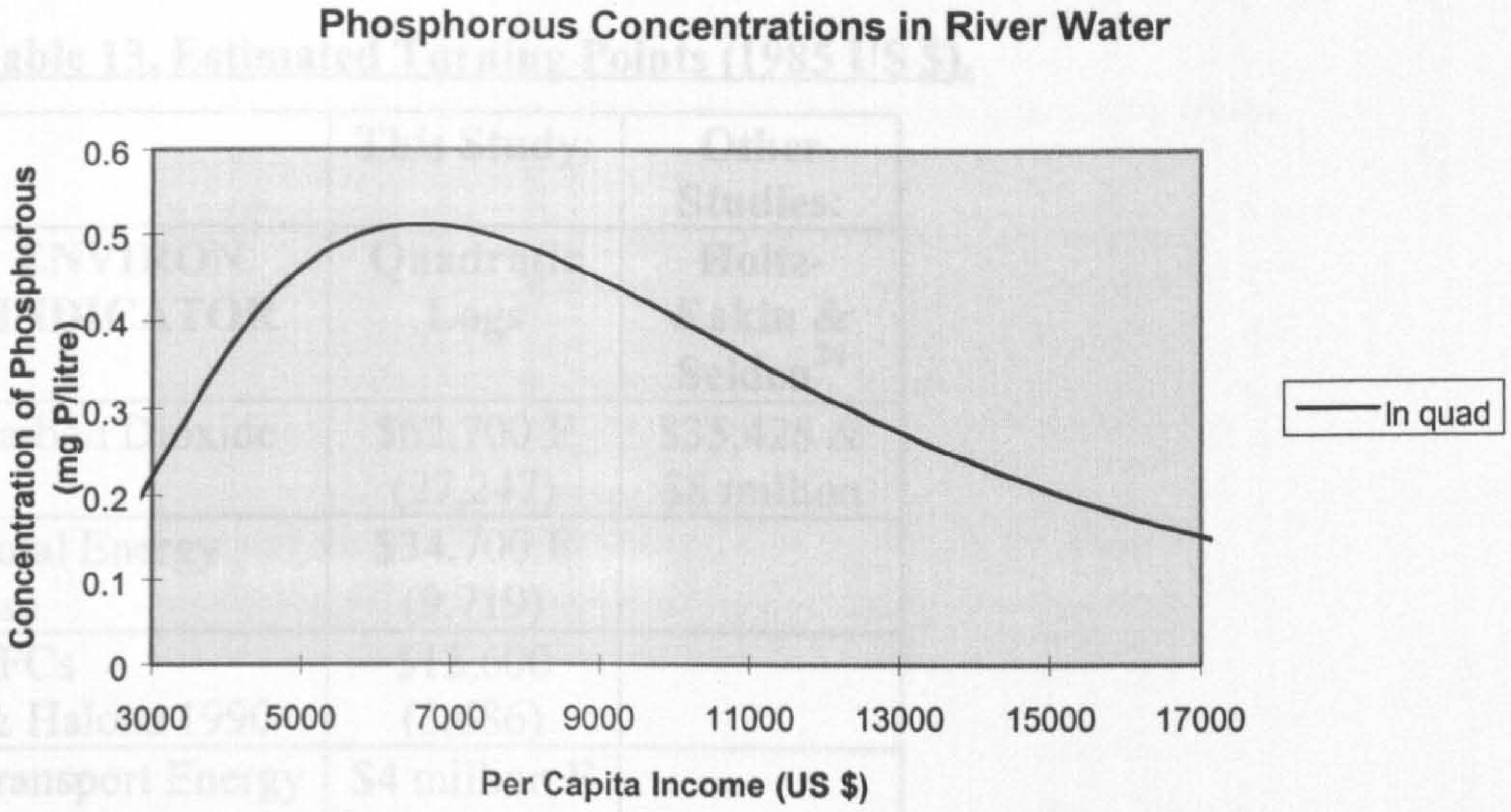
With regard to nitrate concentrations in river water, the estimated turning point occurs at the relatively high per capita income level of approximately $24,500. These turning points are significantly higher than the estimate of $10,524 by Grossman and Krueger (1995).

(ix) Phosphorous.

Table 12.

PHOSPHOROUS - GLS LOGS QUADRATIC	
Y	23.76 (5.706)
Y^2	-1.3511 (-5.931)
CONSTANT	-105.13 (-5.533)
Buse R^2	0.432
28 RIVERS, 4 YEARS = 112 OBSERVATIONS	

Diagram 10.



The inclusion of country-specific dummies in the estimation of the relationship between per capita income and phosphorous concentrations in river water, led to both income terms being statistically insignificant. Furthermore, all of the dummies were themselves statistically insignificant. Due to this fact, in the above estimation, all countries have been given the same intercept, the result being a low R squared value. Nevertheless, diagram 10 illustrates the projected relationship between per capita income and phosphorous concentrations, and indicates a turning point at a per capita income level of approximately $6,600.

Turning points for the above pollutants can be seen to have small standard errors, indicating that the results are reliable - with the possible exception of the quadratic logs turning point for nitrate concentrations.

5.4.2 Indicators with NO DIRECT Local Environmental Impact.

Table 13. Estimated Turning Points (1985 US $).

	This Study:	**Other Studies:**
ENVIRON. INDICATOR	**Quadratic Logs**	**Holtz-Eakin & Selden**[26]
Carbon Dioxide	$62,700 F (27,247)	$35,428 & $8 million
Total Energy Use	$34,700 F (9,719)	
CFCs & Halons 1990	$12,600 (3,686)	
Transport Energy Use	$4 million F (1.5 million)	
Traffic Volumes	$65,300 F (19,412)	
Municipal Waste and Methane	No estimated turning points	

(i) Carbon Dioxide.

Table 14.

CARBON DIOXIDE - GLS LOGS QUADRATIC			
Y	3.505 (8.842)	**D5 S.&C.America**	-0.45546 (-6.866)
Y^2	-0.15865 (-6.633)	**D6 W.Europe**	0.16119 (1.594)
D1 Asia	0.19459 (4.193)	**CONSTANT Africa**	-18.164 (-11.27)
D2 E.Europe	1.0404 (7.239)	**Buse R^2**	0.9649
D3 N.America	0.79388 (7.158)	**Hausman (simultaneity)**	4.0 (8 df)
D4 Oceania	0.056883 (0.4454)	**Hausman (fixedv.random)**	13.6 (2 df)
7 REGIONS, 32 YEARS = 224 OBSERVATIONS			

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[26] Holtz-Eakin and Selden's turning point of $35,428 resulted from a quadratic levels functional form, whilst the turning point of over $8 million was estimated by a quadratic logs function. Data were from the Oak Ridge National Laboratory (1992).

Diagram 11.

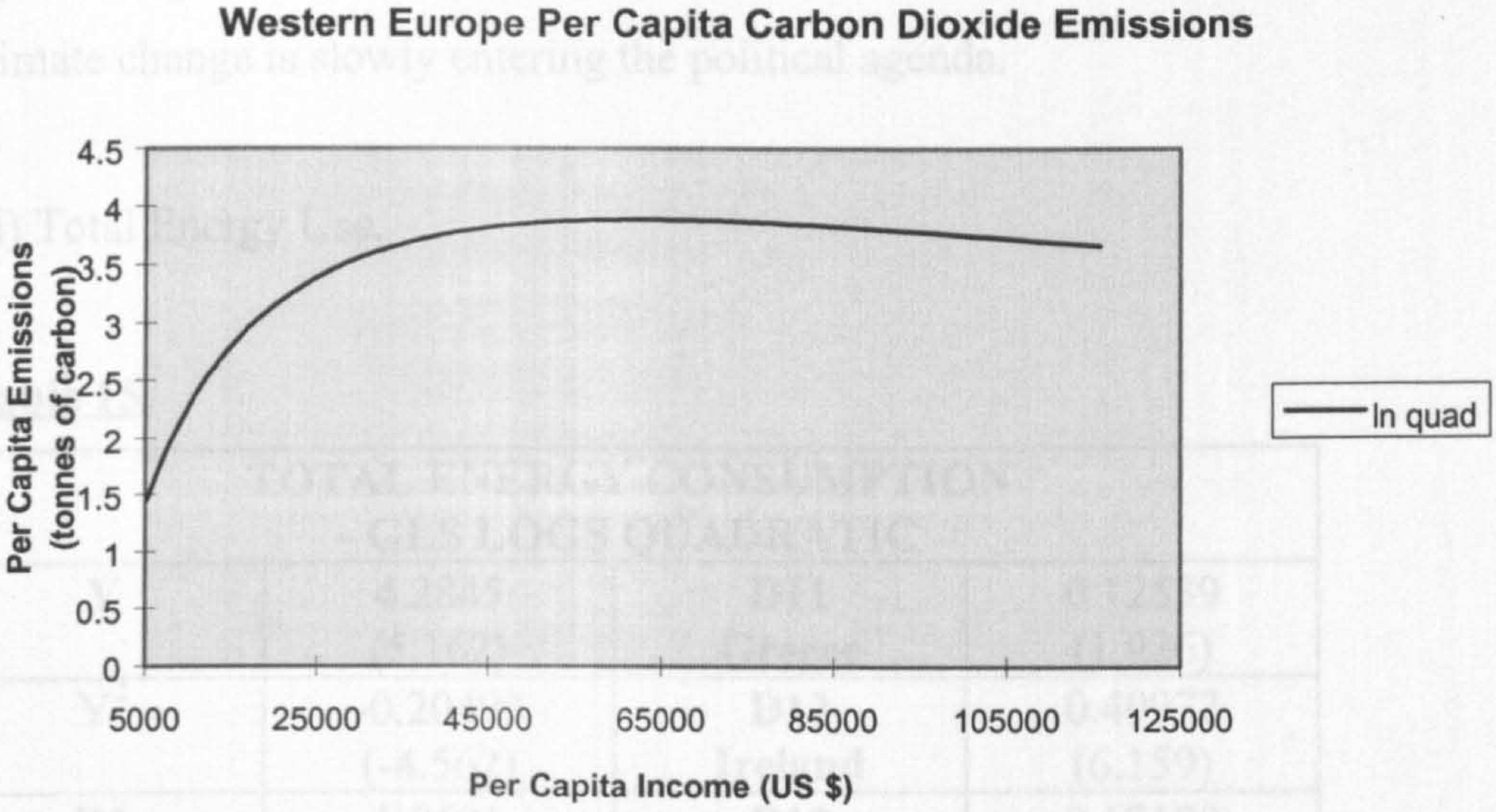

Diagram 11 illustrates the projected relationships between per capita income and per capita carbon dioxide emissions from the GLS results in Table 14. As indicated in Table 13, above, the estimated turning point is at a per capita income level of approximately $62,700. The confidence interval, however, includes a wide range of income. Thus carbon dioxide emissions monotonically increase within the observed income range and little confidence can be had in the estimated turning points. This is also the case for Holtz-Eakin and Selden's (1994) turning points. These results suggest that the global nature of carbon dioxide's impact has indeed provided little incentive for nations to take unilateral action to reduce emissions and multilateral action has been slow to develop. Global projections of total carbon dioxide emissions for the period 1992-2025 are contained in Appendix J, and show total emissions increasing steadily, for both functional forms. On a more positive note however, the 1992 Earth Summit in Rio de Janeiro at least heralded the start of joint action to prevent climate change. At the Summit, the European Union and Japan agreed to reduce greenhouse gas emissions to 1990 levels by the year 2000 and in 1993 the US agreed to join the EU and Japan in this commitment, after at first refusing. Although many nations look unlikely to meet their agreed targets, their very existence at least indicates that the issue of climate change is slowly entering the political agenda.

(ii) Total Energy Use.

Table 15.

TOTAL ENERGY CONSUMPTION - GLS LOGS QUADRATIC			
Y	4.2845 (5.162)	**D11 Greece**	0.12539 (1.926)
Y^2	-0.20493 (-4.562)	**D12 Ireland**	0.40972 (6.159)
D1 USA	1.0681 (13.76)	**D13 Italy**	0.17188 (2.273)
D2 Japan	0.28459 (3.734)	**D14 Netherlands**	0.73154 (9.698)
D3 Australia	0.62443 (8.068)	**D15 Norway**	0.85101 (11.19)
D4 New Zealand	0.47733 (4.534)	**D16 Portugal**	-0.057178 (-1.006)
D5 Austria	0.49294 (6.528)	**D17 Spain**	0.020298 (0.2945)
D6 Belgium	0.70717 (9.273)	**D19 Switzerland**	0.43559 (5.66)
D7 Denmark	0.45486 (5.629)	**D20 Canada**	1.1968 (15.06)
D8 Finland	0.93181 (11.81)	**D21 UK**	0.40821 (5.483)
D9 France	0.3902 (5.126)	**CONSTANT Turkey**	-35.457 (-9.385)
D10 W.Germany	0.58136 (7.315)	**Buse R^2**	0.983
22 COUNTRIES, 13 YEARS = 286 OBSERVATIONS			

Diagram 12.

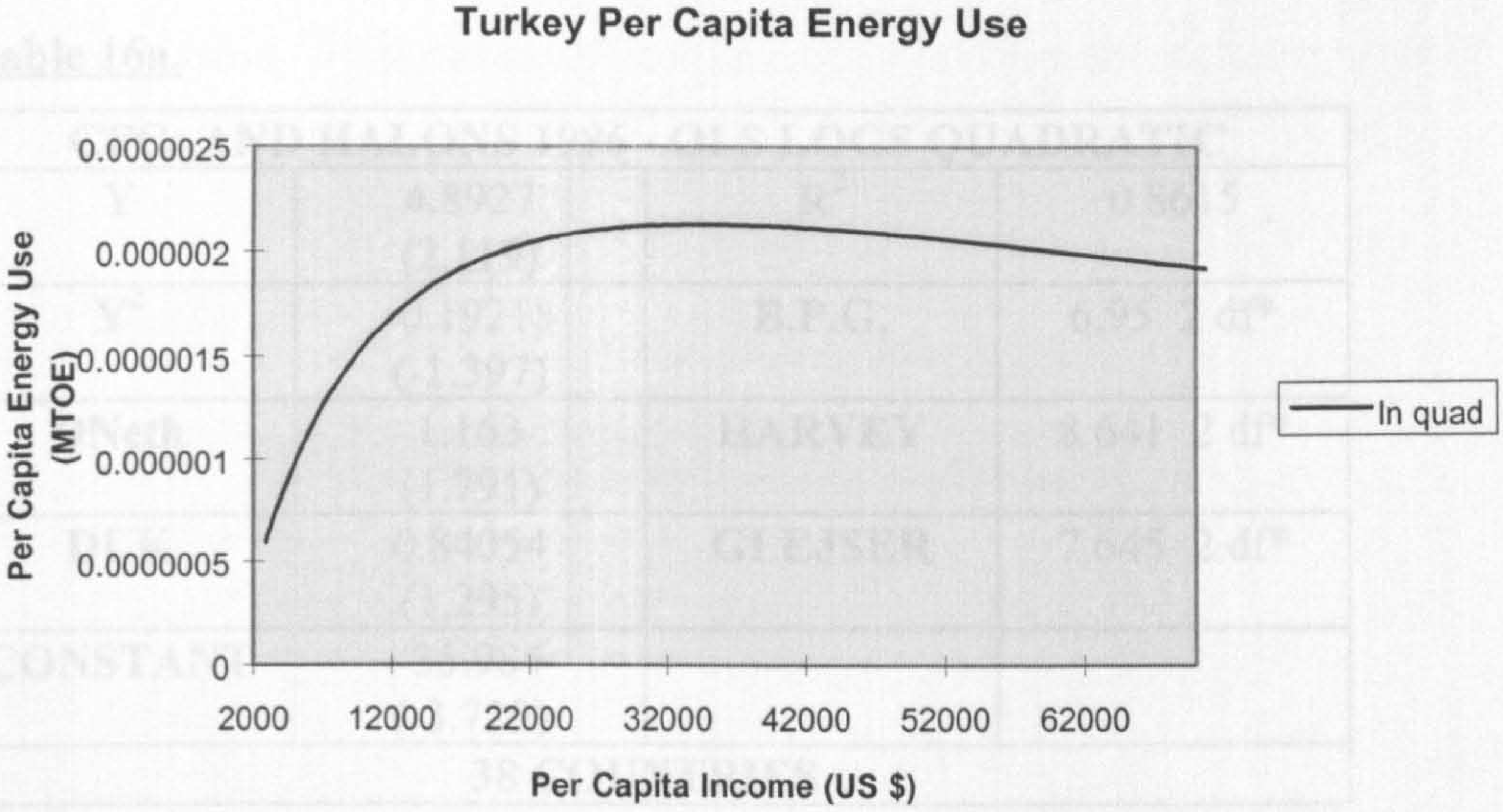

Diagram 12 provides the projected relationships between per capita income and per capita energy consumption from the GLS results contained in Table 15. The turning point is estimated at a per capita income level of approximately $34,700, indicating that per capita energy use has increased throughout the observed income range, despite advances in energy efficiency. Quite clearly, the effect of the growth of GDP has exceeded the extent of any energy efficiency gains. Given this rapid increase in energy use, it is no surprise to find that carbon dioxide emissions are also experiencing a similar increase.

(iii) CFCs and Halons.

Tables 16a and 16b and Diagram 13 illustrate the cross-section relationship between per capita income and the per capita consumption of CFCs and halons. The effects of the UK and the Netherlands, both of whom have very high levels of per capita consumption of CFCs and halons, have been isolated using dummy variables. Linear functions have also been estimated for 1986 due to the income squared terms being insignificant in the quadratic functions. Diagram 13, below, illustrates the log quadratic functional form for 1990 and the log linear functional form for 1986.

Table 16a.

CFCs AND HALONS 1986 - OLS LOGS QUADRATIC			
Y	4.8927 (2.119)	**R^2**	0.8615
Y^2	-0.19218 (-1.397)	**B.P.G.**	6.95 2 df*
DNeth	1.163 (1.791)	**HARVEY**	8.641 2 df*
DUK	0.84054 (1.295)	**GLEJSER**	7.645 2 df*
CONSTANT	-35.984 (-3.739)		
38 COUNTRIES			

Table 16b.

CFCs AND HALONS 1990 - OLS LOGS QUADRATIC			
Y	15.363 (4.255)	**R^2**	0.737
Y^2	-0.81370 (-3.802)	**B.P.G.**	17.031 2 df*
DNeth	0.83182 (0.7826)	**HARVEY**	9.78 2 df*
DUK	0.91106 (0.8564)	**GLEJSER**	32.324 2 df*
CONSTANT	-80.089 (-5.302)		
39 COUNTRIES			

In 1986, countries may have been reluctant to unilaterally reduce their consumption of CFCs and halons due to the global impact associated with these pollutants.[27] However, in 1987 the Montreal Protocol was adopted which committed its signatories to a reduction in a number of substances, including CFCs and halons, by 50% of their 1986 level by July 1999 (UNEP (1993)). The success of this Protocol is illustrated by the estimated

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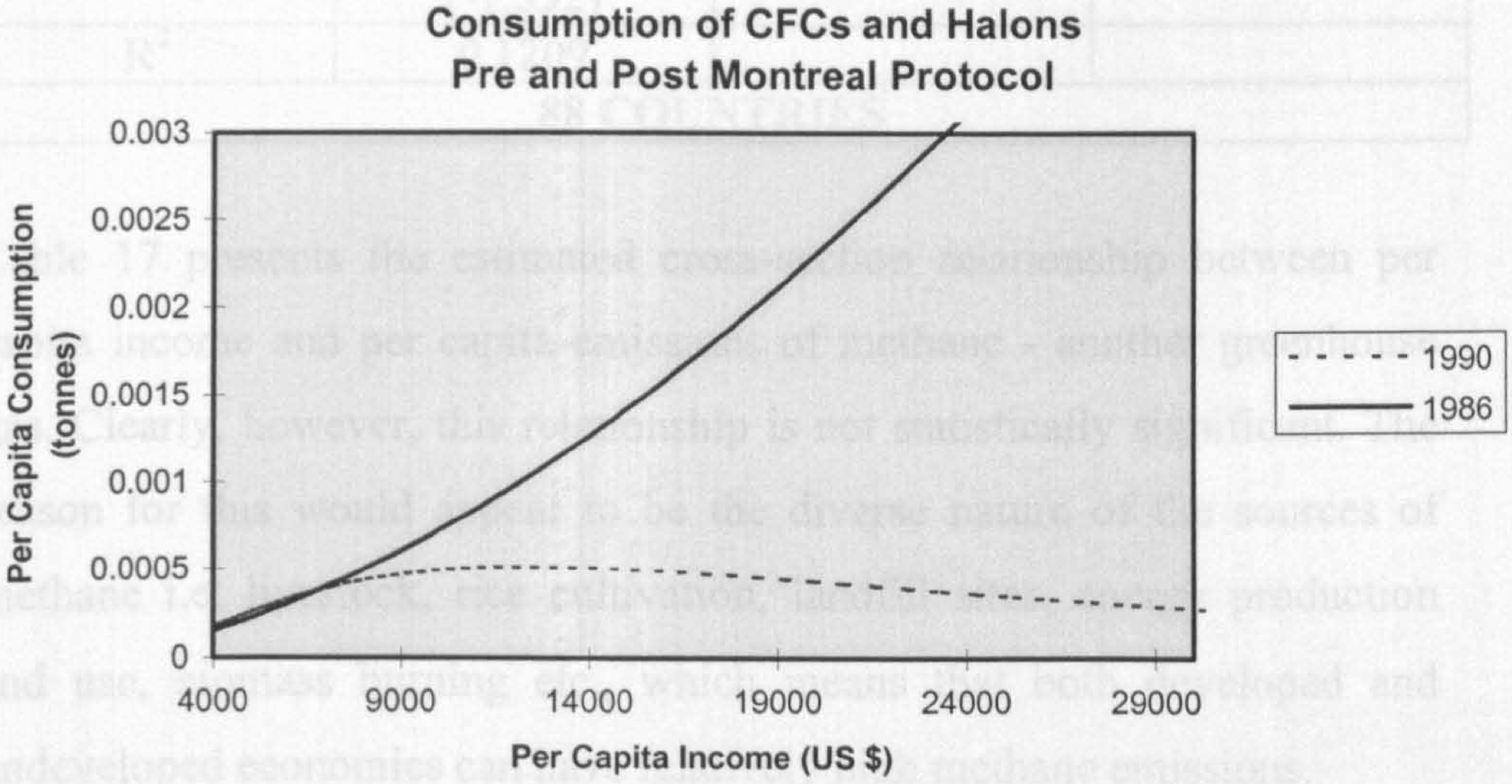
[27] Barrett (1991), however, does point out that the severity of the potential impacts of ozone depletion seems to suggest that individual countries do have sufficient incentive to act unilaterally.

relationship between per capita income and the per capita consumption of CFCs and halons for 1990 which has an estimated turning point at a per capita income level of approximately $12,600. This result would clearly seem to illustrate the potential effectiveness of a multilateral response to an environmental problem.

Diagram 13.



The case of CFCs and halons may well prove to be idiosyncratic, however, due not least to the relative ease with which cleaner alternatives to CFCs and halons have been developed, and hence their relatively low abatement costs. This analysis of CFCs and halons does illustrate that a multilateral policy initiative targetted at a global air pollutant can provide an estimated turning point within the observed income range. Clearly, in this example, the effect of the Montreal Protocol was to 'tunnel through' the original 1986 curve, resulting in the vastly different curve for 1990.[28]

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[28] Munasinghe (1995) introduced the concept of 'tunnelling through'.

(iv) Methane

Table 17.

METHANE late 1980s - OLS LOGS QUADRATIC			
Y	0.50739 (0.5172)	**B.P.G.**	2.272 2 df
Y^2	-0.01838 (-0.2978)	**HARVEY**	1.001 2 df
CONSTANT	-5.8861 (-1.532)	**GLEJSER**	2.3 2 df
R^2	0.1209		
88 COUNTRIES			

Table 17 presents the estimated cross-section relationship between per capita income and per capita emissions of methane - another greenhouse gas. Clearly, however, this relationship is not statistically significant. The reason for this would appear to be the diverse nature of the sources of methane i.e. livestock, rice cultivation, landfill sites, energy production and use, biomass burning etc., which means that both developed and undeveloped economies can have relatively high methane emissions.

(v) Municipal Waste.

In contrast to the environmental indicators considered so far, the estimated relationship between per capita income and per capita municipal waste, as set out in Table 18, below, shows the income term to be negative and the income-squared term to be positive. This also applies to the quadratic levels function in Appendix C. Regional-specific dummies have been used because the use of country-specific dummies would have left few degrees of freedom due to the short time series.

Table 18.

MUNICIPAL WASTE - GLS LOGS QUADRATIC			
Y	-17.466 (-5.501)	D3 Oceania	0.71292 (3.665)
Y^2	0.96572 (5.697)	CONSTANT E.Europe	77.18 (5.252)
D1 W.Europe	0.50138 (2.719)	Buse R^2	0.9364
D2 N.America	0.91676 (5.063)		
13 COUNTRIES, 4 YEARS = 52 OBSERVATIONS			

Diagram 14.

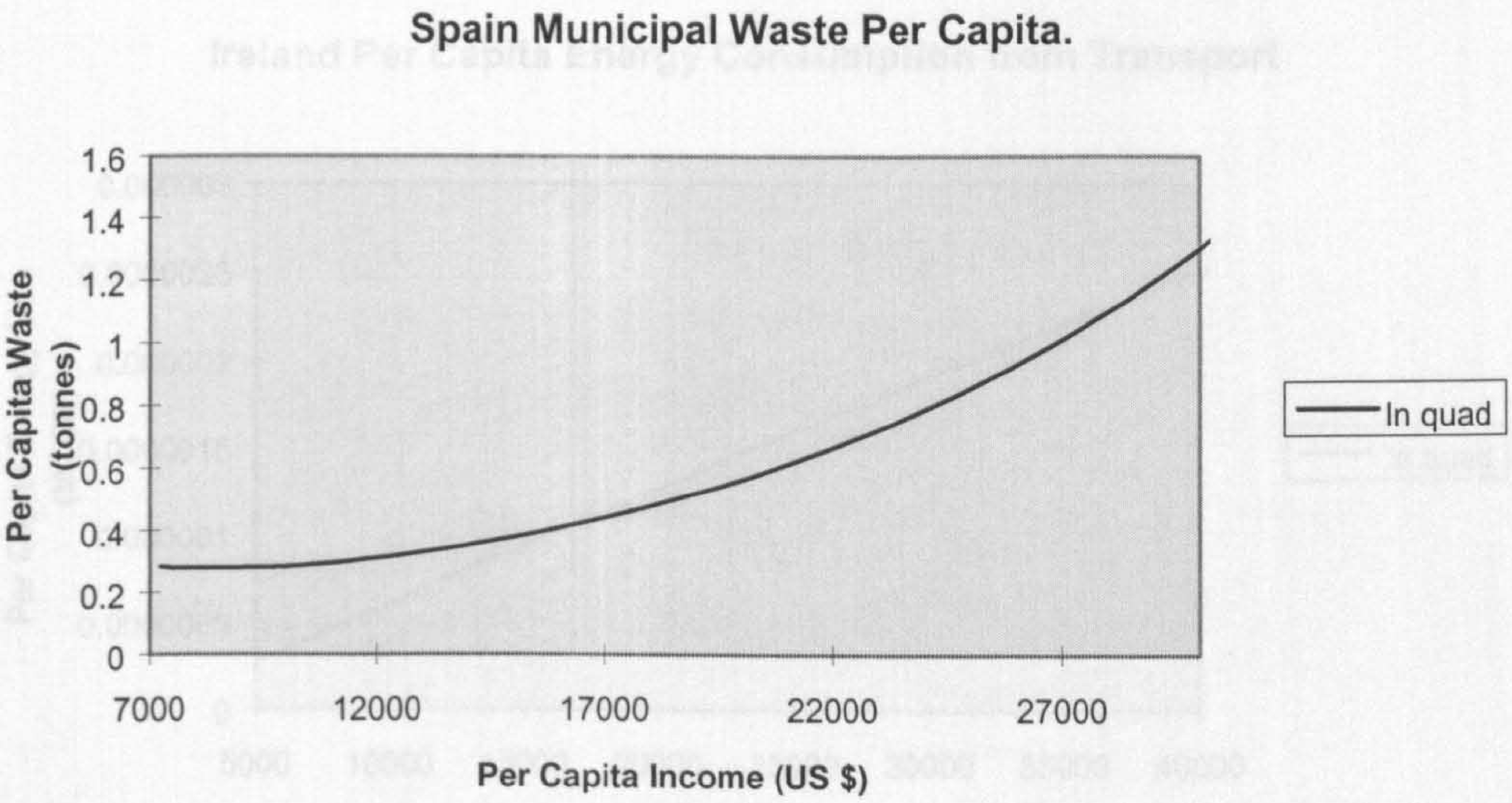

Diagram 14 illustrates the relationship between per capita income and per capita municipal waste and projects that per capita municipal waste will rise steadily with per capita income, with no turning point even in the long term.

(vi) Energy Use from Transport.

Table 19.

ENERGY CONSUMPTION TRANSPORT - GLS LOGS QUADRATIC			
Y	2.3572 (4.244)	**D2** **Oceania**	0.24833 (2.028)
Y^2	-0.067244 (-2.209)	**CONSTANT** **W.Europe**	-30.327 (-11.97)
D1 **N.America**	0.68019 (5.409)	**Buse R^2**	0.9666
24 COUNTRIES, 4 YEARS = 96 OBSERVATIONS			

Diagram 15.

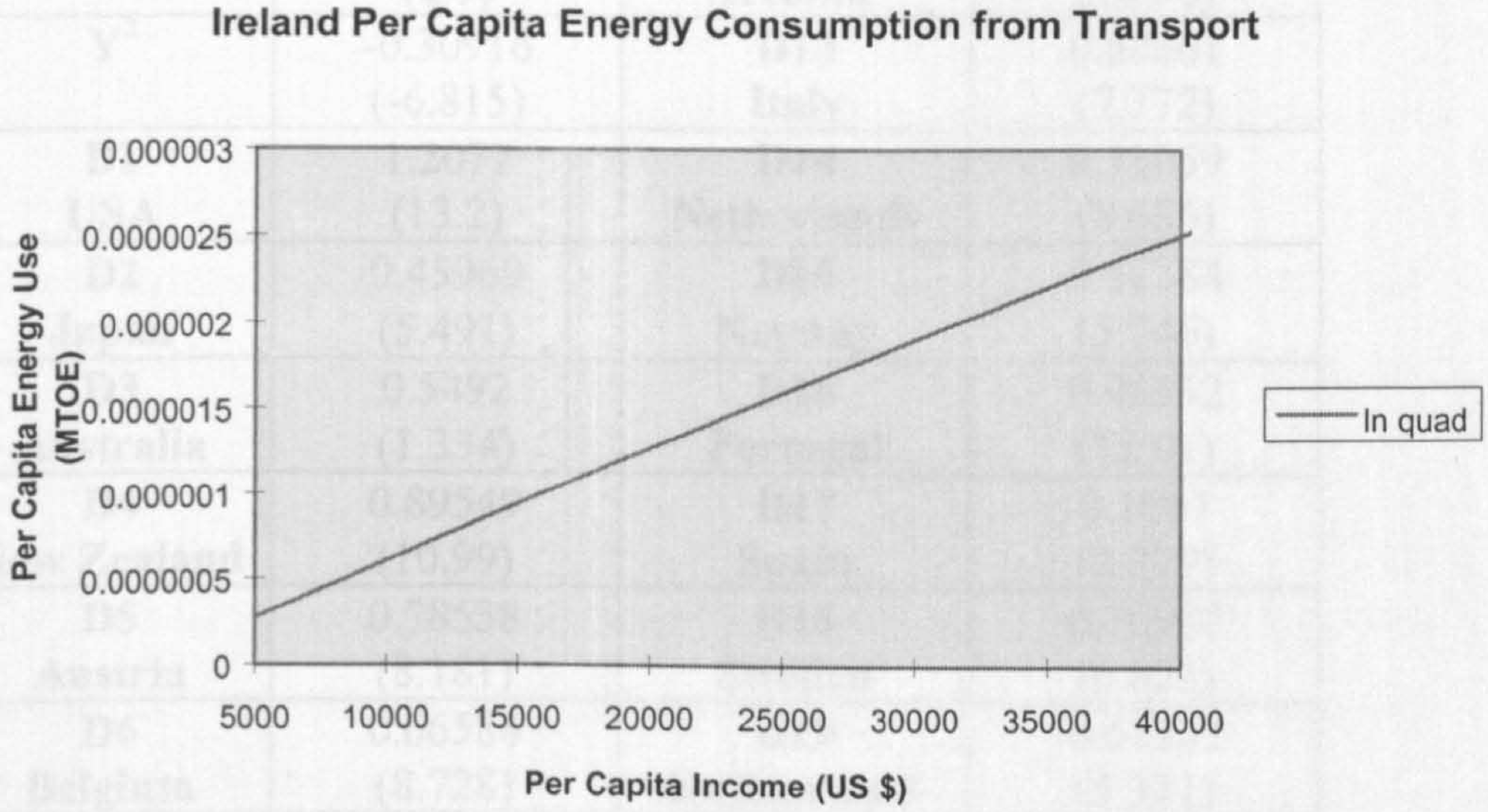

Table 19 contains GLS results for the log quadratic relationship between per capita income and per capita energy consumption from the transport sector.[29] Region specific dummies have been used as the inclusion of country specific dummies would have significantly reduced the degrees of freedom due to the short time series. Diagram 15 shows the quadratic logs

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[29] For the quadratic levels function, the fact that the income squared term was statistically insignificant and since an analysis of the plotted data revealed an almost linear relationship between per capita energy use from transport and per capita income, a linear functional form is also used (see Appendix C).

relationship, which shows per capita energy consumption increasing steadily with economic growth. The function does estimate a turning point, albeit at a per capita income level of over $40 million. Clearly, traffic volumes have increased by such an extent as to cause per capita energy consumption from the transport sector to increase steadily, despite regular advances in fuel efficiency.

(vii) Traffic Volumes.

Table 20.

TRAFFIC VOLUMES - GLS LOGS QUADRATIC			
Y	6.8551 (8.3)	**D12 Ireland**	1.3263 (18.96)
Y^2	-0.30916 (-6.815)	**D13 Italy**	0.68861 (7.772)
D1 USA	1.2077 (13.2)	**D14 Netherlands**	0.71059 (8.686)
D2 Japan	0.45969 (5.491)	**D15 Norway**	0.51384 (5.746)
D3 Australia	0.5492 (1.334)	**D16 Portugal**	0.98332 (12.01)
D4 New Zealand	0.89549 (10.99)	**D17 Spain**	0.1887 (2.279)
D5 Austria	0.78538 (8.181)	**D18 Sweden**	0.76986 (6.623)
D6 Belgium	0.66588 (8.728)	**D19 Switzerland**	0.61242 (5.311)
D7 Denmark	0.79753 (9.64)	**D20 Canada**	0.93151 (10.32)
D8 Finland	0.96266 (11.01)	**D21 UK**	0.76296 (6.607)
D9 France	0.78873 (8.728)	**CONSTANT Turkey**	-29.231 (-7.876)
D10 W.Germany	0.75153 (8.959)	**Buse R^2**	0.9602
D11 Greece	0.83848 (5.472)		
22 COUNTRIES, 15 YEARS = 330 OBSERVATIONS			

Diagram 16.

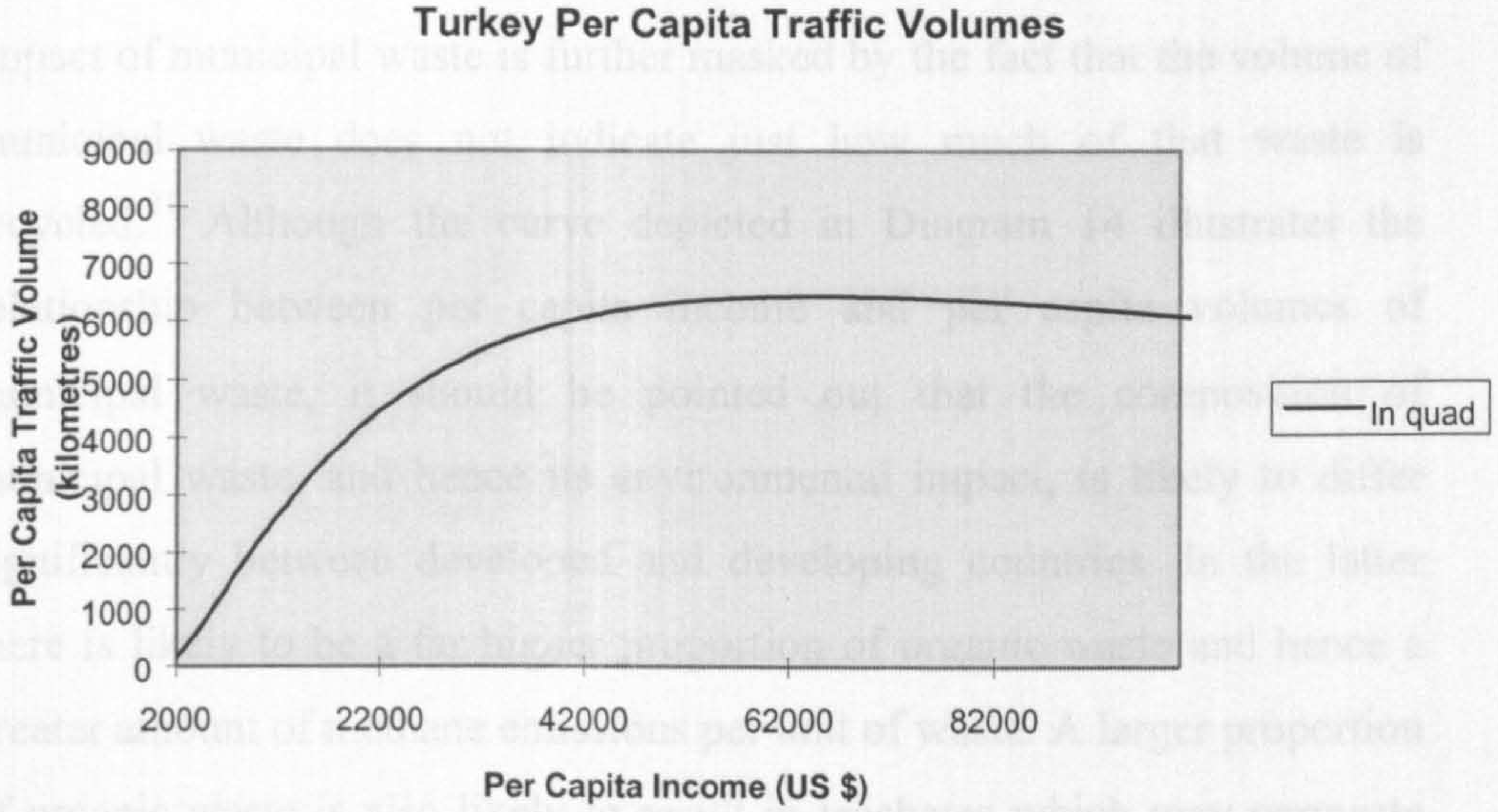

Table 20 provides the GLS quadratic logs results of the relationship between per capita income and per capita traffic volumes.[30] Diagram 16 shows the projection of this relationship between per capita income and per capita traffic volumes. The projection shows a turning point at a per capita income level of $65,300.

The final three environmental indicators - per capita values of municipal waste, energy use by transport and traffic volumes - all increase monotonically throughout the observed income range. The standard errors associated with turning points for per capita energy use from transport and per capita traffic volumes are very large, however, implying that these estimates are unreliable. There is little evidence that the inverted-U pollution / income curve exists for these indicators, probably due to the lack of a direct local environmental impact associated with each. Apart from perhaps causing a loss of amenity value when disposed of in landfill, municipal waste only indirectly harms the environment by representing an increased use of resources and by generating methane via landfill sites.

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[30] Since the income squared term was statistically insignificant for the quadratic levels function, a linear functional form is also used (see Appendix C).

Furthermore, methane is a global air pollutant and as such there is little incentive to reduce emissions unilaterally. In addition, the environmental impact of municipal waste is further masked by the fact that the volume of municipal waste does not indicate just how much of that waste is recycled.[31] Although the curve depicted in Diagram 14 illustrates the relationship between per capita income and per capita volumes of municipal waste, it should be pointed out that the composition of municipal waste, and hence its environmental impact, is likely to differ significantly between developed and developing countries. In the latter there is likely to be a far higher proportion of organic waste and hence a greater amount of methane emissions per unit of waste. A larger proportion of organic waste is also likely to result in leachates which may permeate rocks and enter aquifers.

Like municipal waste, both energy use by transport and traffic volumes may have only an indirect impact on the environment, although an increase in traffic volumes can directly affect the welfare of motorists. Nevertheless, the significant increase in traffic volumes is clearly tending to counteract improvements which have been made in terms of fuel efficiency and pollution levels. It would therefore appear that the already considerable impact of the transport sector on the environment looks unlikely to weaken, at least in the short term.

5.5 Conclusion.

By examining a wide range of environmental indicators this paper has assessed whether EKCs exist for all such indicators, an issue raised by Arrow *et al.* (1995). The manner in which this has been done improves on many existing studies by correcting for autocorrelation and

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[31] Efforts to reduce the volume of municipal waste are beginning to be made, however. For example, on the 1st October 1996 the British government introduced a tax of up to seven pounds per tonne of waste deposited at municipal collection sites.

heteroscedasticity; calculating standard errors at the turning point level of income to indicate the reliability of estimates; and testing for simultaneity to ensure no bias was present in the estimates. These factors overcome at least some of the weaknesses associated with the estimation of EKCs outlined by Stern *et al.* (1996).

Results suggest that meaningful EKCs exist only for local air pollutants, whilst indicators with a more global, or indirect, environmental impact either increase monotonically with income or else have high turning points with large standard errors. Little confidence can be attached to such turning points. The results of this chapter also support the hypothesis of Selden and Song (1994) that urban air concentrations will peak at lower income levels than per capita emissions. This implies that it is easier to improve urban air quality than it is to reduce national emissions. The difference between the two turning point income levels would not appear to be as large as Selden and Song (1994) first suggested, however.

It is important that the EKCs estimated for local air pollutants are not misinterpreted, in terms of their global impact. As pointed out by Stern *et al.* (1996) and Selden and Song (1994), global income distribution is skewed with median world income per capita far less than the mean, so that total emissions of a pollutant can still be increasing in the medium term, even though per capita emissions are estimated to peak at a reasonably low per capita income level. Clearly, despite the existence of EKCs, the reduction of emissions of these local pollutants remains vital, particularly in the developing world.

The fact that, for local air pollutants, estimated turning points for transport generated emissions per capita are higher than those for total emissions per capita, indicates the importance of tackling pollution in the transport sector. In the developed world, emissions of local air pollutants are falling in many sectors, resulting in a reduction in total emissions. If increasing transport emissions could be reversed, however, total emissions would obviously fall more rapidly. Similarly, energy use in the transport sector would appear to be growing more quickly than total energy use. More generally, the results also highlight the need to tackle indirect indicators, particularly energy use and traffic volumes. The steady increase of these indicators is clearly hindering attempts to control carbon dioxide emissions and transport generated emissions of local air pollutants.

With regard to CFCs and halons, the analysis illustrates the importance of multilateral action for a global air pollutant and tends to confirm that, without such a policy initiative, global air pollutants will increase monotonically with income - at least for the per capita income levels that are predicted in the medium-term. Although the case of CFCs and halons may be encouraging, it does indicate that without multilateral action carbon dioxide emissions are unlikely to be controlled in the short term.

Finally, as Grossman and Krueger (1996) have observed, there is nothing inevitable about the relationship between per capita income and environmental quality, as encapsulated in the EKC fitted to historical data. Indeed, the analysis of CFCs and halons illustrates that appropriate policies can 'tunnel through' EKCs. Although there is evidence that developed countries have 'grown out of' some pollution problems, it is important to stress that this is by no means an automatic process. Pollution levels have fallen only in response to investment and policy initiatives.

CHAPTER 6.

ECONOMIC GROWTH AND THE ENVIRONMENT - AN EMPIRICAL ANALYSIS INCORPORATING TECHNOLOGICAL CHANGE.

6.1 Introduction.

Chapter 5 has provided a framework for analysing the relationship between economic growth and a wide range of environmental indicators. However, due to several complicating factors, the analysis in that chapter did not include a time trend and therefore failed to incorporate any factors which are common to all countries but which change over time. The level of technology may be such a factor. Using the same methodology as Chapter 5, but including a time trend as a proxy for the level of technology, this chapter re-tests the hypotheses raised in the previous chapter and assesses whether the inclusion of technological change (or any other factor which changes over time) affects the results. This chapter also examines which environmental indicators appear to have benefited from technological change, and which have not.

6.2 Framework.

The following reduced form equations are estimated[1];

(1) Quadratic in levels;

$$E_{it} = (\alpha + \mu_i F_i) + \beta Y_{it} + \gamma Y^2_{it} + kt + e_{it}$$

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[1] Note that for the reasons given in Chapter 5, trade intensity, population density and the rate of economic growth are omitted from the analysis.

(2) Quadratic in logs;

$$\ln E_{it} = (\lambda + \kappa_i F_i) + \eta \ln(Y_{it}) + \theta(\ln Y_{it})^2 + kt + e_{it}$$

where, E = the environmental indicator in per capita form

Y = per capita income

k = time trend

F = region or country-specific fixed effects

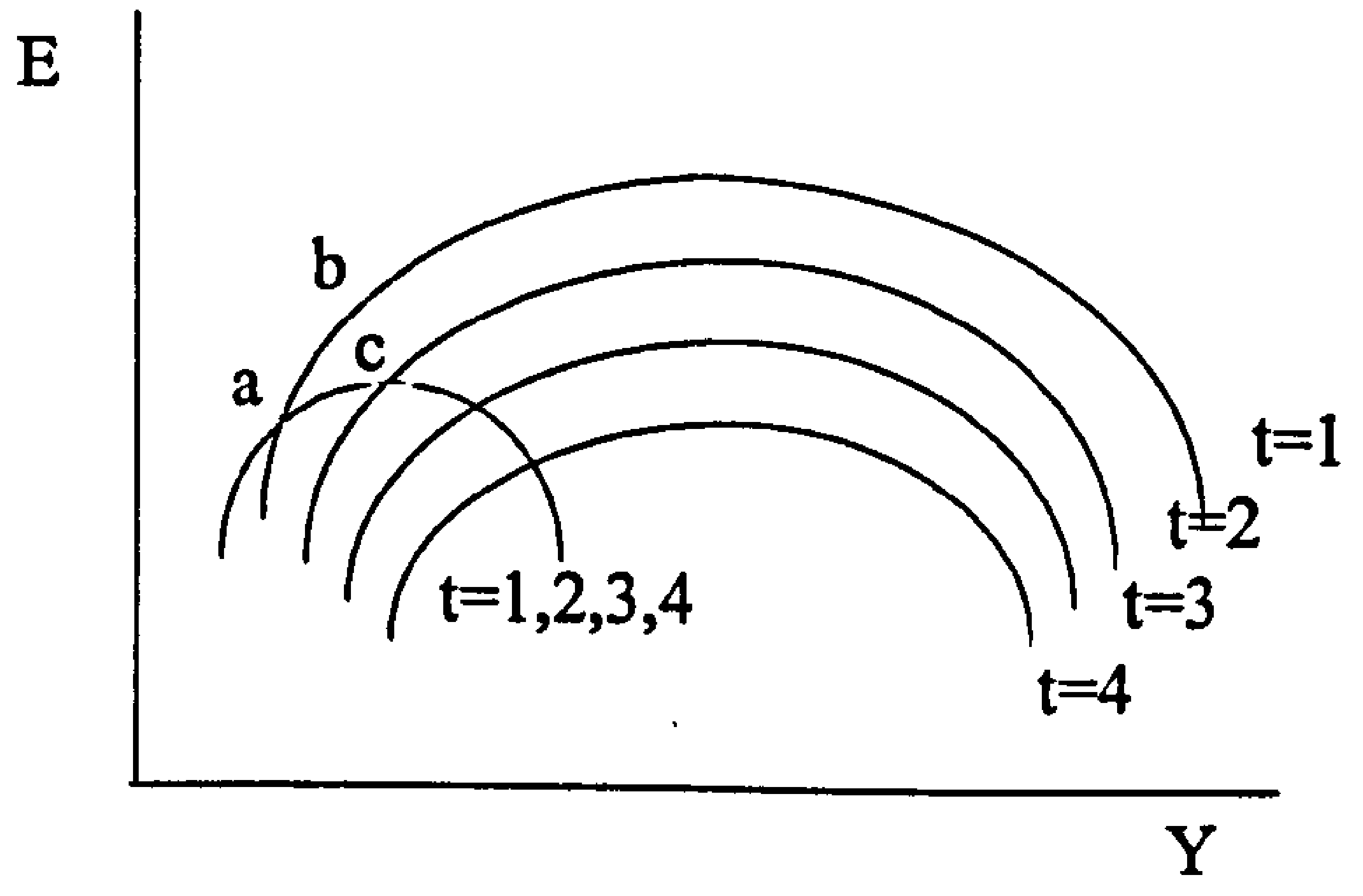
i = 1 .....n regions

t = 1.......T years

The Implications of Using a Time Trend.

The inclusion of a linear time trend in a regression implies that the estimated curve is shifting upwards or downwards over time, depending on whether the estimated coefficient of the time trend is positive or negative, respectively. Diagram 1, below, illustrates a function with a negative time trend drawn for four consecutive years, with the curve falling throughout the period.

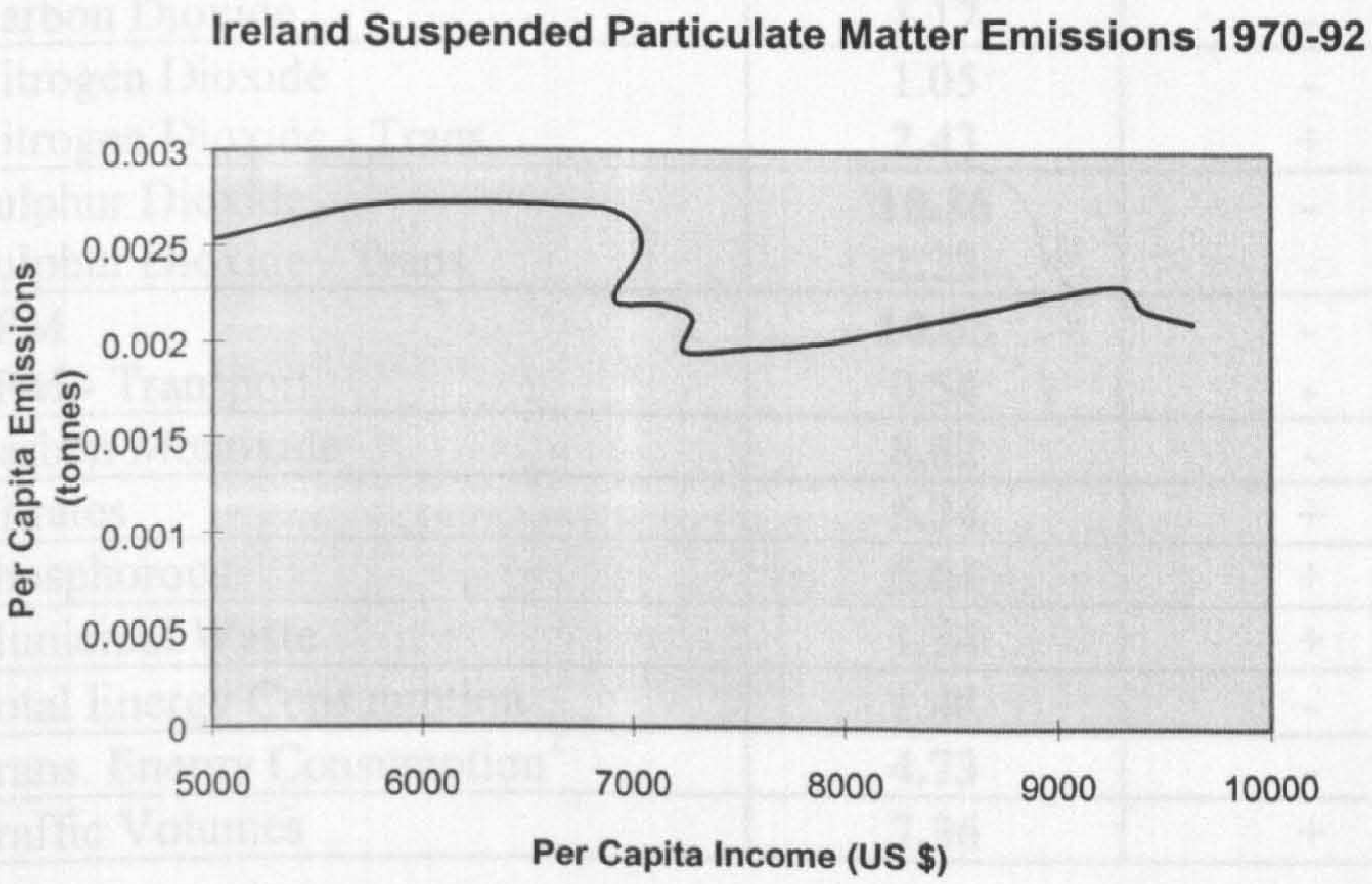
Diagram 1.



However, when the function is plotted for the full four years (t=1,2,3,4), as opposed to one particular year, a complication arises. The relative sizes of the income growth rate and the time trend coefficient will now determine where the estimated turning point will occur, and a function indicated by t=1,2,3,4 may result. Point b, on the diagram, may not be reached, but rather there may be a movement from point a to point c. The size of the negative time trend has 'overcome' the income growth rate and the turning point has been reached 'prematurely'.

A second complication associated with the use of a linear time trend is that each sample level of per capita income is now 'tied' to a particular year. When this is the case, the variable nature of the growth of actual income (as opposed to projected income) produces an extremely uneven relationship between plotted income and emissions. This point is illustrated in Diagram 2, below.

Diagram 2.



The above diagram shows the relationship between actual per capita income and per capita emissions of suspended particulate matter, when a time trend is included. The diagram results from a logged quadratic function and uses Ireland's intercept.

As a result of this complication, it seems advisable that all diagrams illustrate the relationship between per capita income and the environmental indicators using income which grows at a constant rate of growth, rather than actual income. However, due to the first complicating factor, the choice of this income growth rate is now of great importance since it partly determines the position of the estimated turning point. This chapter therefore uses the average rate of per capita income growth across all countries and all years in each sample to obtain diagrams and turning points.

6.3 Results.

Table 1. Time Trends - Direction and T-Statistics.

ENVIRONMENTAL INDICATOR	Quadratic Logs	
	t-stat	sign
Carbon Dioxide	1.17	-
Nitrogen Dioxide	1.05	-
Nitrogen Dioxide - Trans.	**2.43**	+
Sulphur Dioxide	**10.36**	-
Sulphur Dioxide - Trans.	**2.22**	-
SPM	**10.65**	-
SPM - Transport	0.54	-
Carbon Monoxide	**8.82**	-
Nitrates	**5.74**	+
Phosphorous	**5.64**	+
Municipal Waste	1.34	+
Total Energy Consumption	1.48	-
Trans. Energy Consumption[2]	**4.73**	-
Traffic Volumes	**7.36**	+

Table 1, above, provides a summary of the direction of the GLS estimated time trends, together with t-statistics, for all environmental indicators, for

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[2] Transport energy use estimates stem from a log linear function.

the quadratic logs functional form. T-statistics in bold represent time trends which are significantly different from zero at a 95% confidence level.

Tables 2 and 13, below, present the estimated turning points for the quadratic logs functional form, for those environmental indicators for which turning points were estimated. Comparison can be made with the results of other studies. The year that the estimated turning point was/would be reached, in the UK, is indicated in parentheses. The letter 'F' denotes estimated turning points that are higher than the maximum observed per capita income level in the data-set; for the environmental indicators with these projected turning points, per capita emissions / environmental damage are increasing, at a declining rate, throughout the observed income range.

6.3.1. Indicators with a DIRECT Local Environmental Impact.

Table 2. Estimated Turning Points (1985 US $).

	This Study:[3]	**Other Studies:**[4]		
	Emissions	**Urban Concentrations**		**Emissions per capita**
ENVIRON. INDICATOR	**Quadratic logs**	**G&K**	**Shafik**	**S&S**
Sulphur Dioxide	$4,500 (pre 1970)	$4,053	$3,670	$8,916
Sulphur Dioxide - Transport	$9,000 (1975)			
SPM	$3,000 (pre 1970)	$6,151	$3,280	$9,811
SPM - Transport	$18,000 (post 1992)			

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[3] All turning points were calculated using the average level of per capita income growth rate for all the countries in each sample, throughout the time series.

[4] Where, G&K refers to Grossman and Krueger (1995), Shafik refers to Shafik (1994) and S&S refers to Selden and Song (1994). All estimated turning points are in 1985 US dollars. Note that all these studies incorporate time/technological change into their analyses. See Chapter 5, Table 3 for further information regarding these studies.

Table 2 (Continued).

	This Study:	**Other Studies:**		
	Emissions	**Urban Concentrations**		**Emissions per capita**
ENVIRON. INDICATOR	**Quad. logs**	**G&K**	**Shafik**	**S&S**
Carbon Monoxide	$7,100 (pre 1970)			$6,241
Nitrogen Dioxide Nitrogen Dioxide - Transport	$14,500 (post 1992) $19,500 F (post 1992)			$12,041
Nitrates	$31,700 F (post 1992)	$10,524		
Phosphorous	$10,900 (1984)			

The turning points from this study in table 2, above, and Table 13, below, have been calculated by estimating emissions/environmental quality given per capita income and the linear time trend. In effect they stem from curves such as t = 1,2,3,4 in diagram 1. A different manner in which to calculate the turning point from a function which contains a linear time trend is to simply differentiate the estimated function with respect to income. This method, which is used, for example, by Grossman and Krueger (1993, 1995), effectively ignores the time trend, which disappears in the differentiation process. In diagram 1, if this method was used, the estimated turning point would be that found on curves t=1, t=2, t=3 or t=4. Turning points calculated from both methods are presented in Table 3, below, (where the first method is referred to as 'include time' and the second as 'ignore time'), together with the turning points from the previous chapter which did not include a time trend. Standard errors, calculated by the Delta method, are in parentheses.[5] Note that standard errors for the first method, where the time trend is included in the regression and in the estimation of the turning point, would be the same as

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[5] See Chapter 5 for details of the Delta method.

that for the second method, where the time trend is included in the regression but omitted when calculating the turning point. This is because the Delta method uses turning points obtained by differentiation, thus standard errors for the turning points from the first method would be based on the turning points from the second method. Since turning points from the second method are generally at higher income levels than those when the time trend is not included in the regression, standard errors also tend to be larger.

Table 3. A Comparison of the Different Methods of Estimating Turning Points Used in this Study.

ENVIRON. INDICATOR	**Time Trend**		**No time trend[6]**
	Include time	**Ignore time**	
Sulphur Dioxide	$4,500	$15,500 (1,929)	$6,900 (563)
Sulphur Dioxide - Transport	$9,000	$13,000 (1,978)	$9,800 (586)
SPM	$3,000	$27,000 (10,399)	$7,300 (264)
SPM - Transport	$18,000	$20,300 (5,826)	$18,000 (2,709)
Carbon Monoxide	$7,100	$18,600 (3,096)	$9,900 (353)
Nitrogen Dioxide	$14,500	$16,300 (2,015)	$14,700 (587)
Nitrogen Dioxide - Transport	$19,500	$15,700 (1,817)	$17,600 (1,579)
Nitrates	$31,700	$6,700 (2,146)	$24,500 (6,779)
Phosphorous	$10,900	$6,100 (605)	$6,600 (500)

It can be seen that turning points for sulphur dioxide, suspended particulate matter, carbon monoxide and nitrates vary considerably across methods,

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[6] From Chapter 5.

with the second method (where the time trend is included in the regression but ignored when calculating the turning point) generally providing turning points which are quite different to those estimated using the other two methods.

Tables 4-12 and 14-19, below, contain results from the favoured quadratic logs functional form calculated using Kmenta's (1986) generalised least squares approach. Appendix K, includes GLS quadratic levels results as well as GLS linear results (where appropriate), and all OLS results. In order to assess whether the estimated time trend is consistent throughout the full time series, a dummy has been attached to the first half of the time trend for all indicators except those for which there are only four years of observations.[7] This dummy is statistically insignificant for all environmental indicators, and is therefore reported for only the first indicator to be analysed, sulphur dioxide.

(i) Sulphur Dioxide.

Table 4.

SULPHUR DIOXIDE - GLS LOGS QUADRATIC			
Y	25.971 (6.271)	D6 Finland	-0.33603 (-1.931)
Y^2	-1.3458 (-5.976)	D7 France	-1.1033 (-6.346)
k	-0.067253 (-10.36)	D8 Canada	0.45423 (2.088)
D1 W.Germany	-1.2421 (-4.593)	D9 Denmark	-0.51952 (-3.381)
D2 Netherlands	-1.483 (-10.16)	D10 Italy	-0.75387 (-6.078)
D3 Norway	-1.5655 (-8.001)	CONSTANT Ireland	-126.58 (-6.635)
D4 UK	-0.18742 (-1.119)	Buse R^2	0.8673
D5 USA	-0.14577 (-0.4427)		
11 COUNTRIES, 15 YEARS = 165 OBSERVATIONS			

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[7] Namely, nitrates, phosphorous, municipal waste and transport energy use.

Sulphur Dioxide with Dummy on 1st Half of Time Trend.

Sulphur Dioxide	
Y	24.729 (5.58)
Y^2	-1.2786 (-5.32)
k	-0.067441 (-10.42)
dummy on 1st half of time trend	0.0024042 (1.25)

Diagram 3.

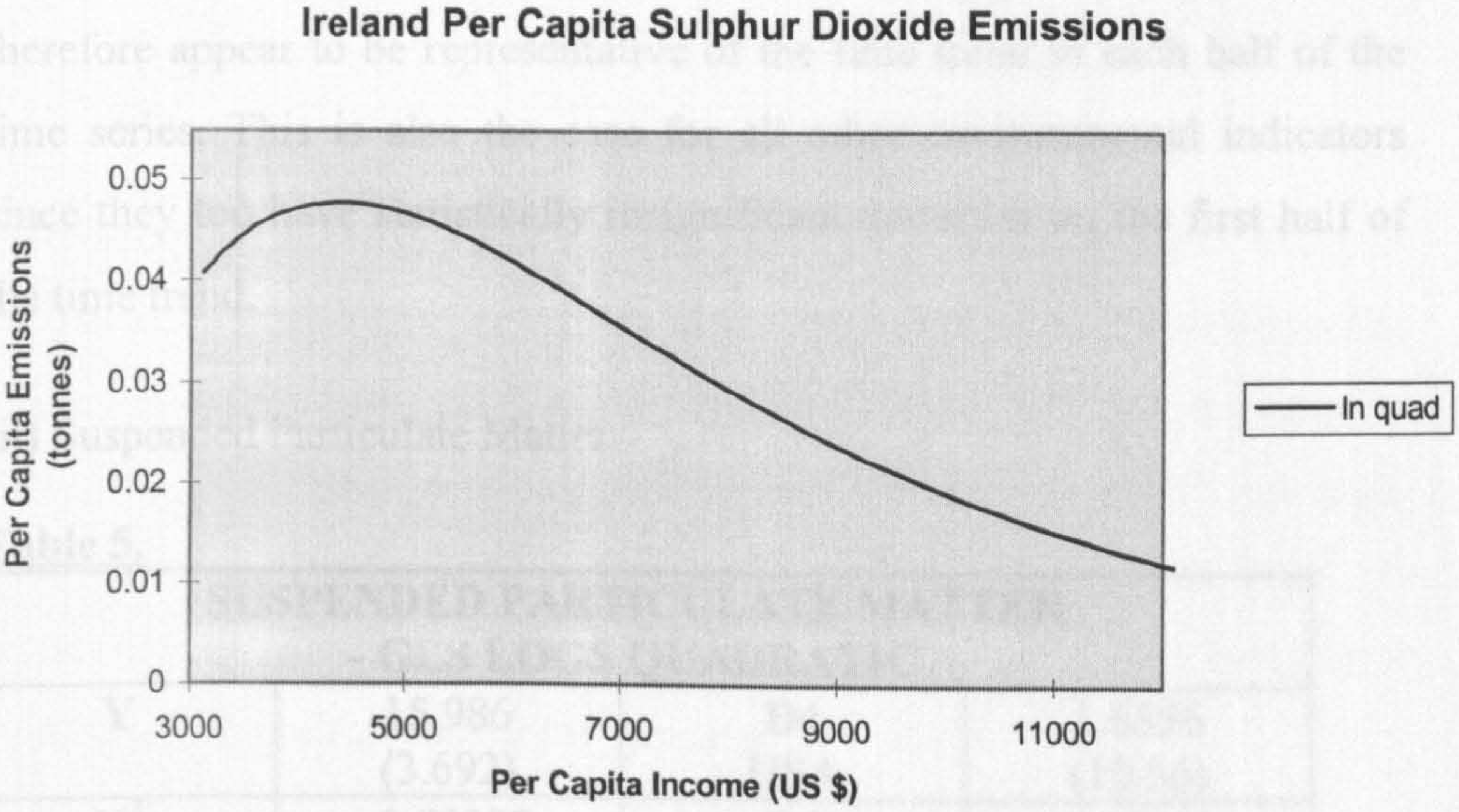


Table 1, above, indicates that sulphur dioxide has a statistically significant, negative time trend. Diagram 3 illustrates the estimated relationship between per capita income and per capita sulphur dioxide emissions when this time trend is included. The estimated turning point is at the relatively low per capita income level of approximately \$4,500 (or \$15,500 if the time trend is ignored when estimating the turning point). Furthermore, Table 3 indicates that there is a large degree of variation between the three different estimated turning points.

The turning point of $4,500 still supports the hypothesis of Selden and Song (1994), that the turning point for per capita *emissions* of pollution will be at a higher level of income than that for urban air concentrations. However, since Grossman and Krueger estimated a turning point for urban air concentrations of sulphur dioxide at $4,053, the difference between the two is clearly small and hence the argument is somewhat weakened.

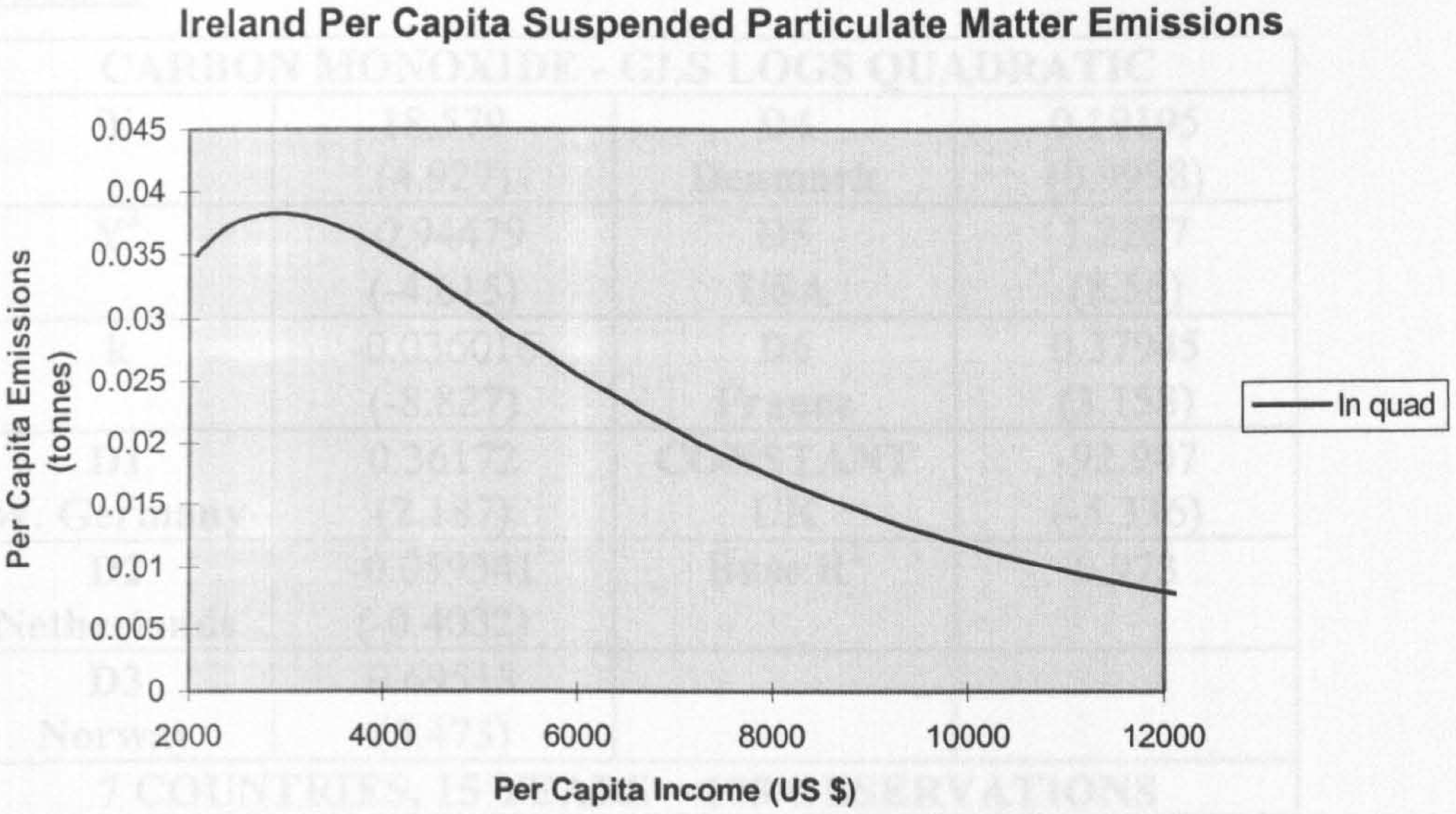
The statistically insignificant dummy on the first half of the time trend implies that there is no statistically significant difference between the estimated time trend in the first half of the time series, compared to that in the second half. The estimated time trend for the full time series would therefore appear to be representative of the time trend in each half of the time series. This is also the case for all other environmental indicators since they too have statistically insignificant dummies on the first half of the time trend.

(ii) Suspended Particulate Matter.

Table 5.

SUSPENDED PARTICULATE MATTER - GLS LOGS QUADRATIC			
Y	15.986 (3.692)	**D4 USA**	1.6556 (10.56)
Y^2	-0.78337 (-3.29)	**D5 W.Germany**	0.55485 (4.755)
k	-0.074815 (-10.65)	**D6 France**	0.12301 (0.9468)
D1 Netherlands	0.34227 (2.711)	**CONSTANT Norway**	-85.239 (-4.316)
D2 Ireland	2.4855 (11.95)	**Buse R^2**	0.9135
D3 UK	0.719 (5.747)		
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

Diagram 4.



Like sulphur dioxide, a statistically significant negative time trend is estimated for suspended particulate matter, with the estimated relationship displayed in Diagram 4. The low turning point level of income, at approximately $3,000, contrasts sharply with the estimate of $27,000 from a regression where the time trend is still included but omitted from the calculation of the turning point. The latter turning point is subject to a large standard error, however, as indicated in Table 3.

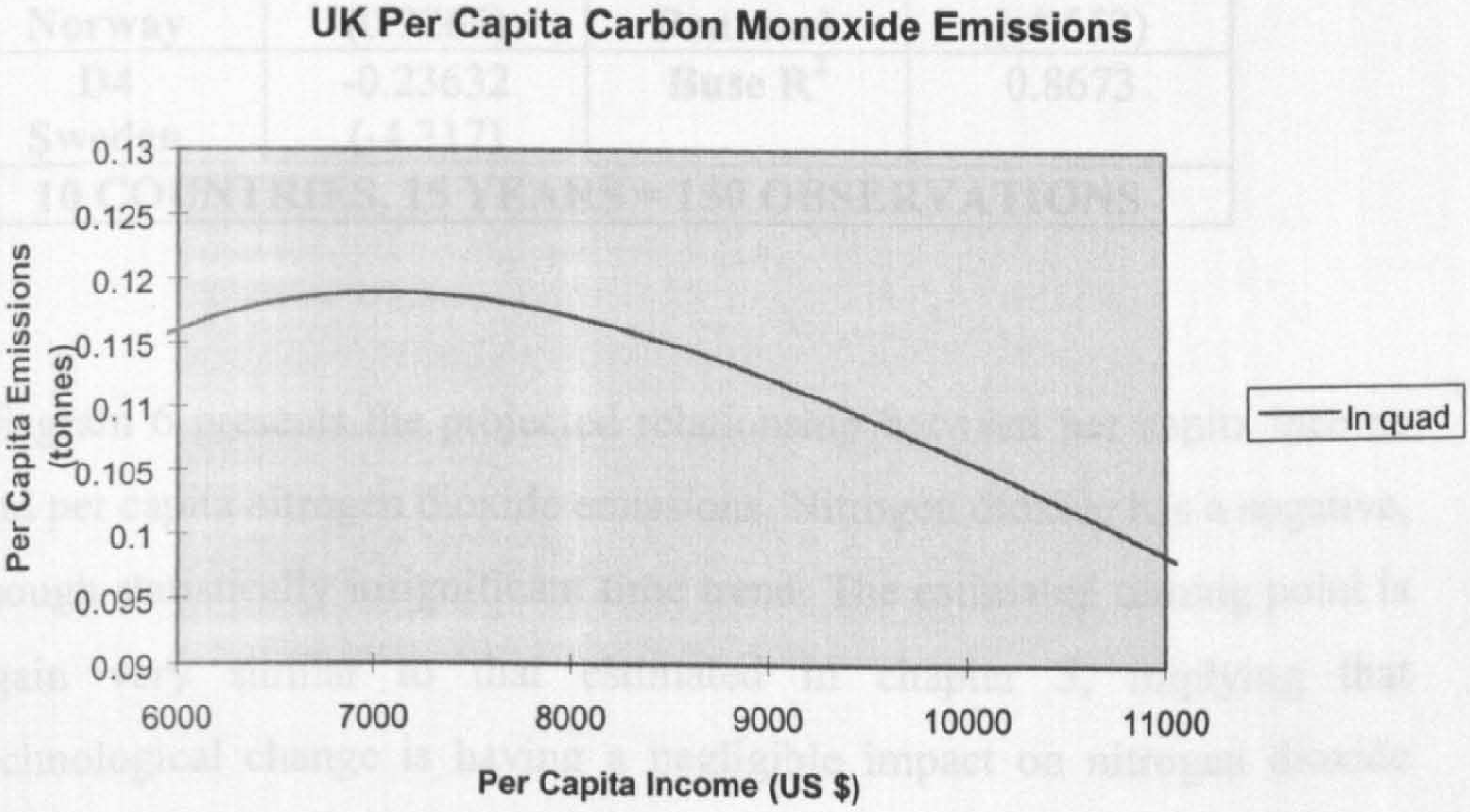
The estimated turning point of $3,000 no longer supports the hypothesis of Selden and Song (1994) that turning points for aggregate emissions of air pollution will be at higher levels of per capita income than those estimated for urban air concentrations. Grossman and Krueger estimate a turning point of $6,151 for urban air concentrations of suspended particulate matter.

(iii) Carbon Monoxide.

Table 6.

CARBON MONOXIDE - GLS LOGS QUADRATIC			
Y	18.579 (4.927)	**D4** **Denmark**	0.19195 (0.9998)
Y^2	-0.94479 (-4.615)	**D5** **USA**	1.2227 (8.56)
k	-0.036016 (-8.827)	**D6** **France**	0.37945 (3.158)
D1 **W. Germany**	0.36172 (2.187)	**CONSTANT** **UK**	-92.907 (-5.336)
D2 **Netherlands**	-0.059341 (-0.4032)	**Buse R^2**	0.973
D3 **Norway**	0.69513 (5.473)		
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

Diagram 5.



Like sulphur dioxide and suspended particulate matter, carbon monoxide is estimated to have a statistically significant negative time trend. The turning point level of income for per capita carbon monoxide is estimated at

$7,100, in contrast to the estimate of $9,900 made in the absence of the time trend in Chapter 5. Both of these estimates are considerably lower than the turning point of $18,600 calculated from a regression which includes a linear time trend, but which ignores it when calculating the turning point.

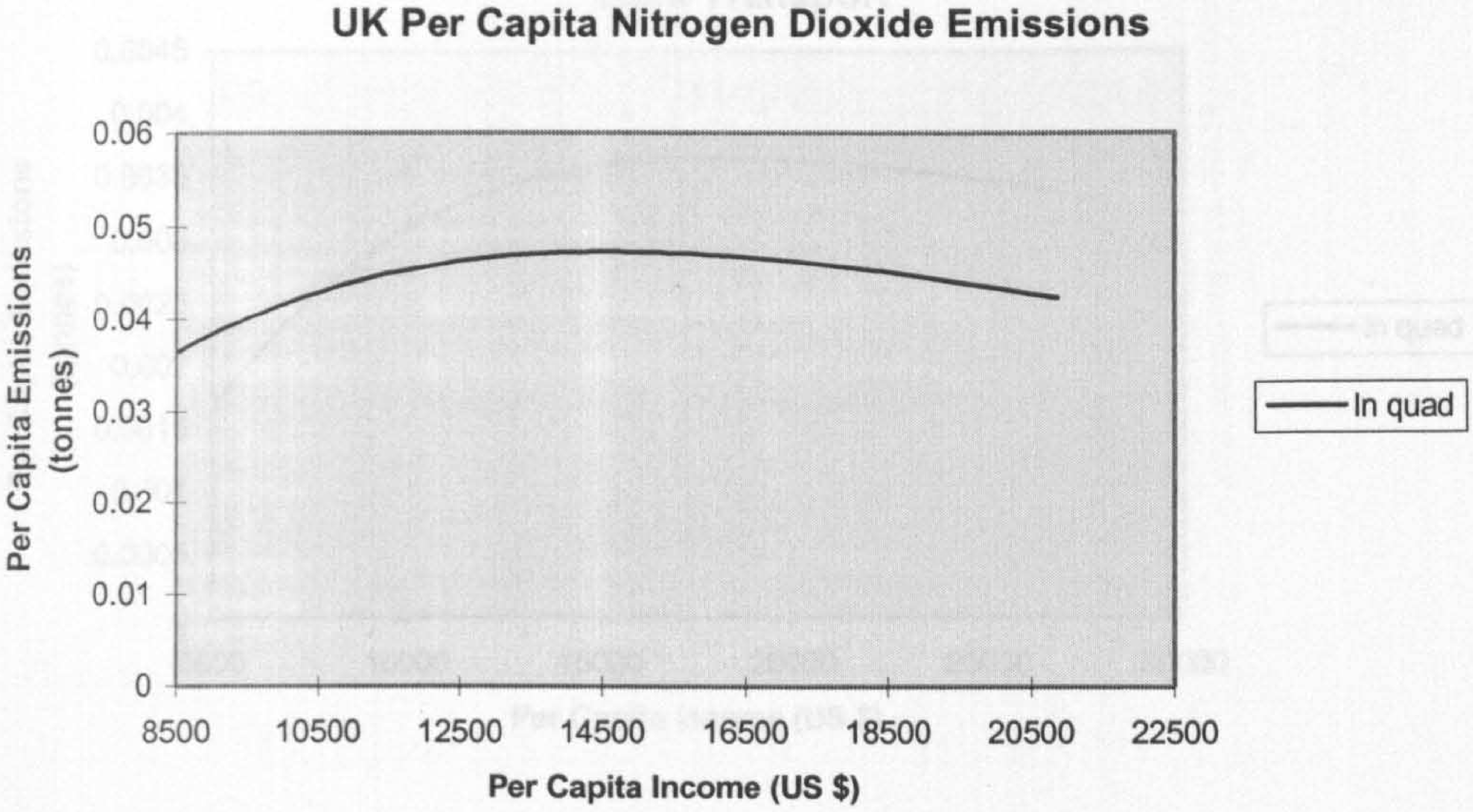
(iv) Nitrogen Dioxide.

Table 7.

NITROGEN DIOXIDE - GLS LOGS QUADRATIC			
Y	17.256 (4.242)	**D5** **UK**	-0.04418 (-0.6186)
Y^2	-0.88961 (-4.084)	**D6** **USA**	0.51308 (7.136)
k	-0.0036694 (-1.056)	**D7** **Finland**	0.10933 (1.367)
D1 **W.Germany**	-0.17025 (-1.757)	**D8** **France**	-0.56663 (-5.382)
D2 **Netherlands**	-0.20066 (-3.191)	**D9** **Canada**	0.38076 (5.871)
D3 **Norway**	0.02304 (0.3265)	**CONSTANT** **Denmark**	-86.568 (-4.552)
D4 **Sweden**	-0.23632 (-4.317)	**Buse R^2**	0.8673
10 COUNTRIES, 15 YEARS = 150 OBSERVATIONS			

Diagram 6 presents the projected relationship between per capita income and per capita nitrogen dioxide emissions. Nitrogen dioxide has a negative, though statistically insignificant time trend. The estimated turning point is again very similar to that estimated in chapter 5, implying that technological change is having a negligible impact on nitrogen dioxide emissions.

Diagram 6.



(v) Suspended Particulate Matter from Transport.

Table 8.

SPM TRANSPORT - GLS LOGS QUADRATIC			
Y	9.391 (5.062)	**D4** **USA**	1.6517 (10.44)
Y^2	-0.47343 (-4.549)	**D5** **W.Germany**	0.070215 (0.4655)
k	-0.0023638 (-0.5422)	**D6** **Norway**	0.50828 (3.384)
D1 **Netherlands**	0.42438 (2.507)	**CONSTANT** **France**	-53.296 (-6.402)
D2 **Ireland**	1.2589 (7.481)	**Buse R^2**	0.9533
D3 **UK**	1.0622 (4.722)		
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

Diagram 7.

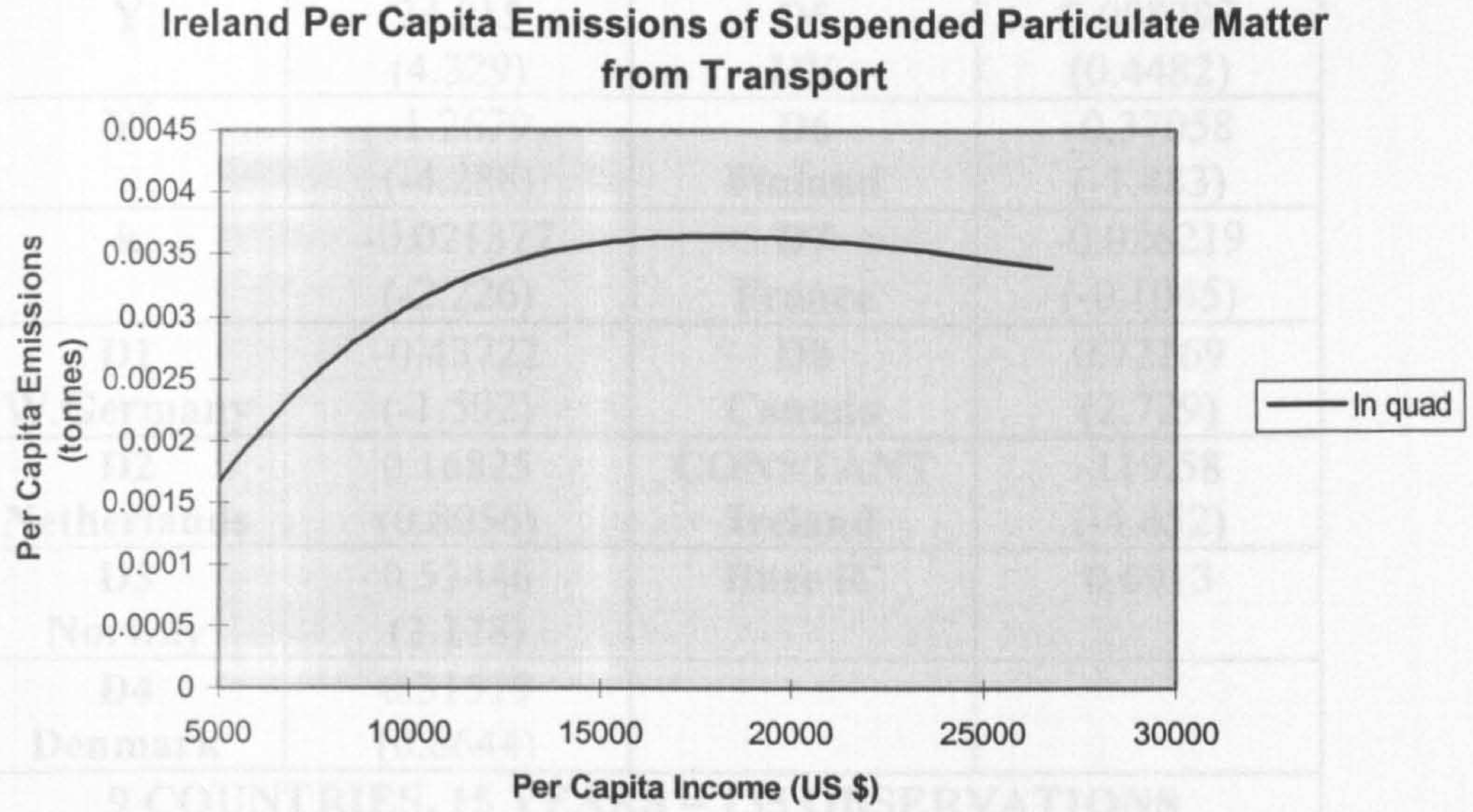


Table 8 and Diagram 7, above, present the relationship between per capita income and per capita emissions of suspended particulate matter from transport. The turning point is estimated at a per capita income level of \$18,000, which is identical to that estimated in the absence of a time trend, whilst a turning point of \$20,300 is estimated when a time trend is included in the regression, but ignored when calculating the turning point. It is, however, considerably higher than the turning point for *total* suspended particulate matter.

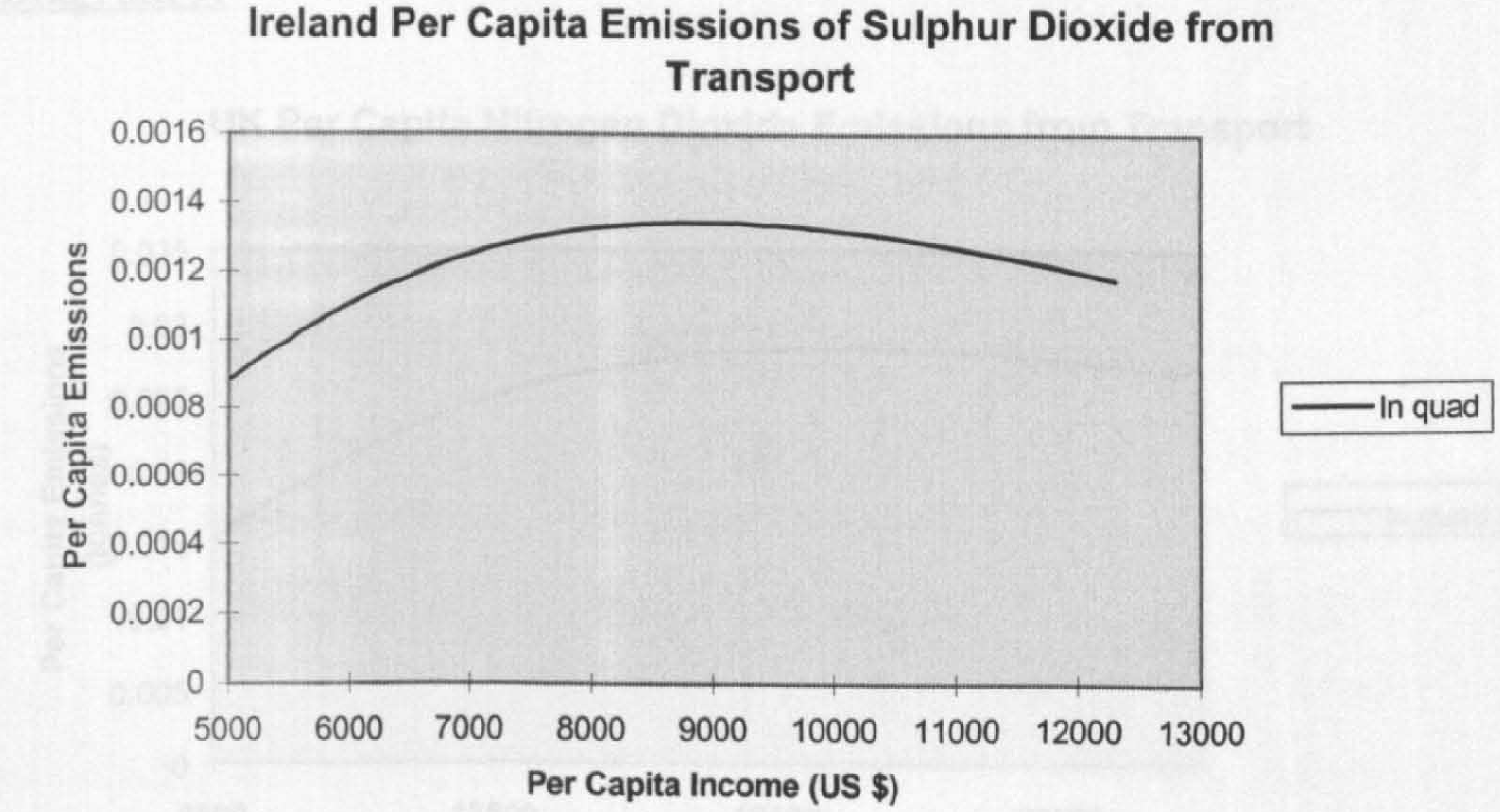
(vi) Sulphur Dioxide from Transport.

Sulphur dioxide from transport is estimated to have a statistically significant negative time trend. The turning point is estimated as \$9,000, as illustrated in Diagram 8, above, (or \$13,000 if the time trend is ignored) both of which are notably higher than the estimated turning point of \$4,500 for *total* sulphur dioxide emissions.

Table 9.

SULPHUR DIOXIDE TRANSPORT - GLS LOGS QUADRATIC			
Y	24.015 (4.329)	**D5** **UK**	0.088392 (0.4482)
Y^2	-1.2679 (-4.288)	**D6** **Finland**	-0.37058 (-1.483)
k	-0.021377 (-2.226)	**D7** **France**	-0.026219 (-0.1045)
D1 **W.Germany**	-0.43722 (-1.592)	**D8** **Canada**	0.72169 (2.729)
D2 **Netherlands**	0.16825 (0.8056)	**CONSTANT** **Ireland**	-119.58 (-4.652)
D3 **Norway**	0.53446 (2.178)	**Buse R^2**	0.6913
D4 **Denmark**	0.31519 (0.8644)		
9 COUNTRIES, 15 YEARS = 135 OBSERVATIONS			

Diagram 8.



(vii) Nitrogen Dioxide from Transport.

Table 10.

NITROGEN DIOXIDE TRANSPORT - GLS LOGS QUADRATIC			
Y	17.174 (4.181)	**D5** **Finland**	0.67633 (18.6)
Y^2	-0.88862 (-4.039)	**D6** **Denmark**	0.36356 (3.772)
k	0.0078369 (2.432)	**D7** **Canada**	0.97943 (16.65)
D1 **W.Germany**	0.40914 (12.83)	**D8** **Norway**	0.83953 (19.01)
D2 **Netherlands**	0.30617 (7.959)	**CONSTANT** **France**	-87.107 (-4.539)
D3 **UK**	0.26929 (7.106)	**Buse R^2**	0.9246
D4 **USA**	0.8256 (11.54)		
9 COUNTRIES, 15 YEARS = 135 OBSERVATIONS			

Diagram 9.

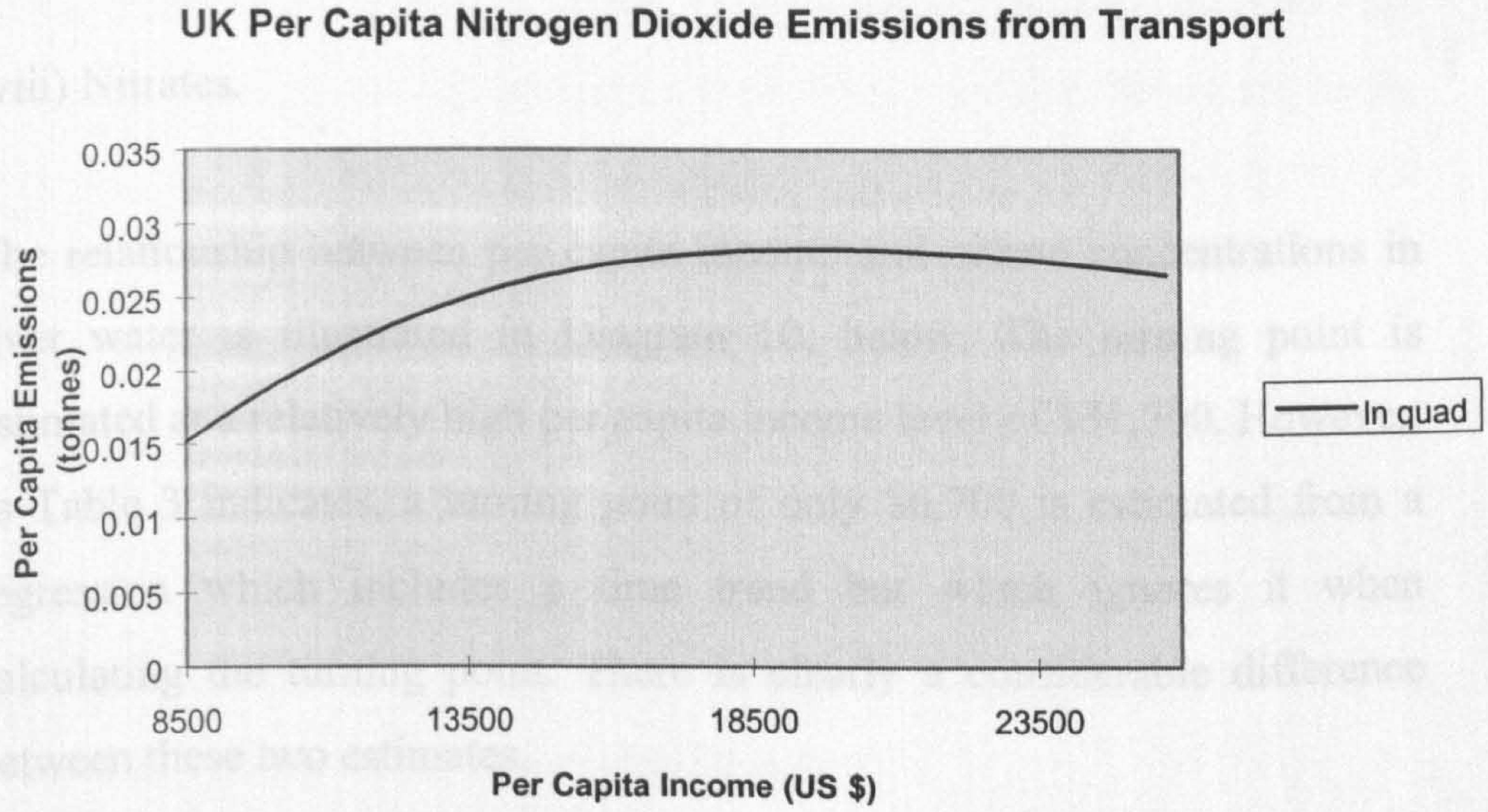


Table 10 provides the results of the estimated relationship between per capita income and per capita emissions of nitrogen dioxide from the transport sector. It can be seen that a statistically significant positive time trend is calculated, although this is in contrast to the negative (statistically insignificant) time trend calculated by the quadratic levels function (see Appendix K). Neither would therefore appear reliable. The turning point is estimated as $19,500 (or $15,700 if the time trend is ignored) and is therefore similar to that estimated in Chapter 5. It is also significantly higher than the turning point of $14,500 estimated for *total* nitrogen dioxide emissions.

As in Chapter 5, it can be seen that the transport generated emissions of local air pollution still have estimated turning points at higher levels of per capita income than those estimated for *total* emissions. Local air pollution from the transport sector is therefore proving more difficult to reduce than in other sectors.

Water Pollution.

(viii) Nitrates.

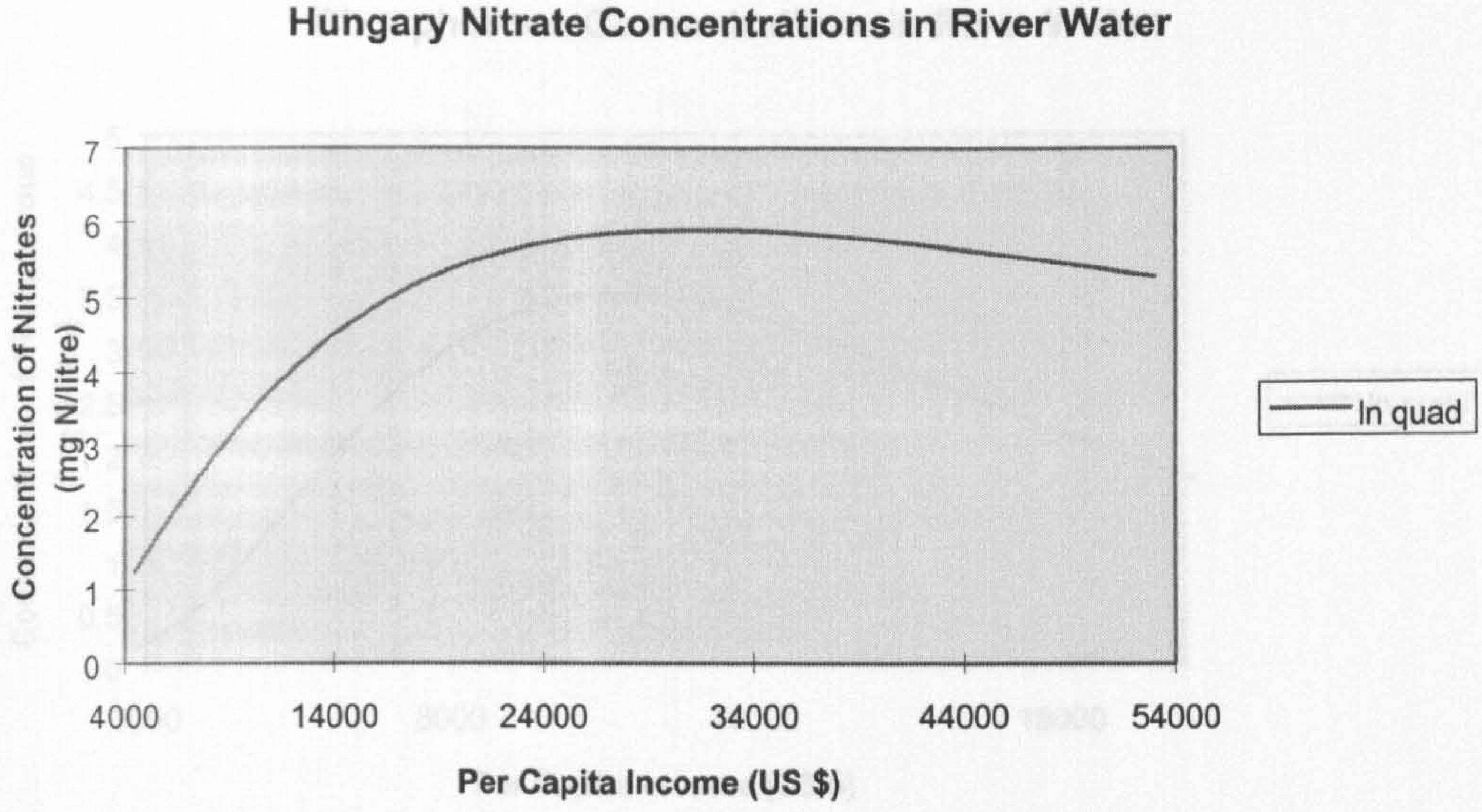
The relationship between per capita income and nitrate concentrations in river water is illustrated in Diagram 10, below. The turning point is estimated at a relatively high per capita income level of $31,700. However, as Table 3 indicates, a turning point of only $6,700 is estimated from a regression which includes a time trend but which ignores it when calculating the turning point. There is clearly a considerable difference between these two estimates.

Table 11.

NITRATES - GLS LOGS QUADRATIC			
Y	7.228 (3.466)	D8 Denmark	2.5873 (4.217)
Y^2	-0.41013 (-3.69)	D9 Finland	0.79384 (3.1)
k	0.13025 (5.742)	D10 Greece	1.5687 (5.541)
D1 Spain	1.7395 (3.993)	D11 Netherlands	2.8851 (13.33)
D2 W.Germany	2.4145 (8.464)	D12 Czech.	2.8634 (7.071)
D3 Norway	0.44524 (2.08)	D13 Hungary	1.8753 (4.588)
D4 Switzerland	2.0601 (7.032)	D14 Belgium	2.5955 (11.13)
D5 UK	3.2457 (8.784)	CONSTANT Canada	-33.566 (-3.392)
D6 USA	1.8996 (9.184)	Buse R^2	0.8734
D7 Italy	2.0971 (9.99)		
30 RIVERS, 4 YEARS = 120 OBSERVATIONS			

A statistically significant positive time trend is estimated - for both quadratic logs and levels, indicating that nitrate concentrations are rising over time in the absence of income changes - even though data suggest that the use of nitrogen based fertilisers is no longer rising in the OECD (see OECD (1995)). This apparent anomaly cannot be explained in terms of technological change, but is likely to result from the fact that once nitrogen accumulates in the soil, it will slowly leach out over many years. This may now be happening, resulting in the positive time trend. Turner *et al.* (1997) provide evidence of the long time period needed for concentrations of nitrates and phosphorous to fall significantly.

Diagram 10.



(ix) Phosphorous.

Table 12.

PHOSPHOROUS - GLS LOGS QUADRATIC	
Y	30.373 (5.024)
Y^2	-1.741 (-5.265)
k	0.21815 (5.643)
CONSTANT	-133.49 (-4.831)
Buse R^2	0.4172
28 RIVERS, 4 YEARS = 112 OBSERVATIONS	

Diagram 11.

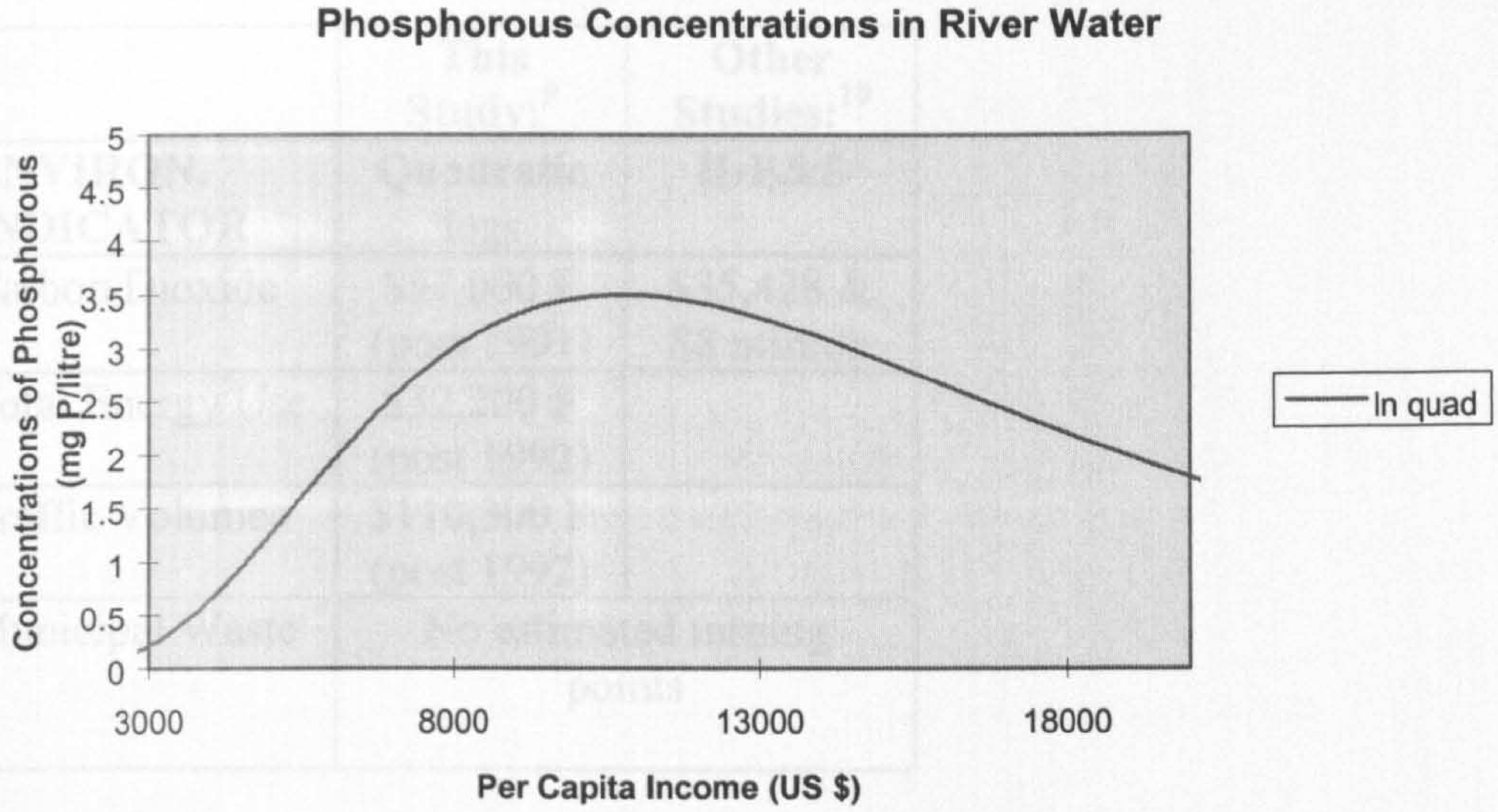


Diagram 11 illustrates that concentrations of phosphorous in river water are estimated to begin falling at a per capita income level of $10,900 (or $6,100 if the time trend is ignored when estimating the turning point). As with nitrates, both functional forms estimate a statistically significant positive time trend. This implies that the relationship between per capita income and concentrations of phosphorous has been shifting upwards i.e. in the absence of income changes concentrations have been rising over time. The reason for this is likely to be the same as for nitrate concentrations, above.

6.3.2 Indicators with NO DIRECT Local Environmental Impact.[8]

Table 13. Estimated Turning Points (1985 US $).

	This Study:[9]	**Other Studies:**[10]
ENVIRON. INDICATOR	**Quadratic logs**	**H-E&S**
Carbon Dioxide	$57,000 F (post 1991)	$35,428 & $8 million
Total Energy Use	$32,200 F (post 1992)	
Traffic Volumes	$110,300 F (post 1992)	
Municipal Waste	No estimated turning points	

Table 14. A Comparison of the Different Methods of Estimating Turning Points Used in this Study.

ENVIRON. INDICATOR	**Time Trend**		**No time trend**[11]
	Include time	**Ignore time**	
Carbon Dioxide	$57,000	$74,300 (35,140)	$62,700 (27,247)
Total Energy Use	$32,200	$44,400 (17,974)	$34,700 (9,719)
Traffic Volumes	$110,300	$29,400 (5,927)	$65,300 (19,412)

Table 14 indicates that the greatest variability amongst estimated turning points is for traffic volumes. Nevertheless, all nine turning points fall beyond current income levels.

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[8] Since only cross-section data exist for CFCs and halons and methane, they are not considered in this chapter, the use of a time trend not being applicable.

[9] All turning points were calculated using the average level of per capita income growth rate for all the countries in each sample, throughout the time series.

[10] Where H-E&S refers to Holtz-Eakin and Selden (1992). Estimated turning points are in 1985 US dollars and incorporate time/technological change. See Chapter 5, Table 2 for further information regarding this study.

[11] From Chapter 5.

(i) Carbon Dioxide.

Table 15.

CARBON DIOXIDE - GLS LOGS QUADRATIC			
Y	3.6186 (8.506)	**D4** **Oceania**	-0.078705 (-0.4449)
Y^2	-0.16131 (-6.541)	**D5** **S.&C.America**	-0.53881 (-5.091)
k	-0.0022109 (-1.176)	**D6** **W.Europe**	0.019537 (0.1189)
D1 **Asia**	0.19483 (4.02)	**CONSTANT** **Africa**	-18.791 (-10.53)
D2 **E.Europe**	0.94531 (5.48)	**Buse R^2**	0.9634
D3 **N.America**	0.61904 (3.219)		
7 REGIONS, 32 YEARS = 224 OBSERVATIONS			

Diagram 12.

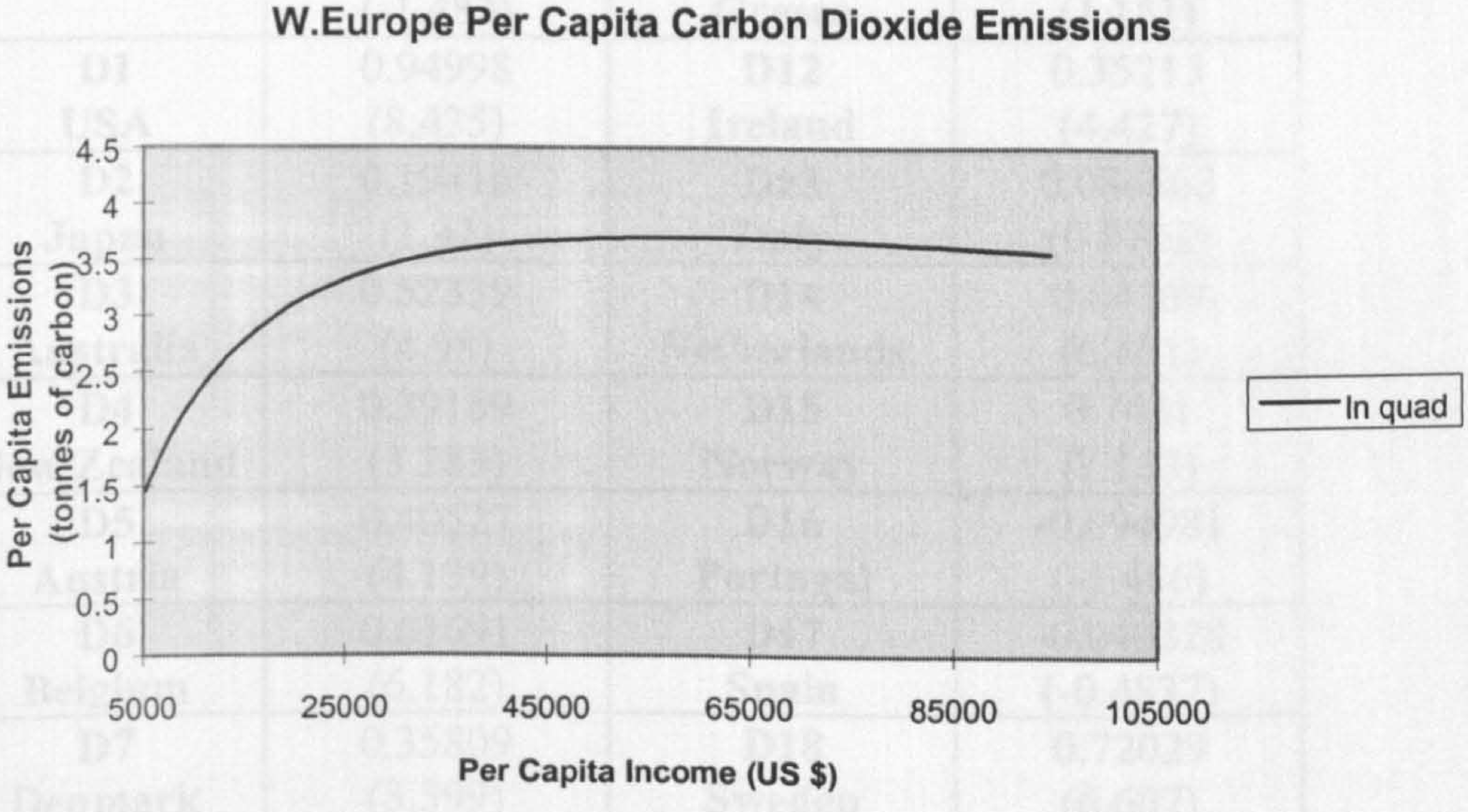


Diagram 12, above illustrates the projected relationship between per capita income and per capita carbon dioxide emissions from the GLS results in Table 15. The time trend can be seen to be negative, implying that in the absence of income changes per capita carbon dioxide emissions are falling over time, although it is not statistically significant. The estimated turning point, at \$57,000, (or \$74,300 if the time trend is ignored) is very similar to that calculated in the absence of a time trend, and clearly falls well outside the observed income range. It would therefore appear that technological advance is having little impact on carbon dioxide emissions.

(ii) Total Energy Use.

Table 16.

TOTAL ENERGY CONSUMPTION - GLS LOGS QUADRATIC			
Y	4.2144 (4.823)	**D9** **France**	0.29667 (2.906)
Y^2	-0.19691 (-4.138)	**D10** **W.Germany**	0.48376 (4.614)
k	-0.0022505 (-1.483)	**D11** **Greece**	0.082791 (1.151)
D1 **USA**	0.94998 (8.435)	**D12** **Ireland**	0.35213 (4.427)
D2 **Japan**	0.19416 (1.92)	**D13** **Italy**	0.084863 (0.8703)
D3 **Australia**	0.52339 (4.98)	**D14** **Netherlands**	0.64169 (6.471)
D4 **New Zealand**	0.39189 (3.283)	**D15** **Norway**	0.7481 (7.133)
D5 **Austria**	0.40527 (4.139)	**D16** **Portugal**	-0.094981 (-1.456)
D6 **Belgium**	0.61691 (6.182)	**D17** **Spain**	-0.040328 (-0.4837)
D7 **Denmark**	0.35809 (3.399)	**D18** **Sweden**	0.72029 (6.607)
D8 **Finland**	0.84106 (8.231)	**D19** **Switzerland**	0.32491 (2.992)

Table 16 (Continued).

TOTAL ENERGY CONSUMPTION - GLS LOGS QUADRATIC			
D20 **Canada**	1.0837 (9.777)	**CONSTANT** **Turkey**	-35.399 (-8.919)
D21 **UK**	0.31973 (3.278)	**Buse R^2**	0.9814
22 COUNTRIES, 13 YEARS = 286 OBSERVATIONS			

Diagram 13.

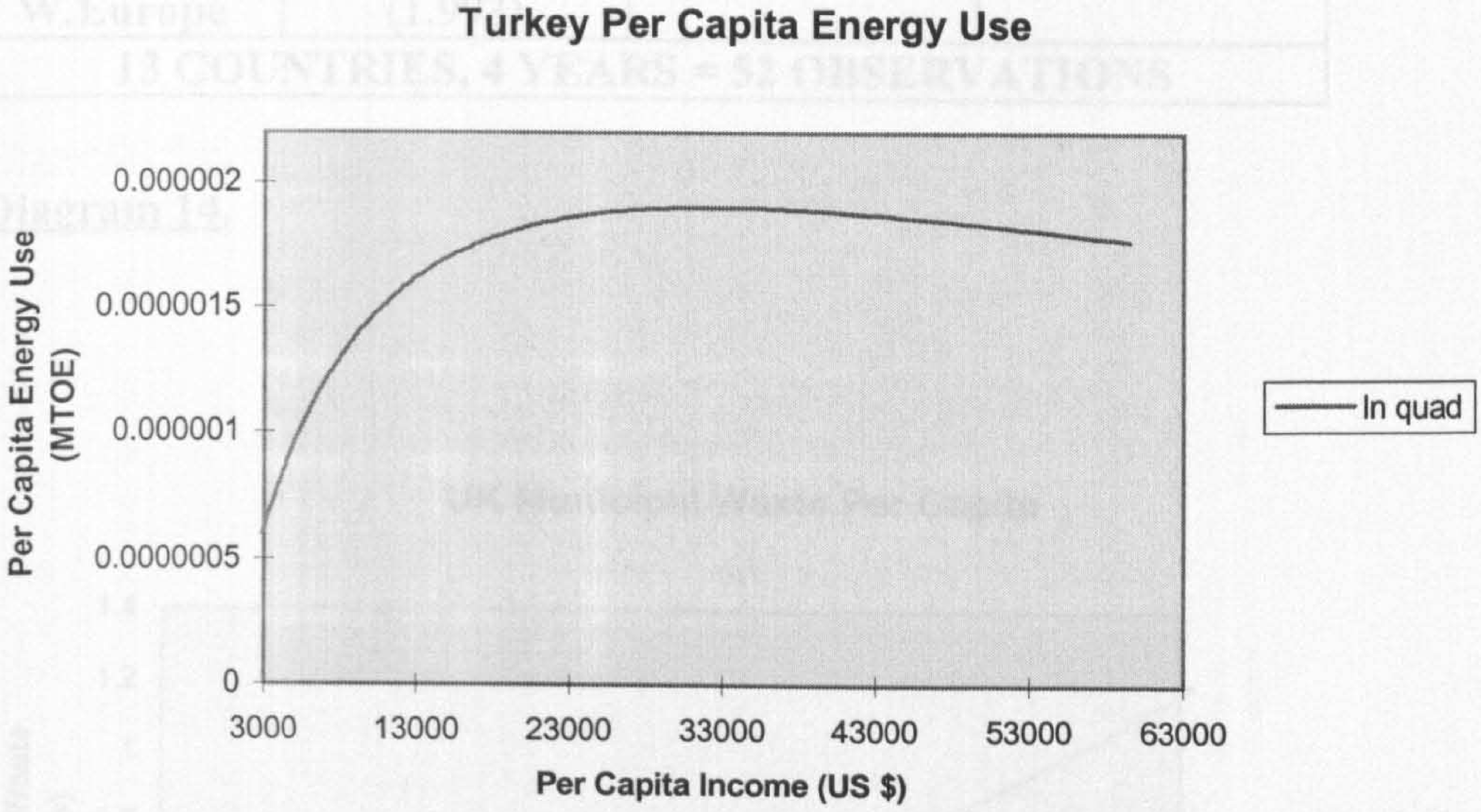


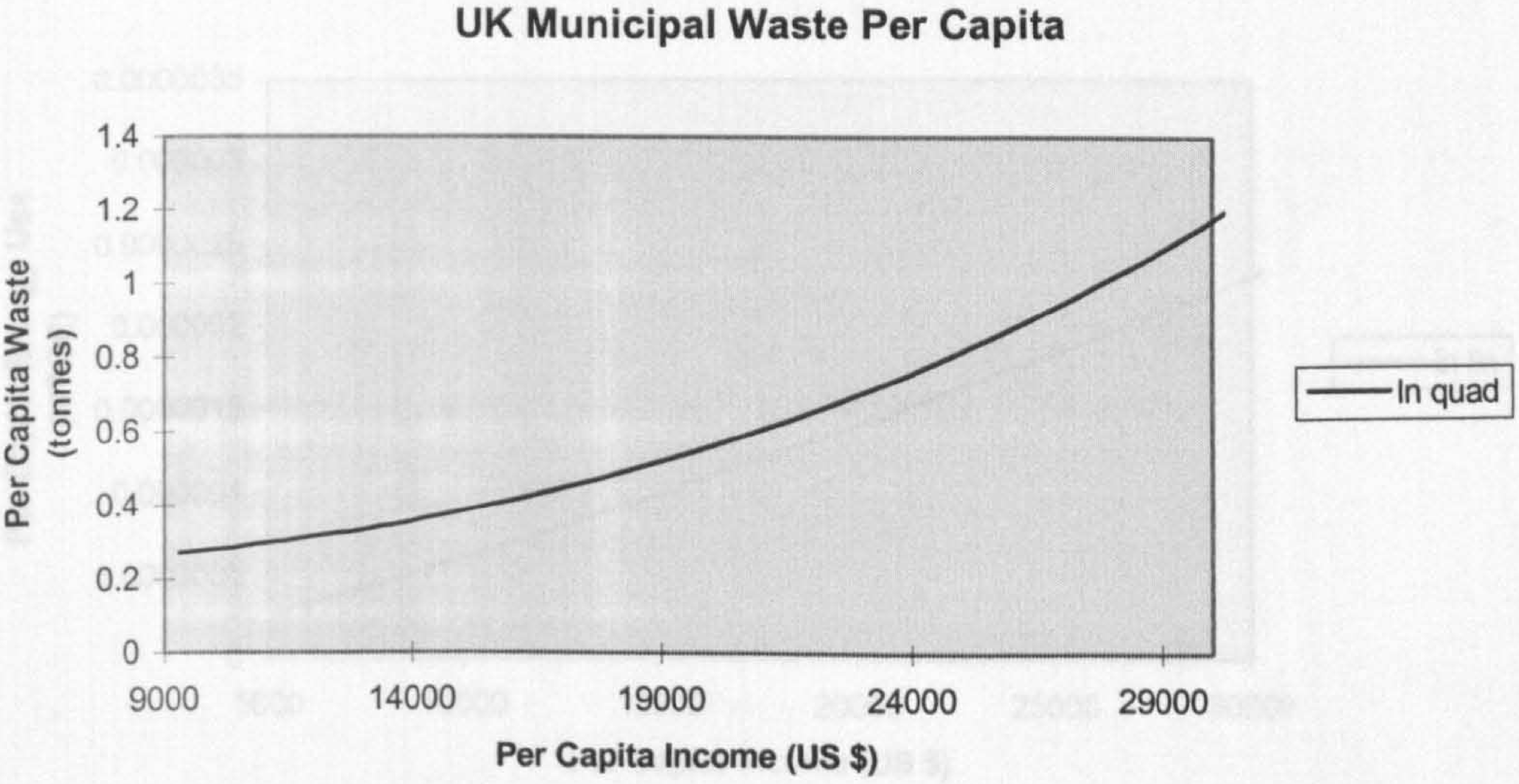
Table 16 and Diagram 13, above, present the estimated relationship between per capita income and per capita energy use. The turning point is estimated at a per capita income level of $32,200 (or $44,400 if the time trend is ignored) and, like carbon dioxide, is well outside the observed income range. These turning points are also subject to a large standard error, thereby questioning their reliability. A negative time trend is estimated, although it is not statistically significant. This last point is perhaps surprising given that energy consumption per unit of GDP has been falling steadily for many years, largely due to technological advance.

(iii) Municipal Waste.

Table 17.

MUNICIPAL WASTE - GLS LOGS QUADRATIC			
Y	-13.272 (-3.41)	**D2** **N.America**	0.82199 (4.814)
Y^2	0.73706 (3.486)	**D3** **Oceania**	0.57364 (3.018)
k	0.019922 (1.34)	**CONSTANT** **E.Europe**	58.057 (3.265)
D1 **W.Europe**	0.34996 (1.993)	**Buse R^2**	0.9352
13 COUNTRIES, 4 YEARS = 52 OBSERVATIONS			

Diagram 14.



Per capita municipal waste, as illustrated above, is estimated to rise steadily with per capita income. A positive time trend has been estimated, although it is not statistically significant.

(iv) Energy Use from Transport.

Table 18.

ENERGY CONSUMPTION TRANSPORT - GLS LOGS LINEAR			
Y	1.2395 (49.53)	**D2** **Oceania**	0.24298 (1.947)
k	-0.0031136 (-4.734)	**CONSTANT** **W.Europe**	-25.706 (-115.2)
D1 **N.America**	0.62624 (4.995)	**Buse R^2**	0.9806
24 COUNTRIES, 4 YEARS = 96 OBSERVATIONS			

Diagram 15.

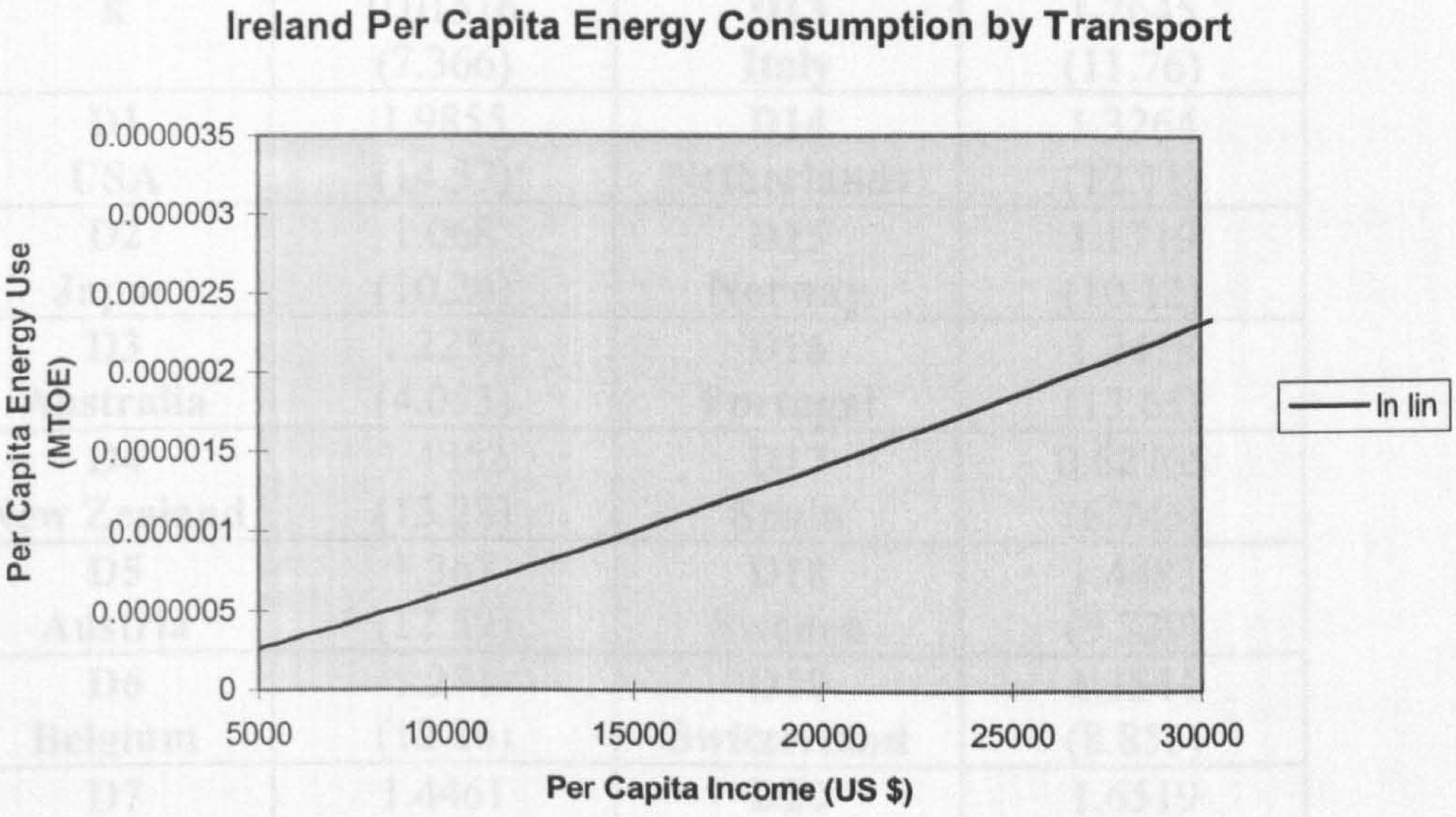


Diagram 15, above, indicates the log linear relationship between per capita income and per capita energy consumption in the transport sector. Since income squared terms were not statistically significant, and since an analysis of the data revealed an almost linear relationship between per capita income and per capita energy use by the transport sector, linear functions are also estimated (see Appendix K). Clearly, energy consumption in the transport sector is rising steadily with per capita income. Table 18 indicates that energy use from transport possesses a statistically significant negative time trend. This finding is intuitive since energy efficiency in the transport sector has been increasing in recent years.

(v) Traffic Volumes.

Table 19.

TRAFFIC VOLUMES - GLS LOGS QUADRATIC			
Y	6.529 (8.854)	**D11 Greece**	1.1324 (7.488)
Y^2	-0.3173 (-7.774)	**D12 Ireland**	1.7254 (22.05)
k	0.01516 (7.366)	**D13 Italy**	1.2645 (11.76)
D1 USA	1.9855 (14.57)	**D14 Netherlands**	1.3264 (12.11)
D2 Japan	1.068 (10.24)	**D15 Norway**	1.1719 (10.12)
D3 Australia	1.2236 (4.053)	**D16 Portugal**	1.2418 (13.65)
D4 New Zealand	1.4862 (13.28)	**D17 Spain**	0.62765 (6.745)
D5 Austria	1.367 (12.59)	**D18 Sweden**	1.4483 (9.739)
D6 Belgium	1.271 (12.26)	**D19 Switzerland**	1.3544 (8.855)
D7 Denmark	1.4461 (12.69)	**D20 Canada**	1.6519 (13.14)
D8 Finland	1.5638 (13.29)	**D21 UK**	1.3636 (10.15)
D9 France	1.4287 (12.32)	**CONSTANT Turkey**	-26.295 (-7.942)
D10 W.Germany	1.402 (12.37)	**Buse R^2**	0.9736
22 COUNTRIES, 15 YEARS = 330 OBSERVATIONS			

Diagram 16.

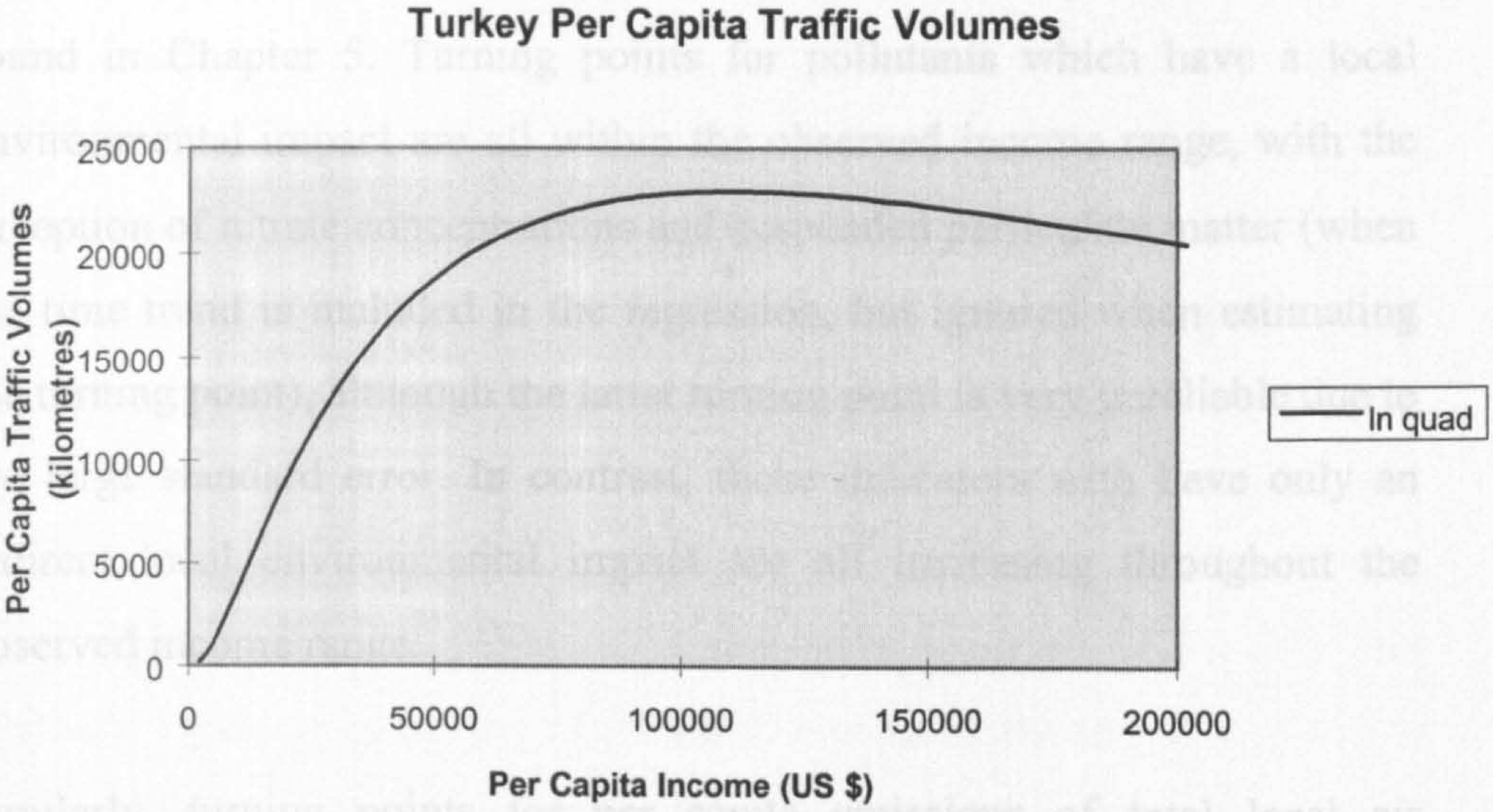


Diagram 16 illustrates that per capita traffic volumes are estimated to begin falling at a per capita income level of over $100,000. Such a high turning point stems from the near linear nature of the income/traffic volumes data.[12] A turning point of $29,400 is estimated from a regression which also includes a time trend but which ignores it when calculating the turning point. Although this estimate is notably lower than that mentioned above, it is still well outside the sample income range. The standard error associated with the latter turning point is also significantly smaller than that calculated in the absence of the time trend. Furthermore, Table 19 indicates that traffic volumes display a statistically significant positive time trend, implying that in the absence of income changes per capita traffic volumes will continue to rise over time. This finding is not unexpected but would not be easily explained in terms of technological change.

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[12] For the quadratic levels function, the income squared term was not statistically significant. A linear function was therefore estimated (see Appendix K).

6.4 Conclusion.

It would appear that the results in this chapter are very similar to those found in Chapter 5. Turning points for pollutants which have a local environmental impact are all within the observed income range, with the exception of nitrate concentrations and suspended particulate matter (when the time trend is included in the regression, but ignored when estimating the turning point), although the latter turning point is very unreliable due to the large standard error. In contrast, those indicators with have only an indirect local environmental impact are all increasing throughout the observed income range.

Similarly, turning points for per capita emissions of total local air pollutants are still all lower than those for per capita emissions of transport generated local air pollutants - with the exception of nitrogen dioxide if the time trend is included in the regression, but ignored when calculating the turning point.

Selden and Song's (1994) hypothesis that per capita emissions of local air pollutants will peak at higher per capita income levels than urban air concentrations is still supported by the results for sulphur dioxide, although the turning point of $4,500 is only marginally higher than that estimated for urban concentrations by Grossman and Krueger (1993, 1995). However, the results for suspended particulate matter no longer support the hypothesis unless the time trend is included in the regression, but ignored when estimating the turning point. This turning point has a very large standard error, however.

All of the local air pollutants considered, with the exception of nitrogen dioxide, have been found to possess a statistically significant negative time trend. Thus, if income changes are controlled for, per capita emissions of these pollutants have still fallen over time, perhaps due to changes in technology. Such an assertion would seem intuitive. In the developed world, the shift away from the use of coal and oil for heating and cooking towards natural gas and smokeless fuels, has seen a marked reduction in the emissions of both sulphur dioxide and suspended particulate matter. Furthermore, technological advance has facilitated a reduction in the emissions of sulphur dioxide from power stations, whilst more energy efficient motor vehicles, together with catalytic converters,[13] are largely responsible for the reductions in carbon monoxide. In contrast, the contribution of the ever growing transport sector has meant that emissions of nitrogen dioxide have largely escaped unchecked. It is only the relatively recent introduction of the three-way catalytic converter that has seen significant reductions in emissions. Thus, for much of the time period under consideration, technology has had little impact on nitrogen dioxide emissions - perhaps explaining the statistically insignificant time trend.

Transport generated emissions of suspended particulate matter and nitrogen dioxide do not display a statistically significant time trend. An explanation for this may be that neither suspended particulate matter from transport nor nitrogen dioxide from transport have been greatly affected by technological change. The recent introduction of catalytic trap oxidisers, designed to reduce particulate emissions from diesel engines would not have significantly reduced emissions during the time period considered. Similarly, as mentioned above, the introduction of the three-way catalytic converter which will reduce nitrogen dioxide, has also occurred only recently. The existence of a statistically significant time trend for sulphur dioxide emissions from transport is perhaps more difficult to explain in terms of technological change. It would appear that emissions have fallen

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[13] Even the earliest form of catalytic converter, the oxidation catalyst, tackled carbon monoxide.

due to greater fuel efficiency, although it is less clear why this has not been the case for nitrogen dioxide.

With regard to time trends for the global / indirect environmental indicators, per capita values of both municipal waste and traffic volumes possess *positive* time trends, implying that the indicators have been increasing over time (in the absence of income changes), although the time trend is not statistically significant for the former. This finding is difficult to explain in terms of the level of technology. In contrast, per capita values of total energy use, transport energy use and carbon dioxide emissions possess *negative* time trends, implying that the indicators have been decreasing over time (in the absence of income changes), although only transport energy use has a statistically significant time trend. Greater energy efficiency may explain why these three indicators all possess negative time trends, although it is less clear why they are not all statistically significant.

The methodology used in Chapters 5 and 6 now contributes to the estimation of the environmental impact of the Uruguay Round of trade negotiations, contained in the next chapter.

CHAPTER 7.

THE ENVIRONMENTAL IMPACT OF THE URUGUAY ROUND.

7.1 Introduction.

It is widely expected that the Uruguay Round of trade negotiations will significantly increase global production and welfare levels. However, little attention has been paid to the possible environmental impact which may also arise as a result of the Uruguay Round. This chapter therefore attempts to quantify the impact of the Uruguay Round on the environmental indicators considered in Chapters 5 and 6. Where possible, the likely monetary cost / saving associated with an increase / decrease in pollution is also estimated.

The impact on the environmental indicators is quantified in terms of the three mechanisms associated with trade liberalisation as outlined by Grossman and Krueger (1993), and referred to in Chapter 3 - the *composition* effect, the *scale* effect and the *technique* effect. The composition effect refers to the fact that trade liberalisation is likely to change the composition of industry as countries specialise to a greater extent in those sectors in which they enjoy a comparative advantage. This change in industrial composition may have either a positive or negative impact on the environment. The scale effect stems from the expansion in the scale of production which is likely to occur as markets expand due to trade liberalisation. Taken in isolation, the scale effect is likely to prove damaging to the environment. Finally, the technique effect refers to the fact that following trade liberalisation, a nation may have greater access to resource efficient production methods whilst at the same time individuals may begin to demand a cleaner environment as they experience increasing incomes. Thus, the manner of production may change as a result of trade liberalisation, to the benefit of the environment.

The composition effect is estimated by combining the local air pollution intensities from Hettige *et al.* (1994) with the estimated effect of the Uruguay Round on the composition of output from Francois *et al.* (1995). Regional sectoral pollution intensities are obtained from the US sectoral pollution intensities of Hettige *et al.* by adjusting for regional differences in *total* pollution intensity. These regional pollution intensities were calculated using environmental Kuznets curves (EKCs). Combined scale and technique effects are also calculated using these EKCs together with Francois *et al.*'s estimates of income gains resulting from the Uruguay Round.[1]

As far as I am aware, no other study has attempted to quantify the environmental impact associated with the Uruguay Round. Grossman and Krueger (1993), however, attempt to partially quantify the environmental impact associated with the North American Free Trade Agreement (NAFTA). The methodology used in this chapter improves on theirs in several ways. First, Grossman and Krueger estimate the composition effect associated with NAFTA in terms of the overall toxic intensity of production rather than in terms of individual air pollutants. As they themselves point out, the problem with using aggregated toxic releases (as opposed to individual types of toxic release) and measuring this in terms of weight is that some relatively heavy releases have little adverse impact on health whilst other relatively light releases may have a serious health impact. Furthermore, when calculating the composition effect Grossman and Krueger used US sectoral toxic intensities for *all* nations, including Mexico. As mentioned above, this chapter adjusts US sectoral intensities according to differences in regional total intensities. Finally, when

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[1] In this chapter the scale effect and the technique effect are combined into one effect. This is hereafter referred to as the *combined scale and technique effect.*

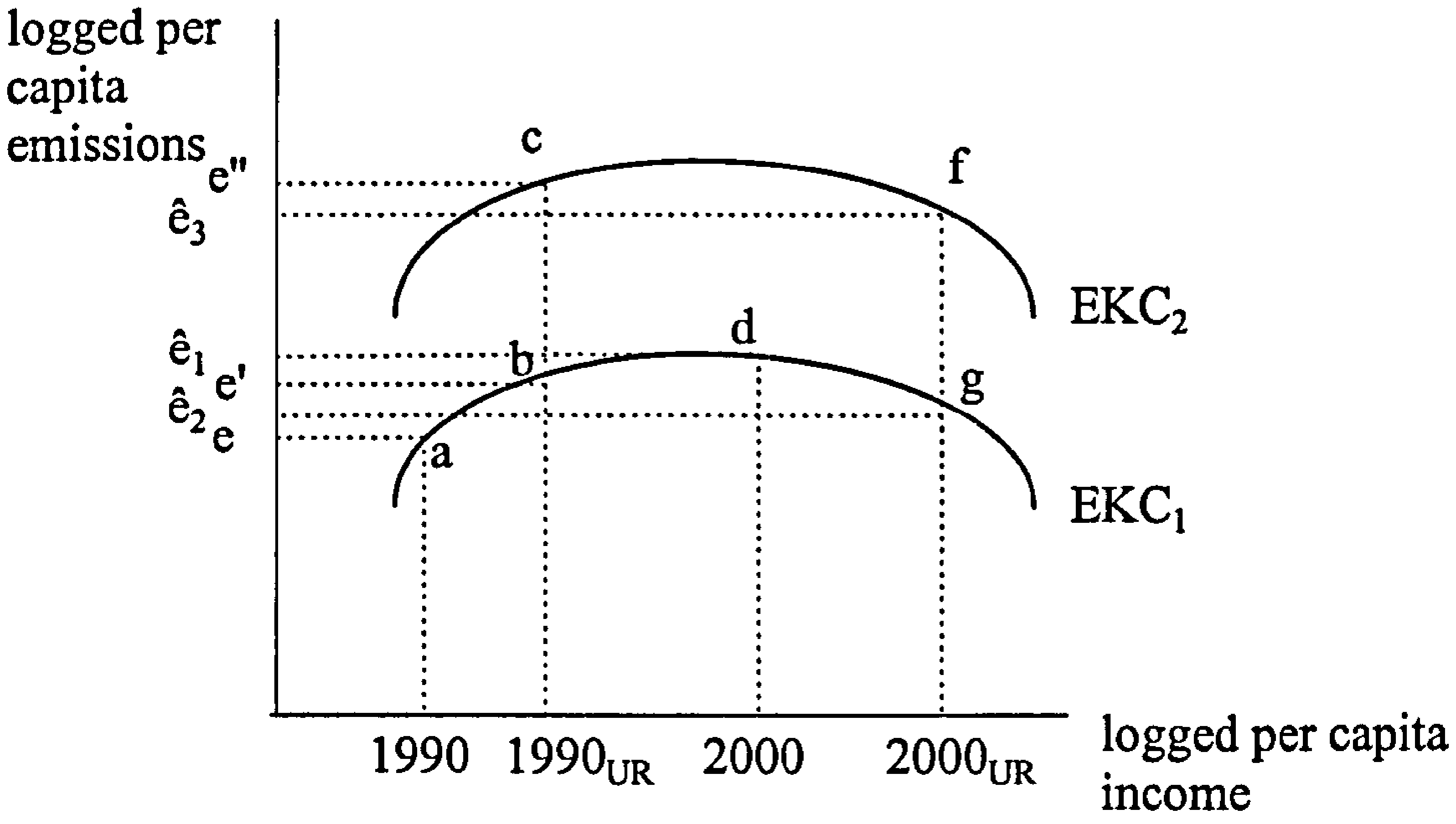
discussing scale and technique effects, Grossman and Krueger consider local air and water pollutants and illustrate that, *generally*, such pollutants follow an inverted-U shaped path. No attempt is made to estimate the size of the scale and technique effects specifically resulting from the NAFTA. This chapter actually estimates the size of the combined scale and technique effect which may result from the Uruguay Round, and does this in terms of a range of local and global indicators. By estimating the size of the composition effect *and* the combined scale and technique effects, simple aggregation provides the *total* impact of the Uruguay Round. From this, monetary estimates can be made of the likely environmental costs / savings.

7.2 Framework.

Composition effects and combined scale and technique effects are estimated using Francois *et al.*s' (1995) estimates of the impact of the Uruguay Round on regional income and sectoral production levels. The impact on the environment of the composition effect and combined scale and technique effects is estimated, firstly, using a comparative static framework. This estimates levels of pollution and energy use for 1990 with and without the Uruguay Round. Secondly, a dynamic framework estimates the difference between levels of pollution and energy use in the year 2000, with and without the Uruguay Round, if the initial 1990 income gain from the Uruguay Round has 'grown' for ten years. This dynamic framework considers both the situation where the Uruguay Round leaves the income growth rate unaffected, and the situation where the Uruguay Round results in an increase in the growth rate of income.

The EKCs in Diagram 1 provide an illustration of how composition and combined scale and technique effects may effect levels of pollution emissions.

Diagram 1. Hypothetical Environmental Kuznets Curves.



EKCs capture the environmental impact of the scale and technique effects associated.with a change in income i.e. if income increases, EKCs combine the increase in emissions resulting from an increase in the scale of production, with the decrease in emissions which occurs as individuals begin to demand a cleaner environment. Thus, if the Uruguay Round generates an increase in 1990 per capita income from 1990 to 1990_{UR}, then starting at point 'a', the combined scale and technique effect may cause a movement to point 'b' and an increase in per capita emissions from e to e'. However, this change in emissions may be offset or augmented by the composition effect associated with the Uruguay Round which, by increasing or decreasing the pollution intensity of each unit of GDP, may raise or lower the EKC. In the diagram above, the composition effect has resulted in a shift of the EKC from EKC_1 to EKC_2. Thus, there is a movement from point 'b' to point 'c' and a further increase in per capita emissions to point e''. Therefore, in the comparative static framework mentioned above, the combined scale and technique effect for 1990 results in a movement along the EKC from point 'a' to point 'b'. The composition effect then causes a shift in the curve and a movement to point 'c'. The overall environmental impact is therefore the difference between per capita emissions level e and level e".

With regard to the dynamic framework, per capita income in the absence of the Uruguay Round is represented by 2000 and in the presence of the Uruguay Round by 2000_{UR}.[2] Using the same logic as above, the combined scale and technique effect is represented by a shift from point 'd' to point 'g'. The composition effect then results in a shift to point 'f'. The overall impact on pollution for the year 2000 is therefore the difference between per capita pollution emissions with and without the Uruguay Round, that is, the difference between points $\hat{e}_1$ and $\hat{e}_3$.

7.2.1 Composition Effect.

The environmental impact of the Uruguay Round's composition effect is estimated using the results of Francois *et al.* (1995) together with the World Bank's Industrial Pollution Projection System (Hettige *et al.* (1994)). Francois *et al.* estimate the effect of the Uruguay Round on the level of production of 68 four digit ISIC manufacturing sectors in twelve countries/regions.[3] Hettige *et al.* (1994) estimate local air pollution intensities for each ISIC sector for the US in terms of pounds of pollution per million 1987 US dollars of output. These pollution intensities were estimated by merging manufacturing census data from over 200,000 factories throughout the US with US Environmental Protection Agency data on air pollution emissions. Intensities are estimated for nitrogen dioxide, sulphur dioxide, carbon monoxide and suspended particulate matter. Multiplying the output change estimated for each sector by that sector's pollution intensity provides the change in air pollution for each

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[2] Note that the position of 2000_{UR} relative to that of 2000, will depend on whether the income growth rate is affected by the Uruguay Round.

[3] The results of Francois *et al.* are given in terms of GTAP sectors which can be broken down into 4 digit ISIC sectors.

country / region resulting from the change in the composition of output.[4] This is therefore an estimate of the environmental impact of the Uruguay Round's composition effect.

As yet, Hettige *et al.* do not estimate sectoral pollution intensities for any country other than the USA. However, rather than apply US intensities to all other countries/regions, US sectoral intensities have been scaled for each country / region according to the difference between that country / region's *total* pollution intensity (for each pollutant) and that of the USA. These total pollution intensities were calculated using the estimated environmental Kuznets curves from the previous chapters. If the estimated environmental Kuznets curve is of the following form;

$$lnx_{it} = a_i + b\, lny_{it} - c\, (lny_{it})^2 + e_{it}$$

and

x_{it} = total pollution / population in country i, year t.
y_{it} = gdp / population in country i, year t.
X_{it} = total pollution in country i, year t.
Y_{it} = gdp in country/region i, year t.
N_{it} = population in country i, year t.
p_{it} = total pollution / gdp (i.e. pollution intensity) in country i, year t.

then,

$$lnX_{it} - lnN_{it} = a_i + b\, (lnY_{it} - lnN_{it}) - c\, (lny_{it})^2 + e_{it}$$

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[4] Since some GTAP sectors cover more than one ISIC sector, to obtain a pollution intensity for that GTAP sector an average of the pollution intensity of the ISIC sectors was taken, weighted by the share of each ISIC sector in each country's GDP. To enable full compatibility, the output change for each sector, and each sector's pollution intensities, have been deflated to 1985 US dollars.

$$lnX_{it} = a_i + b\ (lnY_{it} - lnN_{it}) - c\ (lny_{it})^2 + lnN_{it} + e_{it}$$

$$lnX_{it} - lnY_{it} = lnp_{it} = a_i + b\ (lnY_{it} - lnN_{it}) - c\ (lny_{it})^2 + lnN_{it} - lnY_{it} + e_{it}$$

$$lnp_{it} = a_i + (b - 1)\ (lnY_{it} - lnN_{it}) - c\ (lny_{it})^2 + e_{it}$$

$$lnp_{it} = a_i - (1 - b)\ lny_{it} - c\ (lny_{it})^2 + e_{it}$$

Thus, for example, if China's total sulphur dioxide intensity is estimated, in this manner, for 1992 and is calculated to be 50% higher than the US's total sulphur dioxide intensity, then China's *sectoral* intensities will be estimated by increasing US sectoral intensities by 50%. Whilst such a procedure clearly assumes that each country's sectoral intensities are *uniformly* higher or lower than those of the US, it is felt that such a method is far preferable to the application of US sectoral intensities to other countries without modification.

For sulphur dioxide and nitrogen dioxide, estimated intercepts in Chapters 5 and 6 are not compatible with the regions considered in Francois *et al.* (1995). As a result, pollution intensities for these pollutants stem from new regressions which have been run using UNEP (1993) data, with regression results in Appendix N. Fixed effects intercepts have not been estimated (due to a lack of data) for Latin America, Africa and Eastern Europe. Sectoral intensities for these regions are therefore scaled according to pollution intensities in East Asia, South Asia and China, respectively, due to expected similarities in pollution levels and intensities.[5]

For carbon monoxide and suspended particulate matter, estimated intercepts in Chapters 5 and 6 are also incompatible with the regions considered in Francois *et al.* (1995), and, unlike sulphur dioxide and

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[5] For example, per capita emissions of carbon dioxide in Latin America, Africa and Eastern Europe and broadly similar with those in East Asia, Africa and Eastern Europe.

nitrogen dioxide, alternative data are not available. However, since all of the EKCs estimated for local air pollutants considered in Chapters 5, 6 and Appendix N of this chapter, behave similarly and have turning points at similar income levels, it has been possible to estimate middle and low income country intercepts for carbon monoxide and suspended particulate matter emissions. This has been done by scaling down the average intercept for the OECD countries for carbon monoxide and suspended particulate matter (from Chapter 5) by the proportion that middle and low income country intercepts are lower than the average OECD intercept *for sulphur dioxide and nitrogen dioxide.*[6] European Union intercepts for carbon monoxide and suspended particulate matter are formed by taking an average of the European Union countries' intercepts in each sample.[7] These intercepts are also used for Japan. These manufactured intercepts, together with the estimated intercept for the USA and the estimated income coefficients (from Chapter 5) are reported in Appendix N. Pollution intensities for China, South Asia and Africa were calculated using the low income intercept, whilst those for East Asia, Latin America and Eastern Europe were made using the middle income intercept.

7.2.2 Combined Scale and Technique Effects.

The results of Chapter 5 together with the estimates of the Uruguay Round's contribution to regional/national income levels from Francois *et al.* (1995), are used to estimate the impact on environmental quality of the combined scale and technique effects associated with the Uruguay Round.[8, 9]

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[6] Using the sulphur dioxide and nitrogen dioxide results from Appendix N.

[7] For carbon monoxide this is an average of the intercepts for Netherlands, UK, West Germany, Denmark and France. For suspended particulate matter an average of the intercepts for Netherlands, UK, West Germany and France is taken.

[8] Some environmental indicators considered in Chapter 5 could not be analysed in this chapter since the environmental data used in Chapter 5 are reported for countries/regions which are incompatible with the countries/regions used by Francois *et al.* Other indicators could only be analysed for certain countries/regions since data did not exist for all regions and hence intercepts could not be estimated. Where data allowed, new regressions were

Referring back to Diagram 1 and using the example of the 1990 combined scale and technique effect, if the Uruguay Round generates an increase in per capita income from 1990 to 1990_{UR}, the resultant change in per capita emissions (due to combined scale and technique effects) will be e to e'. Multiplying both levels of per capita emissions by the 1990 level of population provides the level of total emissions with and without the Uruguay Round's combined scale and technique effects. The increase in per capita income is calculated using the estimated welfare gain from the Uruguay Round for each of Francois *et al.*s' regions.

In all, the environmental impact of the scale and technique effects is estimated for three scenarios: (1) for 1990, if the full effects of the Uruguay Round were in place;[10] (2) for the year 2000 if the Uruguay Round's 1990 increase in income had 'grown' for 10 years; and (3) for the year 2000 if the Uruguay Round's 1990 increase in income had 'grown' for 10 years, and per capita income growth rates were 0.5% higher due to the effects of the Uruguay Round. This link between the Uruguay Round and the actual rate of growth is raised by Francois *et al.* (1993), who cite numerous studies as evidence of the empirical link between trade liberalisation and the rate of economic growth.[11] Although unable to quantify the possible impact of the Uruguay Round on the growth rate, Francois *et al.* consider the dynamic gains associated with the Round "as potentially much more important than extant estimates of static and

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run to make the results more compatible with the countries/regions used by Francois *et al.* The results are contained in Appendix N and are very similar to the original results in Chapter 5.

[9] See Appendix L for a summary of Francois *et al.*'s' paper, and see Appendix M for a summary of their estimated income gains resulting from the Uruguay Round. This chapter uses the estimated income gains stemming from their dynamic increasing returns to scale monopolistic competition model with an endogenous savings rate since this was deemed to be their most realistic model.

[10] Francois *et al.* (1995) estimate the welfare effects of the Uruguay Round in terms of 1992 US $. These estimates have therefore been deflated to 1985 US $ to enable comparison with the estimated composition effect.

[11] e.g. Lee (1993), Matin (1993), Barro (1989) and Krueger (1978).

medium-run gains" (Francois *et al.* (1993) p.10). The choice, in this chapter, of a 0.5% addition to the rate of growth is not intended to be an estimate, but merely serves to illustrate the impact on the various environmental indicators of a change in the rate of growth.

Scenario 2 is estimated in the same manner as scenario 1. Per capita emissions are estimated for the year 2000 by allowing actual 1990 per capita income to grow in accordance with World Bank (1994) forecasts of regional per capita income growth.[12] The same is then done for 1990 per capita income when the Uruguay Round is in place. Using UNEP (1993) population forecasts the difference between total emissions in the year 2000, with and without the Uruguay Round, can then be calculated. Finally, scenario 3 uses the same method, but 1990 per capita income when the Uruguay Round is in place is allowed to grow by an additional 0.5% per annum. Again, the difference between year 2000 emissions with and without the Uruguay Round can then be calculated.

Since pollution levels without the Uruguay Round are always compared with pollution levels with the Uruguay Round *in the same year*, estimated regressions do not include a time trend.[13] Thus, unless new regressions have been performed (with results in Appendix N) the regression results used in this chapter stem from Chapter 5.

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[12] Specifically, the following growth rates are used; USA, EU, E.Europe and Japan 2%; East Asia and China 6.2%; South Asia 3.4%; Africa 0.9%; and Latin America 1.7%.

[13] i.e. 1990 pollution without the Uruguay Round is compared with 1990 pollution with the Uruguay Round and 2000 pollution without the Uruguay Round is compared with 2000 pollution with the Uruguay Round etc.

7.3 Results.

7.3.1 Composition Effect.

Given the Uruguay Round Final Agreement, Francois *et al.* (1995) predict that the largest output shocks will result from the phaseout of the Multi-Fibre Agreement (MFA). Their model indicates that the liberalisation of the MFA will result in a significant contraction of textile and clothing production in developed countries, matched by an expansion of these sectors in the developing world, particularly East and South Asia. As the Asian developing countries shift resources into textiles and clothing, the manufacturing sectors contract, particularly transport equipment, steel, non-ferrous metals and other machinery. There is therefore a concurrent expansion of these sectors in the developed economies. Growth of transport equipment production is predicted to occur largely in the USA and Canada, growth in non-ferrous metals is likely to be concentrated in Australia and New Zealand, the USA and Europe, whilst growth in other machinery and other manufactures is likely to occur in the USA, Canada and Europe. Exceptions to the above pattern are Africa and Latin America who are both predicted to expand certain manufacturing sectors.

Attention now turns to the impact of these compositional changes on air pollution. Although large changes are predicted in the output of the textile and clothing sectors, these sectors possess relatively low pollution intensities. Nevertheless, as Tables 1-4 illustrate, the contraction of these sectors has led to a reasonably large reduction in all four pollutants in the developed world, whilst pollution has risen in the developing regions as the clothing and textile sectors expand. East Asia, in particular, is predicted to experience a significant increase in air pollution due to the growth of these sectors.

Table 1. The Impact of the Composition Effect on Nitrogen Dioxide Emissions (thousand pounds).

NITROGEN DIOXIDE INDUSTRY	EU	USA	JAPAN	CHINA	EAST ASIA	SOUTH ASIA	LATIN AMERICA	AFRICA	EAST EUROPE
Processed rice	-0.4	2	17	106	-72	4	23	43	7
Meat products	-119	687	123	532	-460	16	1294	184	279
Milk products	-7	39	7	4	-8	0.1	39	4	14
Other food products	-142	748	235	1455	-1182	47	1785	571	454
Beverages and tobacco	-52	445	200	590	-292	24	572	180	186
Textiles	-30367	-51421	-8816	-32951	180231	11470	6868	2131	6209
Clothing	-451	-1124	-112	340	649	45	63	-5	37
Lumber and wood products	1330	1979	244	670	-2917	-257	699	-10	153
Pulp, paper, printing	6736	10231	740	5807	-3441	-652	3466	-44	942
Petroleum and coal products	7039	-6035	798	-2669	-6475	-1584	4144	782	1077
Chemicals, rubber and plastics	13478	42189	2923	-3578	-8323	-9192	-4738	2365	4098
Iron and steel basic industries	13294	8573	16042	-12973	-137967	-18859	22094	-2015	11185
Non-ferrous metals basic industries	3513	5790	668	-2207	-7259	-417	260	-193	-1495
Fabricated metal products	1276	3501	472	-689	-2465	-128	-577	-29	-213
Transport equipment	444	3419	-166	-808	-2423	-133	-596	111	-154
Other machinery	7298	8870	1375	-10524	-11989	-698	-2427	-689	-1780
Other manufactures	318	339	187	-673	-1182	-33	14	3	-87
total (thou. pnds.) =	**23586**	**28231**	**14938**	**-57569**	**-5574**	**-20345**	**32984**	**3389**	**20912**
total (tonnes) =	**10698**	**12805**	**6776**	**-26113**	**-2528**	**-9229**	**14961**	**1537**	**9485**
percentage =	**0.1**	**0.1**	**0.3**	**-0.3**	**-0.1**	**-0.5**	**0.6**	**0.2**	**0.2**

Table 2. The Impact of the Composition Effect on Sulphur Dioxide Emissions (thousand pounds).

SULPHUR DIOXIDE	EU	USA	JAPAN	CHINA	EAST ASIA	SOUTH ASIA	LATIN AMERICA	AFRICA	EAST EUROPE
INDUSTRY									
Processed rice	-0.4	3	23	261	-148	4	46	44	18
Meat products	-9	67	13	102	-74	1	207	15	54
Milk products	-4	28	5	6	-9	0.1	46	2	19
Other food products	-175	1473	482	4534	-4370	87	6371	620	1500
Beverages and tobacco	-65	701	393	1802	-858	35	1572	195	619
Textiles	-17383	-39968	-7355	-48624	218890	6939	8380	1264	9603
Clothing	-883	-2998	-316	1787	2828	97	275	-11	197
Lumber and wood products	536	1098	144	665	-2342	-103	581	-4	166
Pulp, paper, printing	9237	18340	1345	21483	-10096	-952	10256	-59	3474
Petroleum and coal products	8892	-10357	1455	-8465	-18263	-2226	11706	1062	3658
Chemicals, rubber and plastics	10276	44756	2941	-6045	-14965	-8232	-9380	2544	8401
Iron and steel basic industries	22463	19737	39190	-58938	-519337	-35358	83167	-3778	50813
Non-ferrous metals basic industries	79150	177743	21754	-133690	-364336	-10416	13062	-4815	-90574
Fabricated metal products	262	1058	146	-456	-1375	-35	-299	-6	-117
Transport equipment	719	6783	-364	-3028	-8419	-230	-1928	216	-673
Other machinery	10456	17717	3078	-17825	-40428	-1172	-7111	-738	-6859
Other manufactures	289	459	125	-756	-1623	-23	57	4	-214
total (thou. pnds.)=	**123762**	**236640**	**63058**	**-247188**	**-764926**	**-51584**	**117007**	**-3446**	**-19915**
total (tonnes)=	**56137**	**107337**	**28602**	**-112122**	**-346963**	**-23398**	**53073**	**-1563**	**-9033**
percentage=	**0.3**	**0.4**	**2.0**	**-1.8**	**-4.0**	**-0.6**	**0.5**	**-0.08**	**-0.07**

Table 3. The Impact of the Composition Effect on Carbon Monoxide Emissions (thousand pounds).

CARBON MONOXIDE	EU	USA	JAPAN	CHINA	EAST ASIA	SOUTH ASIA	LATIN AMERICA	AFRICA	EAST EUROPE
INDUSTRY									
Processed rice	-0.1	0.4	3	21	-14	1	4	8	1
Meat products	-30	172	31	133	-115	4	323	46	70
Milk products	-1	7	1	1	-1	0.02	7	1	2
Other food products	-56	227	81	618	-364	15	561	272	179
Beverages and tobacco	-5	44	23	66	-35	3	56	13	19
Textiles	-4306	-7312	-1292	-4646	25061	1595	956	288	885
Clothing	-113	-281	-28	85	162	11	16	-1	9
Lumber and wood products	3260	4827	596	1671	-7228	-638	1721	-23	375
Pulp, paper, printing	14378	20991	1467	12447	-7178	-1359	7157	-83	2011
Petroleum and coal products	6221	-5301	703	-2020	-5752	-1407	3692	645	952
Chemicals, rubber and plastics	17976	68668	4358	-4754	-11308	-12489	-11605	4718	5466
Iron and steel basic industries	47691	30758	57551	-46541	-494962	-67658	79264	-7229	40125
Non-ferrous metals basic industries	50161	82681	9536	-31513	-103651	-5950	3716	-2750	-21350
Fabricated metal products	2158	7251	824	-1906	-7136	-370	-1345	-36	-360
Transport equipment	339	4198	-180	-426	-2042	-105	-791	44	-118
Other machinery	10074	13342	1803	-21258	-16982	-989	-3374	-1231	-2458
Other manufactures	90	123	58	-191	-329	-9	8	2	-25
total (thou. pnds) =	**147838**	**220395**	**75535**	**-98217**	**-631875**	**-89344**	**80366**	**-5316**	**25785**
total (tonnes) =	**67058**	**99969**	**34262**	**-44550**	**-286612**	**-40526**	**36453**	**-2411**	**11696**
percentage =	**0.2**	**0.1**	**0.3**	**-0.1**	**-1.9**	**-0.5**	**0.20**	**-0.05**	**0.07**

Table 4. The Impact of the Composition Effect on Suspended Particulate Matter Emissions (thousand pounds).

SUSP.PART.MATTER	EU	USA	JAPAN	CHINA	EAST	SOUTH	LATIN	AFRICA	EAST
INDUSTRY					ASIA	ASIA	AMERICA		EUROPE
Processed rice	-2	8	111	1286	-729	20	228	215	87
Meat products	-2	19	4	29	-21	0	59	4	15
Milk products	-2	14	3	3	-5	0	24	1	10
Other food products	-151	1307	421	3856	-4281	86	5994	480	1313
Beverages and tobacco	-3	32	24	49	-42	2	90	9	34
Textiles	-3815	-8867	-1661	-9518	42194	1338	1644	229	2130
Clothing	-27	-94	-10	56	88	3	9	0	6
Lumber and wood products	1463	3027	395	1914	-6948	-305	1700	-12	458
Pulp, paper, printing	1794	3591	266	4224	-1997	-188	2009	-12	682
Petroleum and coal products	1096	-1400	190	-3247	-2118	-258	1301	255	456
Chemicals, rubber and plastics	1862	8405	555	-1163	-2694	-1482	-1898	525	1539
Iron and steel basic industries	5148	4573	9081	-13657	-120337	-8193	19271	-875	11774
Non-ferrous metals basic industries	6576	14929	1827	-11229	-30602	-875	1097	-404	-7608
Fabricated metal products	133	586	71	-287	-876	-23	-170	-3	-60
Transport equipment	251	2721	-161	-1475	-3298	-90	-965	66	-238
Other machinery	1342	2401	335	-6981	-5103	-148	-1007	-186	-890
Other manufactures	141	285	77	-533	-895	-12	18	1	-106
total (thou. pnds.) =	**15802**	**31537**	**11526**	**-36672**	**-137664**	**-10127**	**29404**	**295**	**9603**
total (tonnes) =	**7168**	**14305**	**5228**	**-16634**	**-62443**	**-4593**	**13337**	**134**	**4356**
percentage =	**0.2**	**0.2**	**0.3**	**-0.9**	**-3.0**	**-0.4**	**0.4**	**0.02**	**0.07**

In contrast, many of the heavy industry sectors possess large pollution intensities with iron and steel and non-ferrous metals generating large volumes of sulphur dioxide and carbon monoxide in particular. Typically, the direction of the output change in these sectors dictates whether the region as a whole will experience an *overall* increase or decrease in pollution, as a result of compositional changes. The predicted expansion of heavy industry in the developed economies is, thus, likely to raise total compositional pollution for these regions, for all four pollutants. Conversely, most developing regions are predicted to experience a fall in total compositional pollution due to the contraction of heavy industry.

Several exceptions are worth noting, however. Of the developing economies, Latin America is predicted to experience an *increase* in total compositional pollution, for all four pollutants, due to an estimated increase in both iron and steel and non-ferrous metal production, despite contractions in other heavy industries. For nitrogen dioxide and suspended particulate matter, Africa and Eastern Europe are also predicted to experience an overall increase in total compositional output, whilst Eastern Europe is also predicted a similar increase for carbon monoxide. For Africa and Eastern Europe, these predicted increases in pollution are due to an increase in production in certain heavy industries which more than compensate for the contraction of the iron and steel and non-ferrous metals sectors. This same compensation did not occur for sulphur dioxide due to the very large sulphur dioxide pollution intensities associated with these two sectors.

Estimates of total compositional pollution are expressed in both thousand pounds and tonnes and have been expressed as a percentage of each region's total emissions in 1992. The largest absolute *decrease* in total emissions as a result of compositional change occurs in East Asia for sulphur dioxide, carbon monoxide and suspended particulate matter and in China for nitrogen dioxide. The contraction of sulphur dioxide in East Asia is equivalent to 4.0% of total sulphur dioxide emissions. The estimated reduction in pollution in East Asia is due to the contraction of heavy industry in this region, which is not compensated by the increase in pollution stemming from the expanding textiles and clothing sectors. The largest absolute *increases* in total emissions occur in the United States for sulphur dioxide, carbon monoxide and suspended particulate matter and in Latin America for nitrogen dioxide. For both regions this is due to the expansion of heavy industry.

7.3.2 Combined Scale and Technique Effects.

(i) Nitrogen Dioxide Emissions.

Table 5 presents the likely changes in nitrogen dioxide emissions resulting from the Uruguay Round, for the three different scenarios, given Francois *et al.s'* estimates of the Round's income effects. [14] Estimates are expressed in tonnes and as percentages of total emissions.[15] These estimates stem from a new regression which uses UNEP (1993) nitrogen dioxide emissions data. These data cover a wider range of countries than the OECD data, thereby allowing the estimation of intercepts for more countries or regions than was previously possible, although observations exist for only four years.[16] The results of this regression can be found in Appendix N. For both nitrogen dioxide and sulphur dioxide, estimations for Latin America and Eastern Europe were made using East Asia's fixed effects intercept, whilst estimations for Africa were made using South

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[14] From their increasing returns, monopolistic competition model.

[15] All percentages illustrate how much higher that year's estimated emissions are with the Uruguay Round in place, compared with the same year's estimated emissions in the absence of the Uruguay Round.

[16] Observations are for 1975, 1980, 1985 and 1990

Asia's intercept. Table 5 outlines the impact of scale and technique effects on nitrogen dioxide emissions, for all three scenarios.

Table 5. The Impact of Combined Scale and Technique Effects on Nitrogen Dioxide Emissions (tonnes and % of total emissions).

NITROGEN DIOXIDE	Scenario 1. 1990		Scenario 2. 2000		Scenario 3. 2000 + 0.5%	
EU	25,277	0.19%	17,826	0.12%	134,168	0.93%
USA	10,688	0.05%	-7,998	-0.03%	-73,226	-0.29%
Japan	3,212	0.14%	1,918	0.06%	11,396	0.34%
China	133,874	1.57%	236,529	1.23%	1,205,334	6.29%
East Asia	63,886	2.04%	73,398	1.36%	220,232	4.09%
South Asia	18,181	0.98%	34,297	0.92%	245,887	6.58%
Africa	18,971	2.02%	37,174	1.83%	157,998	7.76%
Latin America	36,203	0.92%	43,095	0.73%	217,038	3.68%
E.Europe	3,565	0.06%	3,415	0.05%	130,013	1.99%
GLOBAL	314,601	0.52%	439,654	0.50%	2,248,840	2.56%

With regard to the developed world, the results indicate that there will be a modest increase in nitrogen dioxide emissions in the European Union and Japan for all three scenarios. It is estimated that North America would also experience an increase in emissions in 1990, had the Uruguay Round been in place, but by the year 2000 per capita income levels will be sufficiently high to ensure a decrease in nitrogen dioxide emissions.

The results for the developing world suggest moderate increases in nitrogen dioxide emissions for all three scenarios, for all regions. Asia and Africa look likely to be the worst affected, with emissions increasing by up to 6% or 7% by the year 2000 if the Uruguay Round contributes 0.5% to growth rates. Global nitrogen dioxide emissions are predicted to increase by little over 0.5% if growth rates are unaffected, or by over 2.5% if the latter increase by 0.5%.

(ii) Sulphur Dioxide Emissions.

Estimates are in tonnes and percentages of total emissions. As with nitrogen dioxide, these estimates stem from a new regression which uses UNEP (1993) sulphur dioxide emissions data. The results of this regression can be found in Appendix N. Table 6 provides the estimated impact of combined scale and technique effects on sulphur dioxide emissions.

Table 6. The Impact of Combined Scale and Technique Effects on Sulphur Dioxide Emissions (tonnes and % of total emissions).

SULPHUR DIOXIDE	**Scenario 1. 1990**		**Scenario 2. 2000**		**Scenario 3. 2000 + 0.5%**	
EU	-63,852	-0.39%	-80,780	-0.54%	-658,453	-4.39%
USA	-210,288	-0.66%	-226,719	-0.77%	-1,580,050	-5.37%
Japan	-9,014	-0.64%	-13,103	-0.80%	-93,287	-5.75%
China	130,458	2.13%	225,395	1.38%	1,138,536	6.95%
East Asia	156,222	1.78%	142,832	1.28%	426,213	3.81%
South Asia	54,178	1.33%	105,249	1.12%	752,214	7.97%
Africa	55,294	2.81%	114,753	2.29%	487,239	9.72%
Latin America	70,603	0.66%	51,700	0.37%	264,222	1.91%
E.Europe	380	0.003%	-8,628	-0.07%	-145,264	-1.13%
GLOBAL	135,711	0.15%	310,699	0.27%	591,370	0.52%

Sulphur dioxide emissions are predicted to fall in all developed regions, for all three scenarios, due to the fact that per capita income levels in these regions now exceed that of the estimated turning point. The opposite is true in the developing world, with all regions predicted to experience moderate increases in sulphur dioxide emissions. Asia is estimated to experience the largest absolute increase in emissions, whilst Africa looks set to experience the largest percentage increase.

Global emissions are predicted to increase only moderately, the estimated increase in sulphur dioxide emissions in the developing world having been offset, to an extent, by the reduction in emissions in the developed world.

(iii) Carbon Monoxide Emissions.

Table 7 outlines the estimated impact of combined scale and technique effects on carbon monoxide emissions for each scenario. Estimates are expressed in tonnes and as a percentage of total emissions and were calculated using the regression results in Appendix N.

Table 7. The Impact of Combined Scale and Technique Effects on Carbon Monoxide Emissions (tonnes and % of total emissions).

CARBON MONOXIDE	Scenario 1. 1990		Scenario 2. 2000		Scenario 3. 2000 + 0.5%	
EU	-195,671	-0.34%	-247,550	-0.48%	-2,017,799	-3.91%
USA	-690,409	-0.57%	-735,466	-0.64%	-5,107,152	-4.44%
Japan	-131,383	-0.99%	-201,877	-1.52%	-1,427,120	-10.74%
China	613,486	1.81%	1,058,229	1.67%	5,367,021	8.47%
East Asia	295,918	1.93%	270,553	1.76%	807,336	5.25%
South Asia	107,156	1.27%	205,854	1.22%	1,507,650	8.94%
Africa	109,362	2.44%	221,568	2.31%	965,126	10.06%
Latin America	147,802	0.81%	116,796	0.52%	551,393	2.45%
E.Europe	26,767	0.15%	48,195	0.22%	629,186	2.90%
GLOBAL	339,402	0.11%	736,302	0.22%	1,275,641	0.39%

Table 7 indicates that the developed regions are expected to experience a decrease in carbon monoxide emissions as a result of combined scale and technique effects. In contrast, all other regions are likely to suffer from increased emissions. The USA is predicted to experience the largest absolute fall in emissions whilst Japan may benefit from the largest percentage fall. Conversely, it is estimated that the largest absolute increase in carbon monoxide emissions will occur in China, and the largest percentage increase will be in Africa.

Global emissions are estimated to increase only moderately as a result of combined scale and technique effects as the increased emissions in the developing and transition regions are largely offset by the falling emissions in the developed world.

(iv) Suspended Particulate Matter Emissions.

Table 8, below, provides the estimated impact of combined scale and technique effects on suspended particulate matter emissions, for each scenario, calculated using the regression results in Appendix N. Estimates are expressed in tonnes and as a percentage of total emissions.

Emissions of suspended particulate matter as a result of combined scale and technique effects follow the same pattern as sulphur dioxide emissions and differ from carbon monoxide emissions only in the fact that emissions of suspended particulate matter in Eastern Europe fall for scenarios 2 and 3. Thus emissions are set to fall in the developed world and increase in the developing regions, whilst in Eastern Europe emissions increase in scenario 1 but fall by the year 2000 (scenarios 2 and 3). The largest absolute and percentage fall in emissions occurs in the USA, whilst the largest absolute and percentage increase in emissions occurs in China.

Table 8. The Impact of Combined Scale and Technique Effects on Suspended Particulate Matter Emissions (tonnes and % of total emissions).

SUSP.PART. MATTER	**Scenario 1. 1990**		**Scenario 2. 2000**		**Scenario 3. 2000 + 0.5%**	
EU	-14,533	-0.26%	-18,386	-0.44%	-149,869	-3.58%
USA	-59,577	-0.79%	-63,466	-1.01%	-440,714	-7.08%
Japan	-9,852	-0.54%	-13,522	-0.64%	-96,197	-4.55%
China	37,306	1.99%	63,759	1.86%	341,191	9.95%
East Asia	36,237	1.71%	33,131	1.23%	98,863	3.67%
South Asia	14,502	1.37%	27,284	1.33%	205,329	10.01%
Africa	14,800	2.67%	30,122	2.49%	129,921	10.74%
Latin America	18,099	0.59%	15,373	0.46%	78,571	2.35%
E.Europe	186	0.002%	-4,235	-0.06%	-71,332	-1.01%
GLOBAL	36,058	0.12%	70,060	0.24%	95,763	0.32%

Again, global emissions increase only moderately due to the substantial fall in emissions in the developed world, which partially compensates for the increased emissions in the developing regions.

(v) Carbon Dioxide Emissions.

Table 9, below, provides the estimated impact of the Uruguay Round on carbon dioxide emissions for each scenario. Estimates are in thousands of tonnes of carbon, and as percentages of total emissions.

Table 9. The Impact of Combined Scale and Technique Effects on Carbon Dioxide Emissions (thousands of tonnes and % of total emissions).

CARBON DIOXIDE	**Scenario 1. 1990**		**Scenario 2. 2000**		**Scenario 3. 2000 + 0.5%**	
EU	3,796	0.37%	8,847	0.33%	27,936	2.42%
USA	5,256	0.33%	5,289	0.29%	33,100	1.80%
Japan	1,145	0.37%	1,478	0.32%	10,417	2.28%
China	6,169	1.44%	11,342	1.22%	58,013	6.24%
Asia	20,283	1.61%	38,450	1.39%	168,766	6.09%
Africa	3,092	1.78%	6,098	1.73%	25,963	7.36%
Latin America	2,731	1.02%	3,750	0.90%	19,131	4.59%
E.Europe	534	0.08%	626	0.08%	24,388	3.11%
GLOBAL	31,111	0.51%	64,538	0.70%	309,701	3.34%

It is clear that carbon dioxide emissions are estimated to experience a small to moderate increase, depending on the scenario, in all regions. For all scenarios, the largest absolute increase in emissions is expected to occur in Asia, where total emissions are estimated to increase by over 160,000 tonnes (6.09%) for scenario 3. The largest percentage increase in emissions is predicted to occur in Africa. Globally, emissions increase by at least 0.5%, or by as much as 3.34% if the growth rate of per capita income increase by 0.5%.

(vi) Municipal Waste.

Table 10, below, presents the estimated impact of the Uruguay Round, in terms of municipal waste, for the European Union, North America and Oceania respectively. Estimates are expressed in thousands of tonnes and as percentages of total waste generated.

Table 10. The Impact of Combined Scale and Technique Effects on the Generation of Municipal Waste (thousands of tonnes and % of total waste).

MUNICIPAL WASTE	Scenario 1. 1990		Scenario 2. 2000		Scenario 3. 2000 + 0.5%	
EU	531	0.42%	1,057	0.69%	9,128	5.96%
USA	2,376	1.19%	4,611	1.51%	34,778	11.4%
Oceania	470	0.73%	946	1.03%	7,512	8.21%

All regions are predicted to experience an increase in municipal waste generation, with the largest increase occuring in North America.

(vii) Total Energy Consumption.

Table 11 presents the estimated impact of the Uruguay Round on total energy use. Estimates are expressed in million tonnes of oil equivalent and as percentages of total energy use. These results stem from a different regression to those estimated in Chapters 5 and 6, as data have been aggregated into regions which are more compatible with the results of Francois *et al.* Appendix N contains the regression results.

Table 11. The Impact of Combined Scale and Technique Effects on Total Energy Consumption (MTOE and % of total energy consumption).

TOTAL ENERGY	Scenario 1. 1990		Scenario 2. 2000		Scenario 3. 2000 + 0.5%	
EU	2.89	0.29%	2.76	0.25%	21.8	1.98%
USA	3.52	0.23%	3.16	0.18%	21.47	1.19%
Oceania	1.02	0.28%	1.03	0.23%	7.51	1.66%
Asia	13.31	1.47%	23.23	1.24%	101.35	5.41%

All regions are predicted to experience an increase in total energy use, although this increase is expected to be largest in Asia. Not surprisingly, predicted changes in carbon dioxide in Table 9 can be seen to closely mimic these estimated changes in energy use.

The Transport Sector

(viii) Energy Use from the Transport Sector.

The Uruguay Round's estimated impact on energy use by the transport sector is presented in Table 12. Estimates are expressed in million tonnes of oil equivalent and as percentages of total energy use by the transport sector. As with total energy use, these results stem from a new regression which uses data aggregated into regions which are more compatible with those used by Francois *et al.* The results of this regression can be found in Appendix N.

Table 12. The Impact of Combined Scale and Technique Effects on Energy Use by the Transport Sector (MTOE and % of total energy use from transport).

TRANSPORT ENERGY	Scenario 1. 1990		Scenario 2. 2000		Scenario 3. 2000 + 0.5%	
EU	2.28	0.77%	2.96	0.77%	24.43	6.38%
USA	5.63	0.9%	7.77	0.9%	56.0	6.52%
Oceania	1.39	0.84%	1.99	0.85%	15.13	6.46%
Asia	2.66	1.54%	6.16	1.59%	27.28	7.02%

It can be seen from Table 12 that the largest estimated absolute increase in transport generated energy use occurs in the USA, whilst the largest percentage increase is predicted to occur in Asia.

(ix) Traffic Volumes.

Table 13 contains the estimated impact of the Uruguay Round on total traffic volumes. Estimates are expressed in millions of kilometres travelled by road vehicles and as percentages of total traffic volumes. The results stem from a new regression which uses data aggregated into regions which are more compatible with those used by Francois *et al.*

Table 13. The Impact of Combined Scale and Technique Effects on Traffic Volumes (millions of kilometres and % of total traffic volumes).

TRAFFIC VOLUMES	Scenario 1. 1990		Scenario 2. 2000		Scenario 3: 2000 + 0.5%	
EU	17,893	0.83%	21,445	0.77%	175,015	6.2%
USA	28,787	0.79%	34,442	0.71%	243,397	5.04%
Oceania	6,681	0.84%	8,596	0.77%	64,467	5.77%
Asia	7,938	3.05%	27,200	2.71%	122,061	12.14%

As with transport generated energy use, the largest absolute increase in traffic volumes is estimated to occur in the USA, whilst Asia is predicted to experience the largest percentage increase.

7.3.3 Combining Composition *and* Scale and Technique Effects.

Since both composition effects *and* combined scale and technique effects have been calculated for sulphur dioxide, nitrogen dioxide, carbon monoxide and suspended particulate matter, it is possible to aggregate the two effects to estimate the overall impact of the Uruguay Round on these pollutants. Thus, the combined scale and technique effect is added to (subtracted from) the composition effect. Estimates are expressed in tonnes and as percentages of total emissions.

Table 14. The Estimated Impact of the Uruguay Round on Nitrogen Dioxide Emissions (tonnes and % of total emissions).

NITROGEN DIOXIDE	Scenario 1. 1990		Scenario 2. 2000		Scenario 3. 2000 + 0.5%	
EU	35,911	0.27%	28,524	0.19%	144,866	0.98%
USA	23,493	0.11%	4,807	0.02%	-60,421	-0.23%
Japan	9,988	0.43%	8,694	0.27%	18,172	0.57%
China	118,459	1.39%	210,416	1.09%	1,179,221	6.13%
East Asia	59,960	1.91%	70,870	1.31%	217,704	4.03%
South Asia	8,952	0.48%	25,068	0.67%	236,658	6.35%
Africa	20,508	2.18%	38,711	1.91%	159,535	7.85%
Latin America	59,435	1.51%	58,056	0.98%	231,999	3.99%
E.Europe	13,050	0.22%	12,900	0.19%	139,498	2.04%
GLOBAL	349,756	0.64%	458,046	0.52%	2,267,232	2.58%

It can be seen that all regions are estimated to experience an increase in nitrogen dioxide emissions as a result of the Uruguay Round, with the exception of the USA for scenario 3. China is estimated to experience the largest *absolute* increase in emissions even though the large scale and technique effect is partially offset by a negative composition effect, whilst Africa is predicted to suffer from the largest *percentage* increase. Both East Asia and South Asia benefit from negative composition effects which reduce, to an extent, the positive combined scale and technique effects. The EU, Africa and Latin America all suffer from composition effects and combined scale and technique effects which are both positive. This is also true for the USA for scenario 1, although for scenarios 2 and 3 the combined scale and technique effects are negative.

Table 15. The Estimated Impact of the Uruguay Round on Sulphur Dioxide Emissions (tonnes and % of total emissions).

SULPHUR DIOXIDE	Scenario 1. 1990		Scenario 2. 2000		Scenario 3. 2000 + 0.5%	
EU	-7,715	-0.04%	-24,643	-0.16%	-602,316	-4.03%
USA	-102,951	-0.32%	-119,382	-0.41%	-1,472,713	-5.01%
Japan	19,588	1.38%	15,499	0.95%	-64,685	-3.95%
China	18,336	0.3%	113,273	0.69%	1,026,414	6.28%
East Asia	-190,741	-2.17%	-204,131	-1.83%	79,250	0.71%
South Asia	30,780	0.75%	81,851	0.87%	728,816	7.76%
Africa	53,731	2.73%	113,190	2.26%	485,676	9.69%
Latin America	123,676	1.16%	104,773	0.75%	317,295	2.27%
E.Europe	- 8,653	-0.07%	-17,661	-0.14%	-154,297	-1.25%
GLOBAL	- 63,949	-0.07%	62,769	0.05%	343,440	0.30%

Both the European Union and the USA are predicted to benefit from a reduction in sulphur dioxide emissions as a result of the Uruguay Round, with both regions experiencing large negative combined scale and technique effects which more than offset the positive composition effect. Surprisingly, Japan is predicted to suffer an increase in emissions for scenarios 1 and 2 as a result of a large, positive composition effect which is larger than the negative combined scale and technique effect. In scenario 3, per capita income is sufficient to ensure that the negative scale and technique effects outweigh the positive composition effect. China is predicted to experience only a modest increase in emissions, for scenarios 1 and 2 at least, since the large positive combined scale and technique effect are almost entirely removed by a negative composition effect. In scenarios 1 and 2, the largest fall in emissions is estimated to occur in East Asia due to an extremely large negative composition effect which outweighs a reasonably large positive combined scale and technique effect.

In scenario 3, the combined scale and technique effect has become large enough to overcome the negative composition effect - resulting in a net increase in sulphur dioxide emissions. Both South Asia and Africa are estimated to experience an increase in emissions even though a negative composition effect weakens a positive scale and technique effect. Africa is predicted to suffer the largest percentage increase in emissions. For scenario 1, Latin America is predicted to experience the largest absolute increase in emissions since both the composition effect and the combined scale and technique effect are positive. China suffers the largest absolute increase in emissions in scenarios 2 and 3. As with carbon monoxide and suspended particulate matter, the very small global figure reflects the fact that the decreases in emissions in the USA and the European Union are offset by increasing emissions in the developing world.

Table 16. The Estimated Impact of the Uruguay Round on Carbon Monoxide Emissions (tonnes and % of total emissions).

CARBON MONOXIDE	Scenario 1. 1990		Scenario 2. 2000		Scenario 3. 2000 + 0.5%	
EU	- 128,613	-0.22%	-180,492	-0.35%	-1,950,741	-3.78%
USA	- 590,440	-0.48%	-635,497	-0.55%	-5,007,183	-4.36%
Japan	- 97,121	-0.73%	-167,615	-1.26%	-1,392,858	-10.49%
China	568,936	1.68%	1,013,679	1.60%	5,322,471	8.40%
East Asia	9,306	0.06%	-16,059	-0.10%	520,724	3.39%
South Asia	66,630	0.79%	165,258	0.98%	1,467,124	8.69%
Africa	106,951	2.39%	219,157	2.28%	962,715	10.04%
Latin America	184,255	1.01%	153,249	0.68%	587,846	2.62%
E.Europe	38,463	0.22%	59,891	0.27%	640,882	2.93%
GLOBAL	158,367	0.06%	611,571	0.18%	1,150,980	0.34%

The European Union, the USA and Japan benefit from negative combined scale and technique effects which by far outweigh positive composition effects, and therefore are estimated to enjoy a reduction of carbon monoxide emissions for all scenarios. China, East Asia, South Asia and Africa all experience a negative composition effect which is outweighed by a larger positive combined scale and technique effect, with the exception of scenario 2, in which East Asia's negative composition effect is larger than its positive combined scale and technique effect. Latin America and East Europe suffer from composition and combined scale and technique effects which are both positive. The USA experiences the largest absolute fall in emissions, whilst Japan benefits from the largest percentage decrease. China suffers the largest absolute increase in emissions and Africa the largest percentage increase.

Table 17. The Estimated Impact of the Uruguay Round on Suspended Particulate Matter Emissions (tonnes and % of total emissions).

SUSP.PART MATTER	Scenario 1. 1990		Scenario 2. 2000		Scenario 3. 2000 + 0.5%	
EU	- 7,365	-0.13%	-11,218	-0.27%	-142,701	-3.42%
USA	- 45,272	-0.60%	-49,161	-0.78%	-426,409	-6.79%
Japan	- 4,354	-0.24%	-8,294	-0.39%	-90,969	-4.31%
China	20,672	1.10%	47,125	1.37%	324,557	9.46%
East Asia	-26,206	-1.24%	-29,312	-1.09%	36,420	1.35%
South Asia	9,909	0.94%	22,691	1.11%	200,736	9.79%
Africa	14,934	2.7%	30,256	2.50%	130,055	10.75%
Latin America	31,436	1.02%	28,710	0.86%	91,908	2.75%
E.Europe	4,542	0.07%	121	0.002%	-66,976	-0.95%
GLOBAL	- 1,704	-0.0005%	30,918	0.11%	56,621	0.19%

The developed world is again estimated to experience a fall in emissions as a result of a large negative combined scale and technique effect which more than offsets a positive composition effect. The Asian regions experience negative composition effects which, for China and South Asia, are outweighed by large positive combined scale and technique effects. For East Asia, the negative composition effect is significantly larger than the positive combined scale and technique effects, resulting in a net decrease in emissions. Latin America, Africa and Eastern Europe all suffer from both positive composition and scale and technique effects. The USA experiences the largest absolute decrease in emissions as well as, for scenario 3, the largest percentage decrease. For scenarios 2 and 3, East Asia is estimated to benefit from the largest percentage decrease in suspended particulate matter emissions. In contrast, the largest absolute increase in emissions occurs in Latin America for scenario 1, and China for scenarios 2 and 3. The largest percentage increase is estimated to occur in Africa for all scenarios.

7.3.4 A Monetary Evaluation of Increased / Decreased Environmental Damage.

It is possible to provide monetary estimates of the impact of the Uruguay Round (from both composition effects *and* combined scale and technique effects) on nitrogen dioxide, sulphur dioxide, carbon monoxide and suspended particulate matter emissions. For carbon dioxide, monetary estimates are possible only for combined scale and technique effects, since composition effects have not been estimated.

Monetary estimates of the damage resulting from one tonne of nitrogen dioxide, sulphur dioxide, carbon monoxide and suspended particulate matter have been made by several authors.[17] These estimates are generally made by estimating the likely impact of a tonne of pollution, on the locale in which it is emitted, in terms of factors such as the cost of resultant illness amongst the population exposed to the pollution; the cost of

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[17] See, for example, PACE (1990) and Pearce (1993).

mortality; and damage to buildings. Fankhauser (1995) uses estimates of \$5,000 for each tonne of nitrogen dioxide and \$2,500 for each tonne of sulphur dioxide. For each tonne of carbon monoxide and suspended particulate matter, Pearce (1993) uses estimates of \$15.23 and \$14,283, respectively (converted to 1990 US dollars). These figures, although stemming from site specific estimates, are used for all developed regions (EU, USA and Japan) in the absence of any superior information. Following Fankhauser, to obtain damage cost estimates for the developing regions, these figures are scaled according to differences in income. Specifically, Fankhauser estimates damage costs in middle income and low income regions to be one-fifth and one-tenth of those in developed regions, respectively.

For nitrogen dioxide, the resultant damage costs per tonne of emissions are \$5,000 for the developed regions, \$1,000 for the middle income regions (East Asia, Latin America and Eastern Europe) and \$500 for the remaining low income regions.

Table 18, below, indicates that all regions are estimated to suffer a monetary cost of many millions of dollars due to increased nitrogen dioxide emissions, with the exception of the USA for scenario 3. The cost for each region (and hence the global cost) becomes particularly large once the growth rate has been increased in scenario 3.

Table 18. The Monetary Cost of the Increase in Nitrogen Dioxide Emissions - Based on Table 14 (millions US $).

NITROGEN DIOXIDE	Scenario 1. 1990	Scenario 2. 2000	Scenario 3. 2000 +0.5%
European Union	179.5	142.6	724.3
USA	117.4	24.0	-302.1
Japan	49.9	43.5	90.9
China	59.2	105.2	589.6
East Asia	59.9	70.9	217.7
South Asia	4.4	12.5	118.3
Africa	10.2	19.4	79.8
Latin America	59.4	58.1	232.0
Eastern Europe	13.1	12.9	139.5
GLOBAL	553	489	1,890

Similarly, Fankhauser provides estimates of sulphur dioxide damage of $2,500 for the developed world, $500 for middle income countries and $250 for less developed countries. It should be noted, however, that estimates for both nitrogen dioxide and sulphur dioxide do not take into account the damage from acid rain and therefore may understate the value of total damage caused.

For sulphur dioxide, the large weighting received by emissions in the developed world results in large, monetary savings. As a result, although the developing and transition regions are estimated to suffer a monetary cost, globally, a significant monetary saving is estimated.

Table 19. The Monetary Cost / Saving from the Change in Sulphur Dioxide Emissions - Based on Table 15 (millions US $).

SULPHUR DIOXIDE	Scenario 1. 1990	Scenario 2. 2000	Scenario 3. 2000 +0.5%
European Union	- 19.2	-61.6	-1,505.8
USA	- 257.3	-298.5	-3,681.8
Japan	49.0	38.7	-161.7
China	4.5	28.3	256.6
East Asia	- 95.3	-102.0	39.6
South Asia	7.6	20.5	182.2
Africa	13.4	28.3	121.4
Latin America	61.8	52.4	158.6
Eastern Europe	-4.3	-8.8	-77.1
GLOBAL	- 240	-303	-4,668

Pearce (1993) provides the damage cost of $15.23 (deflated to 1990 US dollars) per tonne of carbon monoxide emitted in the developed world. This figure can then be adjusted following Fankhauser, to obtain the figures of $3.04 for middle income regions and $1.52 for low income regions.

The monetary costs and savings associated with changes in carbon monoxide emissions, in Table 20, can be seen to follow an identical pattern to those associated with sulphur dioxide emissions. Again, the weighting attached to developed world emissions means that monetary savings in these regions far outweigh monetary costs incurred in the developing and transition regions. However, the magnitude of the costs and savings are significantly lower than for nitrogen dioxide and sulphur dioxide.

Table 20. The Monetary Cost / Saving from the Change in Carbon Monoxide Emissions - Based on Table 16 (millions US $).

CARBON MONOXIDE	Scenario 1. 1990	Scenario 2. 2000	Scenario 3. 2000 +0.5%
European Union	- 2.0	-2.7	-29.7
USA	- 9.0	-9.7	-76.3
Japan	-1.5	-2.6	-21.2
China	0.9	1.5	8.1
East Asia	0.03	0.05	1.6
South Asia	0.1	0.3	2.2
Africa	0.2	0.3	1.5
Latin America	0.6	0.5	1.8
Eastern Europe	0.1	0.2	1.9
GLOBAL	- 11	-13	-110

Pearce (1993) also provides a damage figure of $14,283 (converted to 1990 US dollars) per tonne of suspended particulate matter emitted. Pearce points out that damage costs associated with this pollutant are not well researched, but stresses that the figure chosen is well below that found in other studies (e.g. Glomsrod *et al.* (1992)). Again, this figure is adjusted to $2,856 for middle income regions and $1,428 for low income regions.

As Table 21, below, illustrates, the financial impact of Uruguay Round induced changes in emissions of suspended particulate matter again follows a pattern largely identical to that associated with sulphur dioxide emissions and carbon monoxide emissions. The magnitude of the costs and savings is larger than for any other pollutant, however. The weighting attached to emissions reductions in the developed world has meant a significant global monetary saving has been estimated.

Table 21. The Monetary Cost / Saving from the Change in Suspended Particulate Matter Emissions - Based on Table 17 (millions US $).

SUSP.PART. MATTER	Scenario 1. 1990	Scenario 2. 2000	Scenario 3. 2000 +0.5%
European Union	- 105.2	-160.2	-2,038.2
USA	- 646.6	-702.2	-6,090.4
Japan	-62.2	-118.5	-1,299.3
China	29.5	67.3	463.5
East Asia	- 74.8	-83.7	104.0
South Asia	14.2	32.4	286.7
Africa	21.3	43.2	185.7
Latin America	89.8	82.0	262.5
Eastern Europe	13.0	0.3	-191.3
GLOBAL	-721	-839.4	-8,316.8

Fankhauser (1995) also provides an estimate of the global mean value of the marginal social cost associated with carbon dioxide emissions. He estimates this to be $20.3 per tonne of carbon emitted. This figure stems from a global estimate of the cost incurred if carbon dioxide concentrations were to double, which in turn is an aggregation of the regional costs associated with such an increase in concentrations. In the case of carbon dioxide the source of the emissions is not relevant as the resultant impact is globally distributed. The same marginal social cost estimate is therefore applied to emissions from all regions to estimate the monetary cost of the increase in carbon dioxide emissions stemming from the combined scale and technique effect.[18] This is therefore only a partial estimate of the Uruguay Round's impact on carbon dioxide emissions since it fails to take into account the composition effect.

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[18] These points were clarified by personal correspondence with Samuel Fankhauser.

Table 16. The Monetary Cost of the Increase in Carbon Dioxide Emissions Resulting from Combined Scale and Technique Effects Alone (millions US $).

CARBON DIOXIDE	Scenario 1. 1990	Scenario 2. 2000	Scenario 3. 2000 +0.5%
European Union	77.0	179.6	567.1
USA	106.6	107.4	671.9
Japan	23.2	30.0	211.5
China	125.2	230.2	1,177.7
Asia[19]	411.7	780.5	3,425.9
Africa	62.7	123.8	527.0
Latin America	55.4	76.1	388.4
Eastern Europe	10.8	12.7	495.0
GLOBAL	899.2	1,310.1	6,286.8

All regions are estimated to experience a monetary cost as a result of increased carbon dioxide emissions. The largest monetary cost is incurred by Asia and amounts to almost $3.5 billion for scenario 3 and over $6 billion globally.

Although this is only a partial evaluation of the Uruguay Round's impact on carbon dioxide emissions, it is likely that the composition effect on carbon dioxide emissions will follow a similar pattern to that associated with nitrogen dioxide, sulphur dioxide and suspended particulate matter, since all four pollutants stem largely from energy use. Thus it is possible that the composition effect will add to emissions, and hence to the monetary cost, above, for the developed regions and Latin America, whilst emissions may fall in the Asian regions. The effect of compositional

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[19] Includes China.

changes on Africa and Eastern Europe are difficult to predict since they vary depending on the pollutant.

These estimated monetary costs can be seen to form only a small proportion of the estimated Uruguay Round benefits. For example, for China, Africa and Latin America, the monetary costs associated with the above five pollutants form approximately 1.2% of their estimated income gain for 1990.[20] For the European Union this figure is only 0.4% whilst the USA's environmental *benefit* represents 1.8% of the initial estimated gain. Monetary damage estimates of this nature are subject to much uncertainty, however, as is the appropriate mechanism with which to scale costs for the developing regions. The sensitivity of the results to this scaling mechanism can be illustrated by allowing the developing regions to be subjected to the same monetary cost, per unit of pollution, as the developed regions. In this situation, China, Africa and Latin America would experience pollution costs equivalent to between 5-6% of their estimated gains from the Uruguay Round for 1990. Furthermore, pollution costs for the developing regions would be larger than any savings estimated for the developed regions resulting in a global environmental cost for all scenarios.

7.4 Conclusion.

This chapter has attempted to estimate the impact of the Uruguay Round of trade negotiations on carbon dioxide, total energy use and four local air pollutants. Results indicate that the developing and transition regions will experience an increase in energy use and emissions of all five pollutants as a result of the Uruguay Round. In the developed regions emissions of three local air pollutants are predicted to fall whilst nitrogen dioxide emissions, carbon dioxide emissions and energy use rise.

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[20] To allow this comparison, the estimated income gains have here been deflated to 1990 US dollars.

The analysis of the composition effect associated with the Uruguay Round highlights the sectors which may require additional abatement efforts. The expansion of the textile sectors in virtually all developing regions is predicted to lead to an increase in emissions of all four local air pollutants. In the developed regions it is the heavy industrial sectors which are predicted to expand as a result of the Uruguay Round, again, leading to increases in emissions of all four local pollutants. These increases are particularly large due to the high pollution intensities associated with the output from these sectors.

The results also highlight the effect of a change in the *rate* of economic growth on pollution emissions and energy use. As the results indicate, if the Uruguay Round were to increase this rate of growth, the level of emissions and energy use in the year 2000 is likely to be considerably different to that predicted for the year 2000 in the absence of the Uruguay Round. For example, the increase in emissions of local air pollution for the developing regions for the year 2000 is generally 5 to 10 times higher if the growth rate has been increased by 0.5%, with emissions predicted to increase by up to 10% for some regions.

With regard to the monetary costs associated with these changes in pollution, it would appear that, compared to the estimated gains from the Uruguay Round, these costs are small. It is, nevertheless, important that the existence of such costs is recognised. Furthermore, it should, of course, also be pointed out that the above analysis is only a very partial estimate of the environmental impact of the Uruguay Round. Indeed, the monetary cost estimates consider only five air pollutants at the expense of other local air pollutants, greenhouse gases, CFCs, water pollutants and numerous other environmental indicators which may also be affected.

It should, of course, be pointed out that the estimates contained within this chapter depend, not only on the estimated EKCs, but also on the computable general equilibrium income estimates of Francois *et al.* As such, the reliability of the estimated results is open to question. Greater attention should perhaps be given to the *direction* of changes in pollution and energy use rather than to the magnitude of such changes. Nevertheless, this analysis indicates that trade liberalisation may result in some degree of environmental damage, particularly in the developing regions as a result of increased emissions of local air pollutants and perhaps globally for carbon dioxide emissions and energy use.

CHAPTER 8.

POLICY IMPLICATIONS.

8.1 Introduction.

The previous chapters have addressed the broad and complex issue of the relationship between economic growth, trade liberalisation and the environment. Perhaps not surprisingly, the results generated in these chapters have far-reaching implications for both national and international policy. In order to consider these policy implications in more detail, a distinction has been drawn between the implications for the WTO, those which relate to the creation of a World Environmental Organisation (WEO) and those which relate to national environmental policy. These will now be considered in turn.

8.2 Implications for the WTO.

The investigation into the impact of trade liberalisation on the environment highlighted a number of deficiencies in the workings of the GATT - many of which have now been passed on to the WTO.

The first implication for policy stems from the issue of whether liberalised trade suppresses the implementation of environmental legislation, both at a national and international level. Chapter 3 stated that any international environmental agreements which contain trade-based enforcement mechanisms are currently illegal under current WTO rules. Thus, any nations who are signatories to both the GATT/WTO and an agreement such as the Montreal Protocol are subject to conflicting obligations. It is therefore recommended that the WTO be amended to prevent interference with multilaterally accepted environmental agreements.[1] With regard to *national* environmental legislation, Nordhaus (1994) argued that it is economically efficient for nations to harmonise their policies aimed at global environmental issues whilst policies targetted at local environmental problems should be left to the discretion of individual countries. Using standard neoclassical analysis Nordhaus stated that, for global pollutants, the marginal benefits of emissions reduction are likely to be common to all countries, whilst the marginal abatement costs are likely to differ.[2] In these circumstances, it is therefore possible for a single level of pollution tax to equate the marginal benefits and the marginal costs for each nation. In contrast, for local pollutants each nation will possess different marginal costs *and* marginal benefits, thereby also requiring different levels of pollution tax in each country to equate these costs and benefits.[3] This argument is examined in detail in Chapter 3 and is illustrated diagrammatically in Appendix F. Chapter 3 also pointed out that, in reality, policy decisions are not made using economic efficiency arguments alone. As a result, the negotiations necessary before such global legislation could be implemented would need to address a number of other issues, including equity and the environment. Nevertheless, from an environmental point of view Nordhaus's conclusions would also seem sensible. By harmonising the response to global environmental issues, either through the use of common standards or, as Nordhaus recommends, through the adoption of harmonised emissions fees, countries are forced to adopt standards or regulations which are often higher than those which

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[1] Optimal intervention theory suggests that such environmental agreements should not restrict trade but should instead internalise externalities. However, the fact that multilateral agreements of this nature are addressing *global* environmental problems and given the extent of externalities and the difficulties faced in globally internalising them, it would appear that, in the interests of the environment, trade restrictions are necessary if they are in support of a multilaterally accepted agreement.

[2] In reality, it is unlikely that the marginal benefits of abatement will be constant across a number of countries. Global warming, for example, is likely to have an extremely varied impact on different countries.

[3] Nordhaus treats global externalities as traded goods which will experience price equalisation across countries. Conversely, local externalities are treated as non-traded goods and possess prices specific to each country.

individual countries would have adopted. Indeed, as Esty (1994) points out, the Montreal Protocol is just such an example of standards being adopted which are higher than the existing standards of any country. It is clear that the multilateral implementation of environmental regulations avoids the 'prisoner's dilemma' fear associated with unilateral standard setting, since loss of competitiveness is no longer a concern. Chapters 5's analysis of CFC emissions illustrates how effective the Montreal Protocol has been in tackling the use of CFCs, and shows how the implementation of this policy effectively 'tunnelled through' the original pre-Montreal Protocol environmental Kuznets curve. In contrast, the case of carbon dioxide in Chapters 5 *and* 6 indicates that without such multilateral attention, nations do not reduce emissions due to the risk of losing competitiveness combined with the ability to free ride by benefitting from other nations' pollution control.

Whether to harmonise the response to transboundary pollutants (such as nitrogen dioxide and sulphur dioxide - the causes of acid rain), which are neither local or global pollutants, less clear. Nordhaus, himself, points out that his analysis applies only to pure global and local externalities. It would not appear appropriate, for example, to adopt a globally harmonised response to acid rain, given that some nations do not suffer from acid rain and hence the marginal benefits of abatement would be far from equal. Indeed, attaining public acceptability for a policy which charges them for a problem they do not have would also be difficult. Conversely, since the sulphur dioxide emissions, for example, of one country can directly affect the environment of another, it would also appear unwise for abatement to be fully at the discretion of individual countries. From an environmental point of view, there would therefore seem to be a need for multilateral commitment to tackle a transboundary issue such as acid rain. One option would be to adopt a harmonised *regional* response amongst nations with similar income levels. Most European nations are already committed to reduce sulphur dioxide and nitrogen dioxide by common targets under the Convention on Long-Range Transboundary Air Pollution, whilst the US uses a system of marketable permits to reduce emissions of sulphur dioxide. Under the US sulphur dioxide control program, the Clean Air Act sets the national total amount of emissions deemed acceptable. Permits for this total are allocated mainly to power companies generally based on historical emissions levels and on fuel type. In addition, a small amount of permits are released through auction once a year. Permits can then be traded, with their price being determined on the open market. Interestingly, under this system all states are subject to the same national emissions ceiling and all face the same open market permit price even though the marginal benefits of abatement will vary significantly from state to state, with acid rain a particular problem only in the North-Eastern states. The US permit program therefore does not appear to conform with a notion of economic efficiency, if marginal benefits are measured at the level of the state rather than for the nation as a whole.[4] The policy, however, has proved very successful, with emissions of sulphur dioxide falling rapidly since the permit system began.

There is therefore a clear need for the developing regions to follow in the footsteps of Europe and the US and to adopt similar commitments, ideally using marketable permits or pollution taxes common to all countries, rather than the less efficient common standards. However, the number of countries who adhere to the harmonised commitment and whether or not they all suffer from acid rain will be of importance if the policy is to be efficient in economic terms. The level at which any tax was set in the developing world is unlikely to be determined by economic efficiency,

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[4] Even if marginal benefits are measured at a national level it is unclear whether the US permit system is efficient in economic terms i.e. whether it equates the marginal cost and marginal benefit of emissions reduction. However, as with pollution taxes, marketable permits are likely to be *more* efficient than command and control policies since it appears inefficient to force all firms to cut pollution by the same amount when they are likely to face very different marginal abatement costs.

however, since a number of political factors would have to be considered. Indeed, the environment is still considered to be a luxury good in many developing countries, indicating that the necessary co-operation and commitment from these countries may be difficult to achieve. In addition, it is important that the developing countries do not feel that they are being 'bullied' into adopting environmental regulations by the economically powerful North. The issue of environmental protection is even more sensitive since the developing countries may resent having to pay for environmental problems which they consider to have been largely caused by the developed regions. Clearly, environmental regulation in developing countries needs to be established through careful negotiation - a potential role for a World Environmental Organisation, as discussed below.

Many environmentalists have expressed the fear that *any* harmonisation will cause standards to fall to the lowest common denominator. However, this risk can be overcome by simply treating common standards as a baseline, or minimum standard, which countries are allowed to exceed providing the higher standard does not impose an excessive restriction on trade. The WTO should then adopt a test, to use if a dispute arises, which assesses whether in the absence of the new standard, significant environmental damage would have occurred. Thus, if the raised standard was challenged as being an unnecessary restriction to trade, the country responsible would have to demonstrate to the WTO that the disruption to trade was not disproportionate to the environmental benefits resulting from the higher standard.[5] Environmentalists have often criticised the harmonisation of ambient air quality standards and production and process standards due to national variations in environmental endowments and environmental preferences. However, the need to tackle global and

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[5] It would also have to be proved that there was no non-trade distorting measure that would provide equivalent results. Given the recent WTO ruling on the EU's ban on US beef containing growth hormones, it would appear that even if a nation's environmental standard is found to be an excessive restriction on trade, it can remain in place providing compensation is paid to the complainant.

transboundary pollution at a multilateral level would seem to take priority over these objections. Furthermore, the harmonisation of ambient air quality levels, rather than the harmonisation of the tools to achieve these levels, has the advantage of respecting differences in assimilative capacity between nations. In addition, since nations with a high assimilative capacity will face lower environmental compliance costs, such nations will retain their comparative advantage.

Generally, it would seem appropriate that the level at which the environmental regulation is set mirrors the scale of the environmental problem itself. Since some problems are clearly global in nature, then the solution to such problems should be co-ordinated at a global level. Damage to the ozone layer, for example, will continue if only some nations reduce emissions of CFCs, whilst others do not. Thus, global externalities require a harmonised and co-ordinated policy response. Similarly, pollutants which do not have a global impact but are still transboundary in nature (e.g. sulphur dioxide and nitrogen dioxide) also require a co-ordinated multilateral response. In contrast, small scale, or local, environmental problems should be tackled at a local level. Externalities such as the destruction of woodland or emissions of suspended particulate matter would clearly be dealt with more effectively at a national level and hence such policies are ill suited to harmonisation between countries.[6]

The Technical Barriers to Trade Agreement (the Standards Code), however, makes no distinction between standards which address global issues and those which merely deal with local environmental problems. Indeed, by promoting the harmonisation of *all* standards, the Agreement

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[6] Jacobs (1991) argues, however, that the protection of a habitat of particular importance, such as the rainforests, which some may consider to be a local environmental problem, should not be left to the discretion of individual nations, but should be subject to international co-ordination and agreement. Tropical forests provide a number of different functions and services many of which would be 'globally' valued, thereby suggesting that the destruction of such forests should be considered to be a global environmental problem, requiring global agreement.

may be damaging both to the goal of economic efficiency, and possibly to attempts to protect the environment. It is therefore recommended that the Technical Barriers to Trade Agreement concentrates on the harmonisation of only those standards which relate to global environmental issues and should not aim for the global harmonisation of transboundary pollution standards or local pollution standards. However, Stevens (1993), claims that the GATT/WTO is not the appropriate institution to set or harmonise standards, yet at present it is solely responsible for determining whether these standards are legitimate if they are challenged by another nation.[7] The creation of a World Environmental Organisation, as outlined below, would provide a more suitable forum in which the level of environmental standards could be decided.

Chapter 3 next considered the issue of whether trade liberalisation in the presence of divergent environmental standards would provide the nation with the lowest standard with a competitive advantage, thereby providing an incentive for nations to lower their environmental standards. It was seen that the extent of any competitive advantage which results from low environmental standards is empirically uncertain, and hence so too is the strength of any pressure to lower standards. However, if nations, or producer lobbies, perceive there to be an economic gain from lowering standards, some nations may do so - at the expense of the environment. In such a situation the harmonisation of environmental standards is advisable. As stated above, from an environmental point of view, those standards aimed at *local* environmental problems would not be suited to harmonisation, and the possible environmental harm resulting from their harmonisation may not be compensated by the environmental benefit resulting from the removal of pressure to lower standards. As a result, the policy suggestion mentioned above still holds - environmental regulations

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[7] Although the GATT/WTO can decide that an environmental standard is too high, it cannot claim that a standard is too low, thereby illustrating, from an environmental point of view, the unsuitability of the GATT/WTO to deal with such issues.

designed to tackle global environmental issues should be harmonised between nations. In addition, transboundary emissions may be dealt with most effectively by harmonising policies within regions. Such proposals may prove environmentally beneficial as nations are forced multilaterally to adopt standards which are higher than those which would have been adopted unilaterally. In addition, if by operating low environmental standards a competitive advantage *is* gained, this partial harmonisation will at least partially remove a nation's ability to lower its environmental standards.

It was stated in Chapter 3 that the GATT/WTO will allow trade restrictions to be implemented in response to a *consumption* externality, but is wary of allowing trade restrictions in response to *production* externalities (apart from in limited instances under the Technical Barriers to Trade Agreement) due to the extent of the trade restrictions which may follow. Furthermore, trade restrictions may not be implemented in response to environmental damage which occurs *outside* the jurisdiction of the trade-restricting country. However, such extraterritorial environmental damage may seem extremely important to a nation. Whilst the production processes of an exporting country may *directly* damage the environment of an importing country, the importing country may also feel it has suffered if the production methods adversely affect the global commons. It is for this reason that Baker (1992) argues that trade restrictions aimed at protecting the global environment should not be considered to be outside a nation's jurisdiction. As a result, Esty states "Rather than making GATT legality turn on the issue of where the trade measure is aimed - barring extraterritorial actions - the critical determination should be the presence or absence of a bona fide environmental injury..." (Esty (1994) p.139-40). If there is evidence of a significant threat to the environment, then it is here suggested that WTO rules should allow a trade restraint to be placed on the offending product wherever the damage occurred, and irrespective of whether the environmental damage arose through the consumption of the good or through its method of production. WTO rules should therefore be amended to remove the prohibition against extraterritorial actions and to allow a distinction to be drawn between 'like' products which are the result of very different production and processing methods. Although domestic regulations would be preferable to trade restrictions, in reality, such regulations may not be forthcoming. The global nature of many environmental problems and hence both the extent of externalities and the difficulties associated with removing them, suggests that trade restrictions may be necessary in response to production methods which have a significant impact on the environment. If action is to be taken, a multilateral response is preferable. However, at present, it can often prove impossible to obtain global co-operation. Thus, the co-ordination of multilateral action could be one role of a World Environmental Organisation (WEO). Attention now turns to the other possible roles of such an organisation.

8.3 The Creation of a World Environmental Organisation.

Numerous calls have now been made for a global institution designed solely to protect the global environment, although specific details relating to its possible role have remained sparse. Runge (1994) states that a WEO should aim to define and upgrade national environmental policies and standards; monitor and verify national performance; and provide expertise and assistance in WTO trade-environment disputes. Esty (1994) also provides some general principles to which a WEO could adhere, including; the polluter pays principle; a precautionary approach; and an emphasis on pollution prevention rather than 'end of pipe' technology. One factor common to both of these discussions, however, is an acceptance of the need for such an institution if environmental issues are to be dealt with effectively at a global level.

The creation of a WEO would serve to elevate international environmental policy-making to a status similar to that currently enjoyed by international trade policy. Operating parallel to the WTO, the two institutions would ideally possess similar power and authority and would collaborate fully when designing trade and environmental policy. The WEO could arise from a strengthening of existing institutions such as the United Nations Environment Programme, or it could be a new institution designed specifically for the task. Clearly, there is a risk of an unhappy alliance between the WEO and the WTO, and the prospect of repeated deadlock when negotiating trade and environmental policy. However, if the global environment is considered to be as important as the global trading regime, then it too requires a purpose-built institution to protect its interests. Esty (1994) argues that there would need to be recourse to an outside arbiter if the WEO and the WTO could not resolve a conflict, and suggests the International Court of Justice or a yet-to-be-established UN Economic Security Council. The precise relationship between the WEO and the WTO requires careful consideration which is beyond the remit of this research.

Although the funding of the WEO may prove to be a complex issue, one possible source is the Global Environment Facility (GEF), a fund jointly established by the World Bank, the United Nations Development Programme and the United Nations Environment Programme to facilitate global environmental projects. Unfortunately, the GEF relies on voluntary donations from individual countries and is likely to prove insufficient for the WEO's requirements. An additional source of finance could be the revenue from the pollution taxes implemented by the WEO once it is established. The feasibility of this option is questionable, however. It is unlikely that national governments would be prepared to surrender responsibility for the imposition of environmental taxes, and the revenue from them, to an international bureaucracy. Furthermore, the payment of taxes to an unelected global institution is likely to be unpopular with the general public. Nevertheless, the idea is theoretically viable and, as such, requires further investigation.

The results and arguments contained in Chapters 4, 5 and 6 provide some clear guidelines for the implementation of global sustainable development which the WEO could follow. Chapter 4 illustrates the uncertainty which exists regarding the impact of the economy on the environment. However, as Ekins notes, "Modesty in the face of uncertainty is, doubtless, laudable but it can all too easily lead to inaction or mere calls for more research." (Ekins (1993) p.280). The precautionary principle would therefore seem a sensible strategy for the WEO to adopt.[8] As Costanza emphasises, "If we are unsure about future limits the prudent course is to assume they exist. One does not run blindly through a dark landscape that *may* contain crevasses. One assumes that they are there and goes gingerly and with eyes wide open, at least until one can see a little better." (Costanza (1989) p.5). Given the existence of such uncertainty and the possibility of environmental actions being irreversible, it would appear dangerous to assume that man-made capital is a substitute for natural capital. Clearly, natural assets that are critical to human survival, such as biodiversity or the ozone layer, are irreplaceable. It is therefore essential that such natural assets are maintained, since no amount of man-made capital will compensate for their loss.

Diagram 1 illustrates that, when trying to implement the precautionary principle, a number of options are available.

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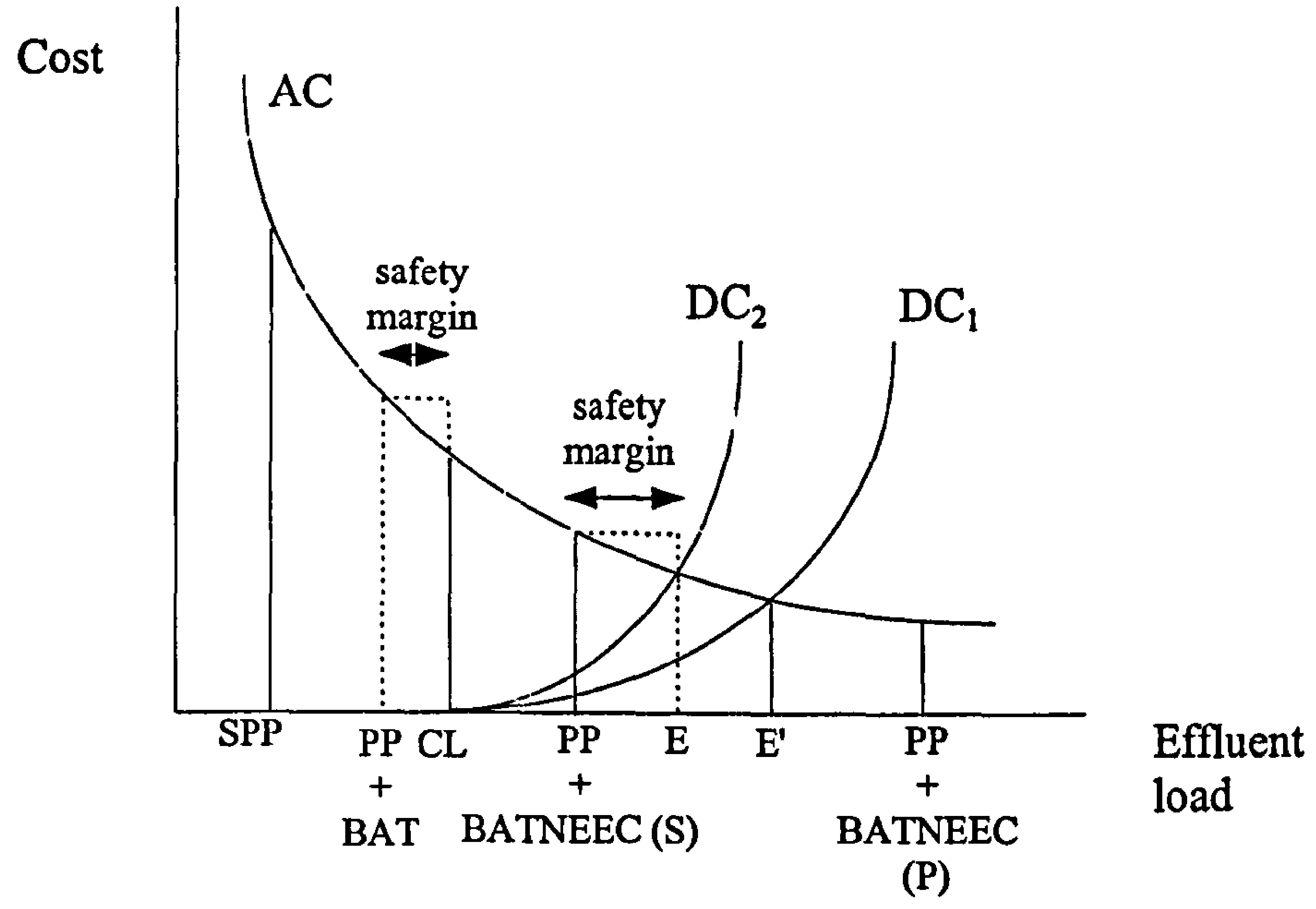
[8] As O'Riordan and Cameron (1994) point out, the precautionary principle states that, in the face of uncertainty and given the severity of potential environmental harm, policy makers should err on the side of caution and risk providing too much environmental protection rather than too little.

Diagram 1.



Where SPP = Strict Precautionary Principle; BAT = Best Available Technology; BATNEEC (S) = Best Available Technology Not Entailing Excessive Net Social Cost; CL = Critical Load; BATNEEC (P) = Best Available Technology Not Entailing Excessive Net Private Cost; E to E' = maximum economic efficiency; DC = Damage Costs; AC = Abatement Costs.

In Diagram 1, the abatement cost (AC) and damage cost functions (DC$_1$ and DC$_2$) assume that pollutants can be emitted/discharged up to the point CL (critical load) without significant environmental damage. Beyond this point the uncertainty surrounding the pollution damage increases, as represented by the divergence between DC$_1$ and DC$_2$. The economically efficient level of pollution control lies between E and E', where marginal abatement costs are equal to marginal damage costs. The precautionary options available are therefore: the strict precautionary principle (SPP) under which only discharges of materials unlikely to damage ecosystems or diminish environmental quality are permitted; the precautionary principle coupled with best available technology (PP+BAT) for discharges likely to result in environmental damage; the precautionary principle using best available technologies not entailing excessive cost (PP+BATNEEC(S)) where 'excessive cost' is interpreted in terms of the full social costs and benefits involved; the precautionary principle using BATNEEC (PP+BATNEEC (P)) interpreted using only the financial costs and benefits involved.

Whichever form of the precautionary principle is chosen, the first step in ensuring that nations maintain at least their stock of critical natural capital, is to ensure that nations maximise 'green' net national product (NNP) rather than GNP. The WEO could provide a clear and common framework through which green NNP could be calculated in all countries, similar to the manner in which the system of national accounts was adopted following the work of Kuznets and Keynes. It was pointed out in Chapter 4, however, that 'green' NNP can increase even if an economy is developing unsustainably and is therefore not, in itself, an indicator of sustainability. It is therefore recommended that the use of 'green' NNP should be accompanied by the adoption of a system of physical accounts, even though such a system suffers from the lack of a common unit of measurement and the inability to assess the relative importance of the different accounts. The use of physical accounts for each environmental indicator is likely to prove vital in the quest for sustainability and the maintenance of at least the stock of critical natural capital. Only by studying the accounts for individual indicators will policy makers be aware of whether the economy is operating in an environmentally sustainable manner and be able to gear policy towards those indicators that are deteriorating. Again, the WEO could provide a common methodology for the calculation of physical accounts and encourage its adoption in all countries, thereby allowing the comparison of each environmental indicator between countries.

There are, however, a number of other ways in which the WEO can help to achieve sustainable development.

Chapter 3 stressed that if nations are to internalise environmental costs, it must be on a multilateral basis due to the considerable disincentives associated with unilaterally raising prices in this manner. It is also vital that developing countries partake in this process of internalisation. This would prevent the developed countries from progressing towards sustainability at the expense of the developing world and reduce the likelihood of disputes arising over hidden environmental subsidies and 'pollution havens'. Clearly, the WEO would be in an ideal position to establish commitments for internalisation in both the developed and the developing regions, by instigating and supervising negotiations. Although estimating the extent that prices need to rise due to numerous environmental costs is fraught with difficulties, attempting to internalise the cost of global warming is likely to be a key priority. Indeed, Chapters 5 and 6 predict that carbon dioxide emissions will increase steadily, in all regions, for many years to come if current practices remain unchanged. Through negotiation and supervision, the WEO could play a key role in the implementation of a global carbon tax or the establishment of an internationally traded marketable permit system.[9] For these policies to be effective it is essential that they are implemented internationally rather than left to the discretion of individual nations. This finding was clearly illustrated in Chapters 5 and 6, thereby indicating the need for a WEO. Although the powers of a WEO to enforce compliance to a carbon tax or a system of marketable permits is unclear, it is reasonable to suggest that such policies would receive the compliance and status currently enjoyed by

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[9] See Jacobs (1991) and Larsen and Shah (1994) for examples of how marketable permits could be used to reduce global emissions of carbon dioxide. See also Howe (1994) for a comparison of taxes and marketable permits in the light of US and EU experience.

multilateral environmental agreements such as the Montreal Protocol and the Basel Convention.

The WEO could also recommend, and encourage adherence to, minimum standards for policies aimed at other global and transboundary environmental issues. This would help to ensure that the policies aimed at these issues are harmonised globally, or regionally for transboundary pollutants, as advocated in the previous section. Policies aimed at local environmental problems which are left to the discretion of individual countries, could still be subject to general WEO guidelines.

8.4 Implications for National Environmental Policy.

The results of Chapters 5 and 6 indicate that emissions of local air pollutants are still increasing in many developing countries and, although falling in the developed world, appear to be still increasing globally. Clearly, such pollutants must be tackled, particularly in the developing world. Although Europe adheres to the UNECE Convention on Long Range Transboundary Air Pollution and to various protocols within the convention, at present the developing world has made no commitments to reduce such pollution.[10] As mentioned above, the WEO could encourage developing countries to adhere to regional harmonised minimum standards for the local air pollutants which also have transboundary impacts (i.e. sulphur dioxide and nitrogen dioxide). However, individual developing countries will determine themselves the extent of policies to tackle the other local pollutants.[11] Clearly, this is an issue which requires attention from domestic policy makers in developing countries.

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[10] UNECE is the United Nations Economic Commission for Europe.

[11] Until the developing world makes the switch from burning coal to electricity and natural gas for cooking and heating, emissions of sulphur dioxide and suspended particulate matter, at least, are likely to remain problematic.

The results of Chapter 7 indicate the effect on local air pollution of changes in the global composition of industry induced by the Uruguay Round. These results highlight the sectors in which increased pollution control efforts are likely to be required. The expansion of the textile sectors in virtually all developing regions is predicted to lead to an increase in emissions of all four air pollutants, indicating that policy makers in these regions should pay particular attention to these sectors.[12] In the developed regions it is the heavy industrial sectors which are predicted to expand as a result of the Uruguay Round, leading to increases in emissions of all four pollutants. These increases are particularly large due to the high pollution intensities associated with the output from these sectors. It would therefore appear wise for domestic policy makers in the developed world to ensure that sufficient attention is paid to the emissions stemming from heavy industry. Once the scale effects associated with the Uruguay Round are also taken into consideration, the results reiterate the findings of Chapters 5 and 6 - namely, that global pollutants will increase in all regions whilst local pollutants will increase in the developing world and fall in the developed world. Nitrogen dioxide is the only exception and is predicted to increase in both the developing and the developed regions.

The results of Chapters 5 and 6 also highlight the need for domestic policy makers to tackle the environmental impact of the transport sector. Since estimated turning points for transport generated emissions of local air pollution were consistently higher than those estimated for total emissions of the same pollutants, it is clear that pollution emissions from transport are proving more difficult to control than emissions from other sectors. Similarly, energy use by the transport sector shows little or no sign of falling compared to total energy use which, although still increasing, is increasing at a decreasing rate. The analysis of traffic volumes illustrates

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[12] Even though the increase in emissions in these sectors is predicted to be more than offset by decreases in emissions in other sectors.

why these problems are occurring, with traffic volumes projected to increase steadily for some years.

The developed nations in particular therefore require an integrated transport policy which places an emphasis on public transport and investigates alternative energy sources to petrol and diesel. Other policies such as the restricted use of vehicles in city centres and road tolls may also be desirable.

Chapters 5 and 6 also highlight the need for governments to tackle indirect environmental indicators such as energy use, municipal waste and, as addressed above, traffic volumes. The multilateral implementation of a carbon tax, or a system of international marketable permits, as advocated in the previous section, is likely to reduce energy use (and associated pollution). These policies should raise the price of energy with the result that consumers are likely to reduce fuel consumption, whilst firms now have more of an incentive to invest in energy saving technology.[13] Volumes of municipal waste may be reduced by taxing firms when depositing at refuse collection sites, as is now the case in the UK. Such a policy needs careful enforcement, however, to prevent the growth of illegal 'fly tipping'. Furthermore, the amount of waste going to landfill sites can be reduced by encouraging greater recycling. The recycling of glass and plastic, however, is unlikely to reduce methane emissions from landfill sites which are generated by decomposing organic waste. The recycling of paper may have a small effect on methane emissions, whilst the composting of organic waste will only serve to move methane emissions from the landfill site to the composting site.

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[13] The environmental impact of the transport sector is also likely to be reduced if the increase in the price of petrol and diesel is sufficient to reduce traffic volumes.

8.5 Conclusion.

The results of the previous chapters raise a number of implications for both trade policy and environmental policy. With regard to the former, several amendments are likely to be required to the WTO if it is to operate in a manner which is more environmentally benign. It has here been suggested that the WTO should not be allowed to interfere with multilaterally accepted environmental agreements and that the Technical Barriers to Trade Agreement should aim to harmonise only those standards aimed at global environmental issues, at least until a WEO could adopt this latter role. In addition, it has been argued that a distinction should be drawn between 'like' products which are the result of very different production and processing methods and that it may also be wise to lift the prohibition on action taken in response to extra-jurisdictional environmental damage.

The creation of an international institution to protect the global environment has also been advocated and several possible roles for such an institution have been highlighted. To help facilitate a notion of sustainability which maintains the natural capital stock (or at least the stock of *critical* natural capital) the WEO could provide a common methodology for the calculation of 'green' NNP and a system of physical accounts, and to encourage their adoption by all nations. The WEO would also be in an ideal position to establish harmonised commitments to tackle carbon dioxide, perhaps via a carbon tax, and to encourage the internalisation of environmental costs in general. It is imperative that such initiatives are implemented multilaterally if the global environment is to benefit and if nations are not to find themselves at a competitive disadvantage. The WEO would also be the most suitable institution to implement the regional harmonisation of commitments to reduce transboundary pollution.

The success experienced by the GATT/WTO in liberalising world trade provides a justification for an institution with similar authority and status to protect the global environment. The relationship between the WTO and the WEO is likely to prove complex, however, and is an issue which deserves greater attention from researchers and policy-makers alike.

Finally, with regard to national policy, it has been argued that in the developing world in particular, greater efforts are required to tackle local air pollution. The need for all nations to address the environmental impact of the transport sector has also been highlighted, as well as the impact of various other sectors in the developed and the developing world resulting from trade-induced changes in the global composition of industry. Finally, the importance of reducing indirect environmental indicators, such as energy use and traffic volumes, has also been emphasised.

It is clear from the above that in order to move towards a notion of global sustainable development a careful mix of both national and international policy will be required, as well as a number of institutional changes. The size of this task should not be underestimated. The extent of future amendments to national environmental policies will depend very much on the political will of national governments. Furthermore, given the difficulties associated with international policy making, as illustrated by the duration of the last round of GATT talks, for example, it appears unlikely that the necessary institutional changes will occur quickly.

CHAPTER 9.

CONCLUSION.

This thesis has analysed, and where possible quantified, the impacts of trade liberalisation and economic growth on the environment. Particular attention has been paid to the Uruguay Round of trade negotiations and the economic growth predicted to arise as a result of these negotiations.

Chapter 1 explained the background to the issues to be discussed, whilst Chapter 2 began the analysis of the relationship between trade liberalisation and the environment by considering the development of the GATT since 1948. Particular attention was paid to the GATT's treatment of the environment throughout this period. The chapter illustrates how successful the GATT has been in reducing the size and number of industrial tariffs and points out that agricultural protection is also now falling as a result of the Uruguay Round. It was seen that the GATT's provisions for the protection of the environment are minimal and it was not until the Uruguay Round, and the creation of the World Trade Organisation (WTO), that any significant advances were made in this area. In contrast to the GATT, the WTO at least formally recognises the need to protect the environment and has created a Committee on Trade and the Environment. This clearly represents a step in the right direction, although there is, as yet, little evidence of any firm commitment to alter the workings of the WTO to benefit the environment.

Chapter 3 examined the environmental implications of the GATT/WTO and trade liberalisation in general. Although trade liberalisation may benefit the environment, for example through the increased exchange of environmentally beneficial products and services or through the removal of distortions in the location and intensity of production, it may also prove environmentally damaging. This chapter examined the different arguments and, together with Chapter 8, provided a number of recommendations for the workings of the WTO. Chapter 4 began the analysis of a major implication of trade liberalisation - the generation of economic growth. Concentrating on theoretical arguments, the chapter highlighted the differences between the pro-growth and anti-growth positions, particularly those which manifested themselves in the 1960s and 70s. Similar positions can still be detected amongst different proponents of sustainable development, indicating that the debate was far from settled. The chapter finished by examining the deficiencies of GNP as an indicator of production and welfare and suggested possible alternatives.

Given the uncertainty surrounding the impact of the economy on the environment, Chapters 5 and 6 attempted to estimate empirically the relationship between economic growth and a wide range of environmental indicators. Improving on the traditional methodology for estimating environmental Kuznets curves (EKCs) the chapters provided a number of interesting findings. For example, results suggest that economic growth is associated with increasing emissions of global pollutants such as carbon dioxide and indicators with an indirect environmental impact, such as energy use and traffic volumes.[1] This would appear to be due to the lack of incentives for unilateral action. In contrast, the emissions of local air pollutants tend to decline with economic growth, once a certain per capita income level is attained. Clearly, governments have a greater incentive to reduce emissions of such pollutants when they directly affect the locale in which they are emitted. The chapters also highlighted the impact of the transport

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[1] CFCs were also increasing steadily prior to them receiving multilateral attention.

sector on pollution and energy use and, in addition, illustrated that urban air concentrations tend to improve before total emissions do.

Chapter 6 re-tested the hypotheses of Chapter 5 with the inclusion of a time trend as a proxy for the level of technology. This did little to alter the results of Chapter 5 and reinforced which pollutants have benefitted from technological change and which have not. Generally, total emissions of local air pollutants have fallen in response to technological advance whilst emissions from transport have not. This latter point may be due to the fact that the introduction of catalytic converters occurred towards the end of the time series under consideration. Energy use and carbon dioxide emissions also possess negative time trends (although not always statistically significant), presumably due to advances in energy efficiency. Despite these advances, both indicators remain on the upward sloping portion of their EKCs and therefore continue to increase.

Chapter 7 estimated the environmental impact of the Uruguay Round of trade negotiations in terms of the environmental indicators considered in Chapters 5 and 6. Using the results of Chapter 5, together with those of Francois *et al.* (1995) and Hettige *et al.* (1994), the chapter estimated the environmental impact of the composition effect and scale and technique effects associated with the Uruguay Round. Results suggested that in the developing and transition regions most indicators will increase as a result of the Uruguay Round, whilst in the developed regions three local air pollutants will fall and the others increase.

As well as highlighting the sectors which are likely to increase or decrease pollution emissions as a result of the Uruguay Round, the analysis also indicated the effect on the environmental indicators of a change in the *rate* of economic growth. An increase in the growth rate effectively amplifies the magnitude of the change in the environmental indicator stemming from the initial income gain. Whether the Uruguay Round will increase the rate of economic growth therefore becomes an issue of considerable importance when trying to determine the Uruguay Round's environmental impact.

Combining estimated pollution changes with estimates of the monetary cost associated with a unit of pollution, allowed the calculation of the monetary cost or benefit associated with the environmental impact of the Uruguay Round. Results suggested that such costs and benefits form only a small portion of the estimated monetary gains from the Uruguay Round. It is important to stress, however, that these monetary costs and benefits stem from changes in only five air pollutants at the expense of a vast array of other potential environmental impacts.

The policy implications stemming from the thesis were discussed in Chapter 8 and a distinction was drawn between those implications for the WTO, those which relate to the creation of a World Environmental Organisation (WEO) and those which relate to national environmental policy. The chapter recommended a number of changes to the workings of the WTO to reduce the environmental impact of trade liberalisation and also advocated the creation of a WEO which would aim to protect the global environment. A number of possible roles and policies for a WEO were highlighted which would help facilitate a notion' of sustainable development. These would then be complemented by various amendments to national environmental policy.

The results and discussions within this thesis suggest that trade liberalisation has the potential to damage the environment.

Amendments to the workings of the WTO could alleviate this damage, to an extent, but in the presence of externalities such damage is likely to continue. Clearly, externalities need to be fully internalised so that product prices reflect their full costs of production. The creation of a WEO is likely to prove vital in the quest to internalise environmental costs at a global level, although the size of the task should not be underestimated. Indeed, the precise role of a WEO, and in particular its relationship with the WTO, is an issue which will require further attention from researchers and policy-makers. The methods with which environmental costs are estimated also require further research. Particularly sparse is information on the monetary costs of environmental damage in developing countries. If such costs are to be internalised, it is likely that their accuracy and reliability will require improvement.

The environmental impact specifically resulting from economic growth is less clear. Although certain environmental indicators can improve in association with economic growth, others continue to deteriorate. As stressed in Chapter 5, however, there is nothing inevitable about the estimated relationship between per capita income and environmental indicators since concerted policy initiatives can 'tunnel through' the EKC. It is also important to note that where improvements in indicators have occurred, this has not been an automatic process. Indicators will only improve as a result of policy and investment and not as a result of economic growth *per se*. If such policy and investment does occur, it appears that economic growth can be compatible with a reduction in emissions of local air pollutants. For other indicators, policy initiatives will need to be multilateral to overcome the disincentives associated with unilaterally tackling indicators such as carbon dioxide or energy use. If appropriate policies are implemented and technological advance continues then it may be possible for global or indirect indicators also to improve in association with economic growth. As noted in Chapter 8, however, only the careful monitoring of physical accounts will tell us to what extent this compatibility is being attained.

With regard to possible extensions of the thesis, Panayotou (1997) has noted that the EKC relationship effectively tells us very little about the actual determinants of environmental quality. Since income is used to cover all changes which may take place with economic development, the EKC relationship can provide little information on how factors such as the structure of the economy, the *rate* of income growth or the quality of institutions will determine environmental quality. In examining the determinants of sulphur dioxide, Panayotou therefore introduces variables to represent the scale of the economy, the proportion of industrial output in GDP, the growth rate of income, the quality of institutions, and per capita income to represent both the demand and supply for pollution abatement. Such an expansion of the typical EKC relationship could provide useful insights for policy-makers. It may therefore prove worthwhile to undertake a similar analysis on the environmental variables considered in this thesis, thereby providing further information on the linkages between the economy and the environment.

An additional point not yet considered in the thesis is the fact that certain pollutants may only be falling in the developed regions because of structural changes in the global economy. More specifically, due to changing comparative advantage many developed economies have seen their industrial share of GDP fall, to be replaced by an expansion of the tertiary sector, whilst many developing economies are experiencing an increase in their industrial share of GDP. It may therefore be the case that pollution is falling in the developed regions as the emphasis of the economy moves from heavy industry, whilst pollution is rising in the developing regions as their industrial sectors expand.[2] If this is so, developing regions may not be able to follow the same pollution paths as those estimated in Chapters 5 and 6 since they may have no-one to whom their industry, and hence pollution, can be passed.

Lucas *et al.* (1992) partially address this issue by considering how the toxic intensity of production has changed in response to economic development for a wide range of developed and developing countries over the period 1960-88. They find that toxic releases from manufacturing, as a proportion of GDP, have an inverted U relationship with per capita GDP. This has to be due to one of two factors; either the manufacturing sector becomes 'cleaner' once a certain per capita income level is attained, or the manufacturing sector becomes smaller, relative to GDP. Lucas *et al.* then estimate the relationship between toxic releases from manufacturing, as a proportion of *manufacturing output*, and per capita GDP. They find that the toxic intensity of manufacturing output increases monotonically with per capita income. Thus, the original inverted U relationship between the toxic intensity of GDP and per capita GDP has to be due to the fact that the manufacturing sector has become smaller relative to GDP, and not actually become 'cleaner'. This finding therefore supports the hypothesis suggested above that, rather than becoming 'cleaner' with economic development, the manufacturing sector simply becomes smaller as manufacturing output shifts to less developed economies. Lucas *et al.* perform the above

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[2] It is important to distinguish this argument from the 'pollution haven' hypothesis, since the two often become confused. It is not being claimed that industries will uproot from developed countries and move to developing countries to take advantage of lax environmental standards. Rather, it is suggested that changes in comparative advantage occur as economies develop resulting in a natural progression from industrial output towards the service sector.

analysis using sectoral toxic intensities, but the publication of sectoral *air pollution* intensities by Hettige *et al.* would now allow such an analysis for local air pollutants. It is therefore suggested that a useful extension to this thesis would be to examine the manner in which the pollution intensity of GDP and of manufacturing output has changed with economic development, following Lucas *et al.* This would then provide an explanation of why the EKC inverted U relationship arises. It may also indicate whether the developing regions are likely to experience difficulties in trying to attain turning points at similar income levels to those experienced in the developed regions.

To conclude, this thesis has indicated the complexity of the linkages between trade liberalisation, economic growth and the environment. Although these relationships are becoming better understood, there is still much uncertainty and a number of unresolved issues. Something far more certain, however, is that these linkages will attract increasing attention in policy-making circles, particularly due to the continued globalisation of national economies.

Appendix A.

GATT Articles of Agreement.

I	General Most-Favoured Nation Treatment
II	Schedules of Concessions
III	National Treatment on Internal Taxation and regulation
IV	Special Provisions Relating to Cinematograph Films
V	Freedom of Transit
VI	Anti-dumping and Countervailing Duties
VII	Valuation for Customs Purposes
VIII	Fees and Formalities connected with Importation and Exportation
IX	Marks of Origin
X	Publication and Administration of Trade Regulations
XI	General Elimination of Quantitative Restrictions
XII	Restrictions to Safeguard Balance of Payments
XIII	Non-discriminatory Administration of Quantitative Restrictions
XIV	Exceptions to the rule of Non-discrimination
XV	Exchange Arrangements
XVI	Subsidies
XVII	State Trading Enterprises
XVIII	Governmental Assistance to Economic Development
XIX	Emergency action on Imports of Particular Products
XX	General Exceptions
XXI	Security Exceptions
XXII	Consulatation
XXIII	Nullification or Impairment
XXIV	Territorial Application-Frontier Traffic-Customs Unions and Free Trade Areas
XXV	Joint Action by the Contracting Parties
XXVI	Acceptance, Entry into Force and Registration
XXVII	Withholding or Withdrawal of Concessions
XXVIII	Modification of Schedules and Tariff Negotiations
XXIX	The Relation of this Agreement to the Havana Charter
XXX	Amendments
XXXI	Withdrawal
XXXII	Contracting Parties
XXXIII	Accession
XXXIV	Annexes
XXXV	Non-application of the Agreement between particular Contracting Parties

Appendix B.

The GATT Negotiating Rounds.

Round	Dates	No. of countries	Value of trade covered
Geneva	1947	23	$10 billion
Annecy	1949	29	-
Torquay	1950-51	32	-
Geneva	1956	33	$2.5 billion
Dillon	1961-62	39	$4.9 billion
Kennedy	1964-67	74	$40 billion
Tokyo	1973-79	99	$155 billion
Uruguay	1986-94	103	-

Appendix C.

Uruguay Round Negotiating Groups.

Trade Barriers
Tariffs
Non-Tariff Measures

Sectors
Natural Resource Based Products
Tropical Products
Textiles and Clothing
Agriculture

GATT System
Safeguards
Subsidies and Countervailing Measures
GATT Articles
MTN Agreements and Arrangements
Functioning of the GATT System
Dispute Settlement

New Issues
Trade-Related Intellectual Property Rights
Trade-Related Investment Measures
Services

Appendix D.

Timetable for Further WTO Negotiations.

DATE		ITEM	SOURCE
1995	January 1	WTO enters into force	Marrakesh Decl.
	June 30	Deadline for negotiations on financial services and on movement of natural persons	GATS Annex; ministerial decision
1996	January 1	Government Procurement Agreement enters into force	GPA Article XXIV.1
	April 30	Deadline for negotiations on basic telecommunications services	GATS Annex; ministerial decision
	June 30	Review of operation of provision regarding R&D subsidies	Article 8.2, footnote 25 of subsidies agreement
	June 30	Deadline for negotiations on maritime services	GATS Annex; ministerial decision
1997	January 1	Start negotiations on government procurement of services	GATS Article XIII
	January 1	First review of provisions on preshipment inspection(reviews every 3 years thereafter)	Article 6 of preshipment inspection agreement
	January 1	First review of TRIPs section on geographical indications	TRIPs Article 24.2
	December 31	Deadline for negotiations on emergency safeguards for services	GATS Article X
1998	January 1	Examine standard of review for antidumping disputes, and consider its application to countervail cases	Ministerial agreement

	January 1	First review of operation and implementation of TBT provisions (reviews are to be held every 3 years thereafter)	Article 15.4 of the TBT agreement
	January 1	Deadline for report with recommendation from Working Party on Trade in Services and the Environment on modification of GATS Article XIV (general exceptions)	Ministerial decision
	January 1	Review of operation and implementation of sanitary and phytosanitary provisions (further reviews to be held as need arises)	Article 12.7 of sanitary and phyto sanitary agreement
1999	January 1	Start negotiations on further improvement of the GPA (extensions of coverage)	GPA Article XXIV.7
	January 1	Deadline for review of provision on patent or sui generis protection of plant varieties	TRIPs agreement Article 27.3b
	January 1	Deadline for review of dispute settlement rules and procedures	Ministerial decision
	June 30	Start review of provisions on serious prejudice and nonactionable subsidies	Article 31 of subsidies agreement
2000	January 1	Start first round of negotiations on progressive liberalisation of services (new negotiations to increase the general level of specific commitments)	GATS Article XIX
	January 1	Review of Article II (MFN) exemptions	GATS Annex

January 1	Launch new negotiations to continue reform process in agriculture	Article 20 of agriculture agreement
January 1	First review of TRIPs agreement; reviews to be held every 2 years thereafter	TRIPs agreement Article 71.1
January 1	Deadline for review of TRIMs agreement and consideration of whether to complement it with provisions on investment and competition policy	TRIMs agreement Article 9
January 1	Review of interpretation of the rules on modification and withdrawal of concessions	Understanding on Interpretation of GATT Article XXVII
January 1	First review of grandfathering of US Jones Act (and like provisions); reviews to be held every 2 years thereafter	Paragraph 2 of GATT 1994
January 1	Deadline for appraisal of TPRM	TPRM agreement section F
Unspecified	Negotiations on increased protection for geographical indications for wines and spirits	TRIPs agreement Articles 23 and 24.1
Unspecified	Subsidies in services	GATS Article XV

Appendix E.

GATT/WTO Membership, 1994. (Dates indicate accession to the GATT).

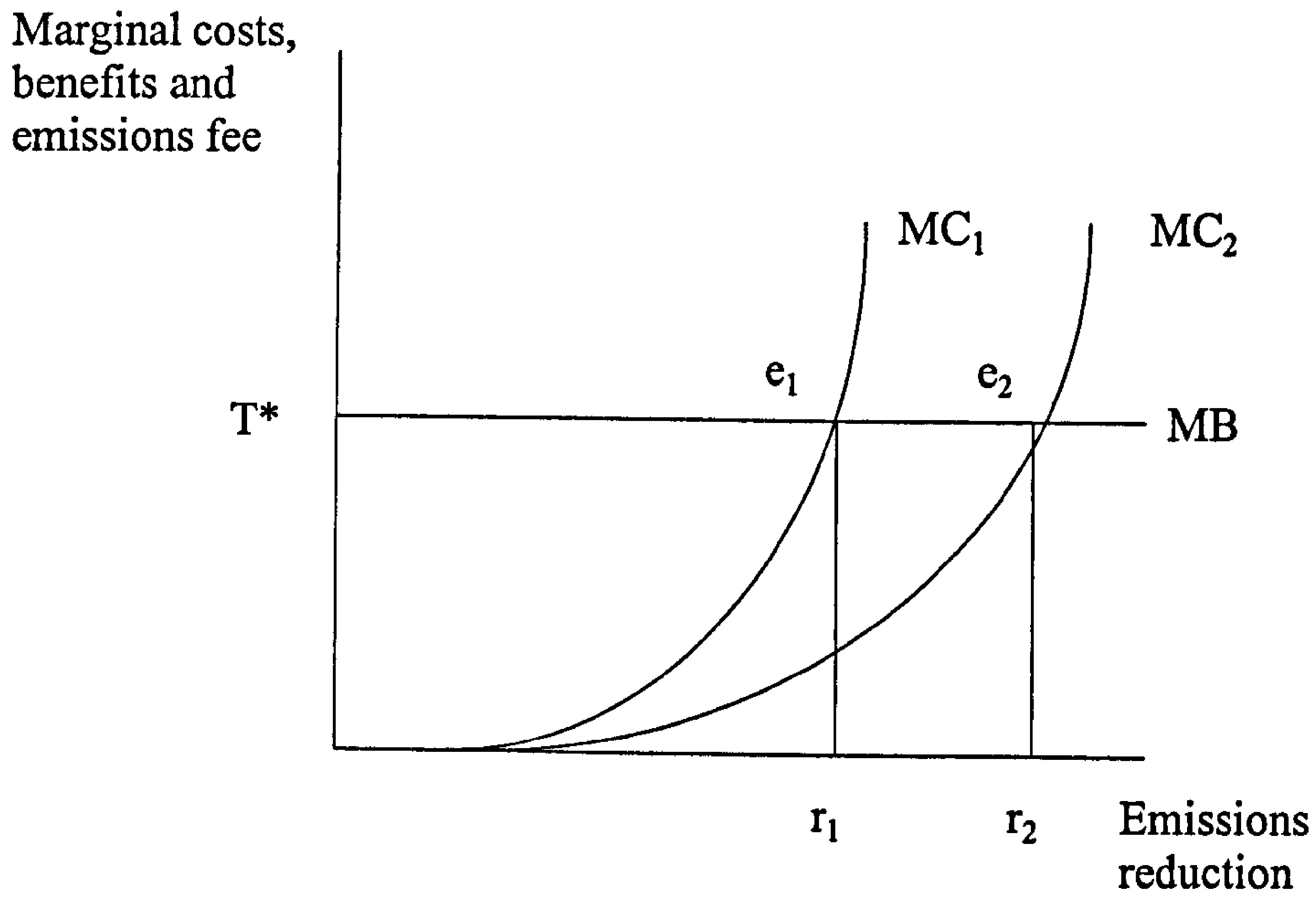
Angola	1994
Antigua and Barbuda	1987
Argentina	1967
Australia	1948
Austria	1951
Bahrain	1993
Bangladesh	1972
Barbados	1967
Belgium	1948
Belize	1983
Benin	1963
Bolivia	1990
Botswana	1987
Brazil	1948
Brunei	1993
Burkina Faso	1963
Burundi	1965
Cameroon	1963
Canada	1948
Central African Republic	1963
Chad	1963
Chile	1949
Colombia	1981
Congo	1963
Costa Rica	1990
Cote d'Ivoire	1963
Cuba	1948
Cyprus	1963
Czech Republic	1993
Denmark	1950
Djibouti	1994
Dominica	1993
Dominican Republic	1950
Egypt	1970
El Salvador	1991
Fiji	1993
Finland	1950
France	1948
Gabon	1963
Gambia	1965
Germany	1951
Ghana	1957
Greece	1950
Grenada	1994
Guatemala	1991
Guinea, Republic of	1994
Guinea-Bissau	1994
Guyana	1966
Haiti	1950
Honduras	1994
Hong Kong	1986
Hungary	1973
Iceland	1968
India	1948
Indonesia	1950
Ireland	1967
Israel	1962
Italy	1950
Jamaica	1963
Japan	1955
Kenya	1964
Korea, Republic of	1967
Kuwait	1963
Lesotho	1988
Liechtenstein	1994
Luxembourg	1948
Macao	1991
Madagascar	1963
Malawi	1964
Malaysia	1957
Maldives	1983
Mali	1993
Malta	1964
Mauritania	1963
Mauritius	1970
Mexico	1986
Morocco	1987
Mozambique	1992
Myanmar	1948
Namibia	1992

Netherlands	1948	South Africa	1948
New Zealand	1948	Spain	1963
Nicaragua	1950	Sri Lanka	1948
Niger	1963	Surinam	1978
Nigeria	1960	Swaziland	1993
Norway	1948	Sweden	1950
Papua New Guinea	1994	Switzerland	1966
Pakistan	1948	Tanzania	1961
Paraguay	1993	Thailand	1982
Peru	1951	Togo	1964
Philippines	1979	Trinidad and Tobago	1962
Poland	1967	Tunisia	1990
Portugal	1962	Turkey	1951
Qatar	1994	Uganda	1962
Romania	1971	United Arab Emirates	1994
Rwanda	1966	United Kingdom	1948
St. Kitts and Nevis	1994	USA	1948
St. Vincent and Grenadines	1993	Uruguay	1953
Senegal	1993	Venezuala	1990
Sierra Leone	1963	Yugoslavia	1966
Singapore	1961	Zaire	1971
Slovak Republic	1993	Zambia	1982
Slovenia	1994	Zimbabwe	1948
Solomon Islands	1994		

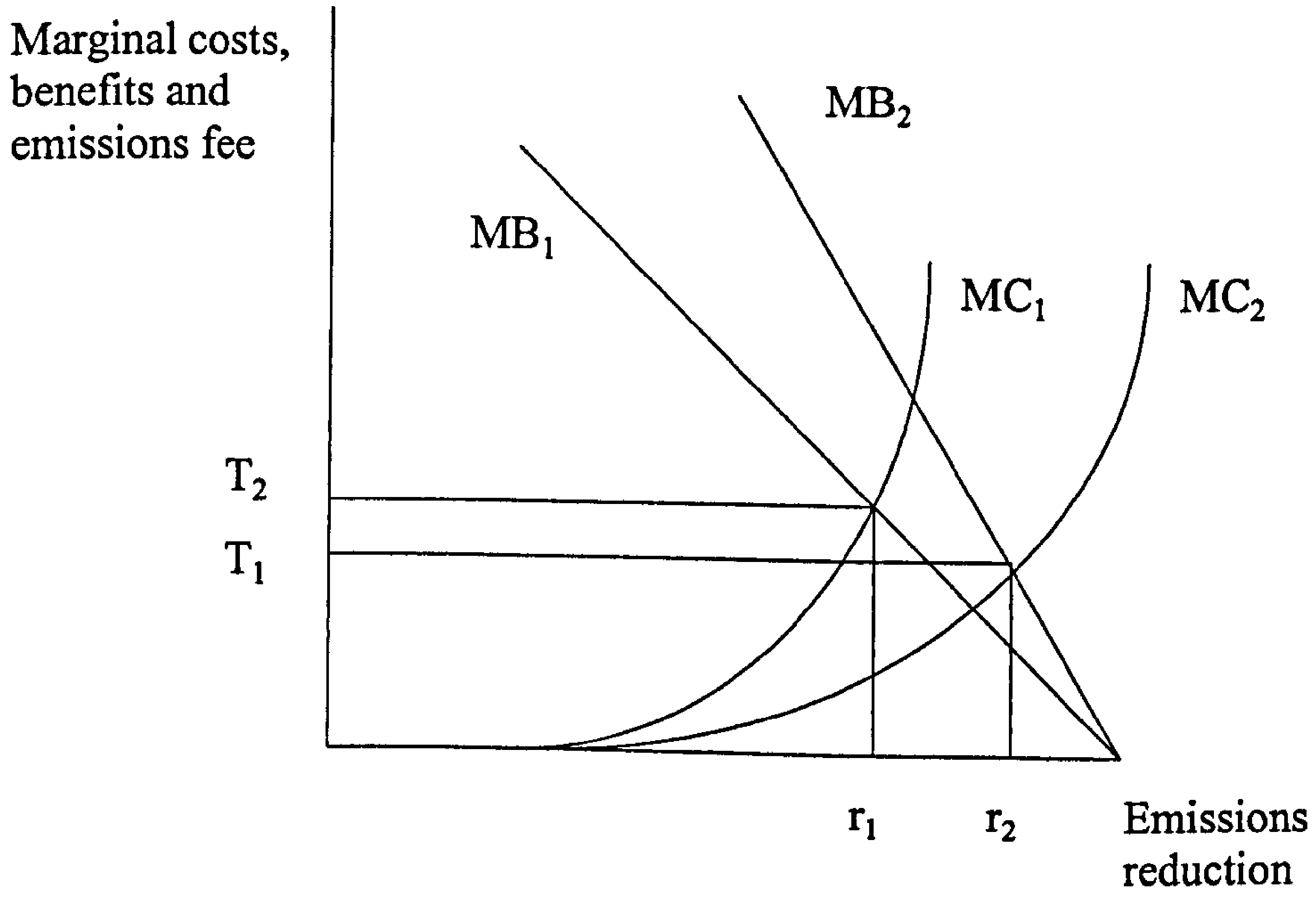
Source: Hoekman and Kostecki (1995).

Appendix F. Diagrams from Nordhaus (1994).

Policy for Global Externalities. DIAGRAM 1 (from Nordhaus (1994)).



Policy for Local Externalities. DIAGRAM 2 (from Nordhaus (1994)).



Appendix G.

Quadratic levels functions are symmetric around a maximum turning point, quadratic logs functions are not. A proof.

Turning points for 2 example functions:

Quadratic levels:

$$e = a + by - \frac{1}{2}cy^2$$

$$\frac{de}{dy} = b - cy$$

Quadratic logs:

$$\ln e = a + b\ln y - \frac{1}{2}c(\ln y)^2$$

$$\frac{d\ln e}{d\ln y} = b - c\ln y$$

turning points:

$$y^* = \frac{b}{c}$$

$$\ln y = \frac{b}{c}$$

$$y^* = e^{\frac{b}{c}}$$

and $e^* = a + b\left(\frac{b}{c}\right) - \frac{1}{2}c\left(\frac{b}{c}\right)^2$ for both functions.

Consider $y^* \pm z$ for the quadratic levels function;

$$e = a + b(y \pm z) - \frac{1}{2}c(y \pm z)^2$$

$$e^+ = a + by^* - \frac{1}{2}cy^{*2} + bz - cy^*z - \frac{1}{2}cz^2 \quad \text{for } y = y^* + z$$

$$e^- = a + by^* - \frac{1}{2}cy^{*2} - bz + cy^*z - \frac{1}{2}cz^2 \quad \text{for } y = y^* - z$$

but $y^* = \dfrac{b}{c}$

therefore $e^{+}=e^{-}=e^{*}-\frac{1}{2}cz^{2}$ and the function is symmetric around the maximum turning point.

Now consider the quadratic logs function;

as before;

$$\ln e=a+b(\ln y^{*}\pm\ln z)-\frac{1}{2}c(\ln y^{*}\pm\ln z)^{2}$$

and $\ln e^{+}=\ln e^{-}=\ln e^{*}-\frac{1}{2}c(\ln z)^{2}$

this function is also symmetric around lny^* but, as shall be seen, not around y^*.

$\ln y^{+}=\ln y^{*}+\ln z$ $\quad$ $\ln y^{-}=\ln y^{*}-\ln z$

$y^{+}=y^{*}.z$ $\quad$ $y^{-}=\frac{y^{*}}{z}$

and $\frac{y^{+}}{y^{-}}=z^{2}$

symmetry implies $y^{+}-y^{*}=y^{*}-y^{-}$ for all values of y

therefore $(y^{-}z^{2})-y^{*}=y^{*}-y^{-}$

$$\left(\frac{y^{*}}{z}z^{2}\right)-y^{*}=y^{*}-\frac{y^{*}}{z}$$

$$y^{*}z-y^{*}=y^{*}-\frac{y^{*}}{z}$$

$$z^{2}-z=z-1$$

$$z^{2}-2z+1=0$$

This condition does not hold for z > 1. So if z > 1 $y^{+}-y^{*}>y^{*}-y^{-}$

The log quadratic function is therefore not symmetric around y^*, since the same e value requires $(y^+ - y^*) > (y^* - y^-)$.

Appendix H.

Kmenta's (1986) GLS Process.

This process firstly estimates the regression coefficients by ordinary least squares and obtains estimated residuals. These estimated residuals are then used to calculate estimates of the autocorrelation parameter for each region (p'_i), where;

$$p'_i = \frac{\sum e_{it} e_{it-1}}{\sum e^2_{it-1}} \qquad t = 2, 3, \ldots T \qquad \ldots(1)$$

To avoid the possibility of p' exceeding one in value, p_i is estimated by the sample coefficient of correlation between e_{it} and e_{it-1} ie.

$$p'_i = \frac{\sqrt{e_{it} e_{it-1}}}{\sqrt{\sum e^2_{it}}\sqrt{\sum e^2_{it-1}}} \qquad \ldots(2)$$

The estimated autocorrelation parameters are then used to transform the observations, such that;

$$Y^*_{it} = B_1 X^*_{it,1} + B_2 X^*_{it,2} + \ldots + B_k X^*_{it,k} + u^*_{it} \qquad \ldots(3)$$

where, $Y^*_{it} = \sqrt{1 - p'^2_i} Y_{it}$ for t = 1

$Y^*_{it} = Y_{it} - p'_i Y_{it-1}$ for t = 2, 3, ... T

and $X^*_{it,k} = \sqrt{1 - p'^2_i} X_{it,k}$ for t = 1

$X^*_{it,k} = X_{it,k} - p'_i X_{it-1,k}$ for t = 2, 3, ... T

k = 1, 2, ... K

i = 1, 2, ... I

If ordinary least squares is then applied to equation (3), the resultant regression residuals (u^*_{it}) can be used to estimate the variances of u_{it} by;

$$s^2_{ui} = \frac{1}{T-K} \sum_{t=1}^{T} u^{*2}_{it} \qquad \ldots(4)$$

Note that equation (3) can be considered as the transformation to remove autocorrelation. To remove heteroscedasticity, both sides of equation (3) should be divided by s_{ui} which is obtained from equation (4). This leads to;

$$Y^{**}_{it} = B_1 X^{**}_{it,1} + B_2 X^{**}_{it,2} + \ldots + B_k X^{**}_{it,k} + u^{**}_{it} \qquad \ldots(5)$$

where $$Y^{**}_{it} = \frac{Y^{*}_{it}}{s_{ui}}$$

$$X^{**}_{it,k} = \frac{X^{*}_{it,k}}{s_{ui}} \qquad k = 1, 2, \ldots K$$

$$u^{**}_{it} = \frac{u^{*}_{it}}{s_{ui}}$$

t = 1, 2, ... T
I = 1, 2, ... N

The disturbance u^{**}_{it} is asymptotically nonautoregressive and homoscedastic. Equation (5) is then estimated by ordinary least squares, utilising all the NT pooled observations. (Kmenta (1986) pp.618-620).

Appendix I.

Alternative GLS, OLS and Random Effects Results.

SULPHUR DIOXIDE	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.81939e-05 (2.135)	31.39 (5.842)	0.33209e-05 (0.8002)
Y^2	-0.71465e-09 (-4.327)	-1.7912 (-6.2)	-0.57026e-09 (-3.393)
D1 W.Germany	0.017498 (2.474)	0.30511 (2.741)	0.028315 (3.961)
D2 Netherlands	-0.0031415 (-0.4357)	-0.26173 (-2.411)	0.0060405 (0.8741)
D3 Norway	0.012036 (1.099)	0.044347 (0.3965)	0.024822 (3.466)
D4 UK	0.048151 (5.523)	0.92703 (8.75)	0.054036 (8.045)
D5 USA	0.12386 (11.24)	2.1271 (16.87)	0.13489 (16.87)
D6 Finland	0.053008 (5.279)	1.0427 (9.63)	0.064974 (9.404)
D7 France	0.014667 (1.859)	0.29183 (2.633)	0.025156 (3.532)
D8 Canada	0.18313 (9.794)	2.4336 (20.29)	0.18915 (24.94)
D9 Denmark	0.042668 (5.756)	0.91282 (8.208)	0.053384 (7.484)
D10 Italy	0.0090662 (1.278)	0.26878 (2.607)	0.017733 (2.733)
CONSTANT Ireland	0.029371 (1.469)	-140.47 (-5.631)	0.056657 (2.586)
Buse R^2 /R^2	0.787	0.9092	0.9093
D.W.		0.751*	1.0185*
B.P.		142.965 23 df*	75.624 23 df*
B.P.G.		23.522 12 df*	42.536 12 df*
HARVEY		21.218 12 df*	36.006 12 df*
GLEJSER		26.363 12 df*	84.82 12 df*
11 COUNTRIES, 15 YEARS = 165 OBSERVATIONS			

SULPHUR DIOXIDE	GLS LOGS QUADRATIC RANDOM EFFECTS		
Y	30.402 (5.48)	CONSTANT	-135.39 (-5.25)
Y^2	-1.7353 (-5.82)	R^2	0.6017
11 COUNTRIES, 15 YEARS = 165 OBSERVATIONS			

SUSPENDED PARTICULATE MATTER	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.39428e-05 (3.714)	28.864 (5.905)	0.72573e-05 (3.91)
Y^2	-0.24249e-09 (-4.845)	-1.6247 (-6.158)	-0.38616e-09 (-5.092)
D1 Netherlands	-0.0013904 (-0.2912)	0.029657 (0.4362)	-0.0028923 (-1.429)
D2 Ireland	0.016411 (3.414)	1.1006 (11.06)	0.017827 (5.894)
D3 UK	0.7618e-03 (0.1579)	0.30848 (4.487)	-0.69844e-03 (-0.3422)
D4 USA	0.04309 (6.888)	2.3457 (30.7)	0.043728 (17.89)
D5 W.Germany	0.0030954 (0.6441)	0.45076 (6.924)	0.0018076 (0.9293)
D6 France	-0.0011918 (-0.246)	-0.064738 (-0.9852)	-0.0026658 (-1.357)
CONSTANT Norway	-0.0035521 (-0.5037)	-132.82 (-5.867)	-0.021393 (-1.85)
Buse R^2 / R^2	0.8788	0.9495	0.8594
D.W.		0.7391*	1.4469*
B.P.		143.694 23 df*	34.701 23 df
B.P.G.		34.345 8 df*	23.886 8 df*
HARVEY		29.076 8 df*	36.889 8 df*
GLEJSER		41.766 8 df*	76.247 8 df*
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

SPM	GLS LOGS QUADRATIC RANDOM EFFECTS		
Y	26.614 (5.03)	CONSTANT	-121.92 (-4.98)
Y^2	-1.502 (-5.26)	R^2	0.5045
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

CARBON MONOXIDE	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.63047e-04 (6.768)	37.037 (4.004)	0.95703e-04 (7.674)
Y^2	-0.31289e-08 (-7.993)	-1.9961 (-4.048)	-0.4245e-08 (-8.566)
D1 W. Germany	0.084724 (3.137)	0.46752 (8.294)	0.063569 (6.553)
D2 Netherlands	0.0052853 (0.2776)	-0.038853 (-0.7023)	-0.004113 (-0.4333)
D3 Norway	0.14203 (4.746)	0.89956 (15.32)	0.14472 (14.44)
D4 Denmark	0.045859 (25.12)	0.35333 (6.283)	0.042779 (4.422)
D5 USA	0.43489 (25.12)	1.7615 (21.39)	0.42718 (30.0)
D6 France	0.067419 (4.632)	0.46714 (8.339)	0.057734 (5.988)
CONSTANT UK	-0.20746 (-3.685)	-174.1 (-4.015)	-0.43272 (-5.545)
Buse R^2 / R^2	0.9261	0.916	0.8749
D.W.		0.5491*	0.8638*
B.P.		254.236 23 df*	163.043 23 df*
B.P.G.		29.725 8 df*	28.881 8 df*
HARVEY		18.834 8 df*	19.076 8 df*
GLEJSER		31.294 8 df*	34.788 8 df*
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

CARBON MONOXIDE	GLS LOGS QUADRATIC RANDOM EFFECTS		
Y	10.345 (0.81)	CONSTANT	-49.843 (-0.83)
Y^2	-0.557 (-0.82)	R^2	0.01
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

NITROGEN DIOXIDE	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.80679e-05 (4.943)	26.532 (4.523)	0.12668e-04 (4.1)
Y^2	-0.26678e-09 (-4.171)	-1.3881 (-4.445)	-0.44159e-09 (-3.653)
D1 W.Germany	-0.0092725 (-1.983)	-0.14526 (-3.291)	-0.0076604 (-2.718)
D2 Netherlands	-0.010546 (-3.904)	-0.23342 (-5.246)	-0.01101 (-3.876)
D3 Norway	-0.68834e-03 (-0.2079)	-0.010597 (-0.2357)	-0.0016903 (-0.5926)
D4 Sweden	-0.011491 (-5.031)	-0.26573 (-5.98)	-0.012899 (-4.546)
D5 UK	-0.0043921 (-1.549)	-0.092727 (-2.067)	-0.005269 (-1.838)
D6 USA	0.035871 (12.65)	0.54449 (9.763)	0.036343 (10.09)
D7 Finland	0.006736 (1.118)	0.065263 (1.47)	0.0053541 (1.889)
D8 France	-0.022132 (-4.748)	-0.62368 (14.13)	-0.024292 (-8.618)
D9 Canada	0.023866 (9.067)	0.40114 (8.069)	0.024533 (7.735)
CONSTANT Denmark	-0.0082642 (-0.7731)	-129.72 (-4.71)	-0.037049 (-1.859)
Buse R^2/R^2	0.897	0.8878	0.8473
D.W.		1.1181*	1.4809*
B.P.		60.468 23 df*	32.357 23 df
B.P.G.		16.034 11 df	11.037 11 df
HARVEY		30.944 11 df*	36.784 11 df*
GLEJSER		61.224 11 df*	47.471 11 df*
10 COUNTRIES, 15 YEARS = 150 OBSERVATIONS			

NITROGEN DIOXIDE	GLS LOGS QUADRATIC RANDOM EFFECTS		
Y	22.771 (3.69)	CONSTANT	-112.3 (-3.88)
Y^2	-1.1857 (-3.61)	R^2	0.2509
10 COUNTRIES, 15 YEARS = 150 OBSERVATIONS			

SULPHUR DIOXIDE TRANSPORT	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.42555e-06 (2.622)	30.458 (4.4)	0.60036e-06 (2.763)
Y^2	-0.22752e-10 (-3.154)	-1.6588 (-4.45)	-0.29304e-10 (-3.251)
D1 W.Germany	0.2376e-03 (0.6638)	-0.15201 (-1.13)	-0.17416e-03 (-0.5442)
D2 Netherlands	0.0012188 (2.684)	0.39097 (2.988)	0.6903e-03 (2.219)
D3 Norway	0.0024231 (4.698)	1.0005 (7.379)	0.002435 (7.658)
D4 Denmark	0.0021622 (3.35)	0.92562 (6.886)	0.002377 (7.436)
D5 UK	0.90140e-03 (2.539)	0.28989 (2.274)	0.48331e-03 (1.604)
D6 Finland	0.96483e-04 (0.3029)	-0.089637 (-0.6897)	-0.10766e-03 (-0.3492)
D7 France	0.7915e-03 (2.097)	0.34288 (2.501)	0.57535e-03 (1.799)
D8 Canada	0.0034701 (10.37)	1.277 (8.674)	0.0033188 (9.845)
CONSTANT Ireland	-0.47144e-03 (-0.5758)	-146.24 (-4.557)	-0.0013808 (-1.224)
Buse R^2 / R^2	0.6281	0.7721	0.7902
D.W.		0.8204*	0.8332*
B.P.		130.057 23 df*	140.143 23 df*
B.P.G.		19.129 10 df*	24.565 10 df*
HARVEY		22.029 10 df*	17.117 10 df
GLEJSER		35.059 10 df *	40.623 10 df*
9 COUNTRIES, 15 YEARS = 135 OBSERVATIONS			

SPM TRANSPORT	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.45984e-06 (5.795)	6.0208 (1.761)	0.39248e-06 (4.101)
Y^2	-0.15332e-10 (-4.285)	-0.28686 (1.761)	-0.10955e-10 (-2.802)
D1 Netherlands	0.55799e-03 (2.661)	-0.28686 (1.555)	0.70813e-03 (7.115)
D2 Ireland	0.0022374 (17.51)	1.3591 (20.13)	0.0023976 (15.64)
D3 UK	0.0020182 (4.127)	1.1066 (24.23)	0.0019407 (19.34)
D4 USA	0.0047677 (23.29)	1.6687 (28.15)	0.0045623 (32.27)
D5 W.Germany	0.12608e-03 (0.7484)	0.12823 (2.852)	0.97011e-04 (0.9813)
D6 Norway	0.7044e-03 (5.457)	0.57379 (12.49)	0.70663e-03 (6.973)
CONSTANT France	-0.0022817 (-4.954)	-38.219 (-2.413)	-0.0021894 (-3.622)
Buse R^2 / R^2	0.9159	0.9605	0.9733
D.W.		0.6598*	0.558*
B.P.		189.408 23 df*	280.644 23 df*
B.P.G.		15.355 8 df*	30.474 8 df*
HARVEY		36.69 8 df*	17.452 8 df*
GLEJSER		34.445 8 df*	35.359 8 df*
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

NITROGEN DIOXIDE TRANSPORT	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.81929e-05 (9.206)	31.433 (7.38)	0.10342e-04 (12.07)
Y^2	-0.27281 (-7.267)	-1.6332 (-7.199)	-0.35426e-09 (-10.56)
D1 W.Germany	0.0085555 (10.58)	0.43631 (13.77)	0.0092286 (11.85)
D2 Netherlands	0.0064873 (6.479)	0.34627 (10.87)	0.0071632 (9.148)
D3 UK	0.0062889 (10.95)	0.30275 (9.426)	0.0064817 (8.201)
D4 USA	0.022396 (16.78)	0.82012 (20.0)	0.023362 (22.97)
D5 Finland	0.016311 (17.15)	0.67701 (21.28)	0.15931 (20.37)
D6 Denmark	0.0084184 (4.89)	0.42724 (13.49)	0.00945 (12.14)
D7 Canada	0.029057 (18.88)	0.99178 (27.31)	0.030264 (33.98)
D8 Norway	0.021993 (12.17)	0.83472 (25.73)	0.022016 (27.8)
CONSTANT France	-0.042209 (-7.941)	-155.24 (-7.765)	-0.056221 (-10.16)
Buse R^2 / R^2	0.9195	0.9447	0.9611
D.W.		1.363*	1.1225*
B.P.		31.316 23 df	58.869 23 df*
B.P.G.		32.036 10 df*	29.087 10 df*
HARVEY		19.288 10 df*	35.925 10 df*
GLEJSER		62.129 10 df*	48.609 10 df*
9 COUNTRIES, 15 YEARS = 135 OBSERVATIONS			

NITRATES	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.63998e-03 (7.048)	11.301 (1.206)	0.74768e-03 (1.517)
Y^2	-0.20548e-07 (-6.458)	0.55558 (-1.1)	-0.24934e-07 (-1.293)
D1 Spain	2.4616 (3.726)	2.9367 (9.833)	3.1249 (3.514)
D2 W.Germany	3.0431 (5.098)	2.8811 (12.92)	2.8297 (4.325)
D3 Norway	0.31205 (1.753)	0.74755 (2.843)	0.27501 (0.3585)
D4 Switzerland	1.0368 (2.328)	1.818 (9.543)	0.99675 (1.797)
D5 UK	6.0931 (10.47)	3.559 (16.01)	5.5116 (8.523)
D6 USA	0.97829 (5.699)	1.77 (8.366)	0.91055 (1.464)
D7 Italy	2.2282 (19.38)	2.6568 (9.281)	2.2059 (2.657)
D8 Denmark	4.2815 (1.712)	3.1075 (13.86)	4.0885 (6.21)
D9 Finland	0.61917 (6.343)	1.2184 (4.468)	0.61981 (0.7799)
D10 Greece	2.8385 (11.63)	2.9203 (7.531)	2.961 (2.507)
D11 Netherlands	3.997 (16.09)	3.199 (14.88)	3.6898 (5.84)
D12 Czech.	6.43 (14.38)	5.0296 (7.048)	6.9325 (3.951)
D13 Hungary	3.5471 (6.877)	3.4533 (7.18)	3.7783 (2.697)
D14 Belgium	3.1955 (6.151)	3.0243 (12.94)	3.2042 (4.691)
CONSTANT Canada	-4.7062 (-7.171)	-59.016 (-1.357)	-5.3282 (-1.67)
Buse R^2 / R^2	0.9033	0.8463	0.6617
D.W.		1.3303*	1.2965*
B.P.		61.691 23 df*	57.405 23 df*
B.P.G.		36.943 16 df*	32.668 16 df*
HARVEY		25.709 16 df	80.684 16 df*
GLEJSER		45.268 16 df*	92.88 16 df*
30 RIVERS, 4 YEARS = 120 OBSERVATIONS			

PHOSPHOROUS	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.66417e-04 (2.67)	32.132 (3.692)	0.11973e-03 (2.303)
Y^2	-0.33954e-08 (-3.165)	-1.8343 (-3.793)	-0.70288e-08 (-3.008)
CONSTANT	0.22404 (1.538)	-141.19 (-3.612)	0.089794 (0.316)
D.W.		0.6398*	1.0538*
B.P.		97.085 23 df*	73.36 23 df*
B.P.G.		1.145 2 df	2.346 2 df
HARVEY		2.459 2 df	2.68 2 df
GLEJSER		2.834 2 df	3.12 2 df
Buse R^2 / R^2	0.1261	0.1727	0.1435
28 RIVERS, 4 YEARS = 112 OBSERVATIONS			

CARBON DIOXIDE	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.25205e-03 (11.79)	4.1986 (15.99)	0.28167e-03 (13.39)
Y^2	-0.50253e-08 (-3.432)	-0.20934 (-13.36)	-0.81351e-08 (13.39)
D1 Asia	0.0789 (2.641)	0.16831 (6.768)	0.051587 (1.113)
D2 E.Europe	1.9272 (27.17)	1.1587 (23.29)	1.9147 (27.17)
D3 N.America	2.5543 (9.773)	1.1834 (17.7)	2.9347 (26.35)
D4 Oceania	0.126 (0.8974)	0.35812 (6.153)	0.23485 (2.479)
D5 S.&C.America	-0.25222 (-4.389)	-0.37002 (-7.881)	-0.28756 (-4.653)
D6 W.Europe	0.25222 (1.31)	0.40552 (6.879)	0.2951 (3.021)
CONSTANT Africa	-0.023432 (-1.028)	-20.536 (-19.09)	-0.052139 (-1.32)

CARBON DIOXIDE (continued)	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Buse R^2 / R^2	0.9518	0.9925	0.9883
D.W.		0.2333*	0.2353*
B.P.		648.395 23 df*	657.894 23 df*
B.P.G.		108.946 8 df*	113.096 8 df*
HARVEY		68.075 8 df*	246.804 8 df*
GLEJSER		119.935 8 df*	200.125 8 df*
7 REGIONS, 32 YEARS = 224 OBSERVATIONS			

CARBON DIOXIDE	GLS LOGS QUADRATIC RANDOM EFFECTS		
Y	4.1986 (16.21)	CONSTANT	0.34323 (1.60)
Y^2	-0.20934 (-13.54)	R^2	0.8254
7 REGIONS, 32 YEARS = 224 OBSERVATIONS			

TOTAL ENERGY USE	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.21177e-9 (10.92)	5.3516 (8.214)	0.26248e-9 (6.745)
Y^2	-0.46992e-14 (-5.011)	-0.25974 (-7.327)	-0.65421e-14 (-4.239)
D1 USA	0.32697e-5 (12.84)	0.91146 (15.35)	0.30653e-5 (20.12)
D2 Japan	0.33553e-6 (4.643)	0.12845 (2.217)	0.11988e-6 (0.7906)
D3 Australia	0.12757e-5 (12.84)	0.47099 (7.999)	0.1054e-5 (6.701)
D4 New Zealand	0.84074e-6 (3.955)	0.3132 (5.431)	0.58268e-6 (3.89)
D5 Austria	0.86326e-6 (11.35)	0.34779 (6.025)	0.66396e-6 (4.415)
D6 Belgium	0.15255e-5 (17.02)	0.55587 (9.582)	0.13006e-5 (8.541)
D7 Denmark	0.76078e-6 (7.15)	0.29248 (4.997)	0.51659e-6 (3.323)

TOTAL ENERGY USE (Continued)	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
D8 Finland	0.24085e-5 (14.42)	0.77001 (13.23)	0.21318e-5 (13.88)
D9 France	0.58824e-6 (7.709)	0.23674 (4.044)	0.36789e-6 (2.362)
D10 W.Germany	0.11242e-5 (11.19)	0.43433 (7.413)	0.92348e-6 (5.922)
D11 Greece	0.14872e-6 (2.749)	0.02549 (0.5758)	0.44704e-7 (0.4906)
D12 Ireland	0.62216e-6 (11.87)	0.29285 (5.787)	0.48636e-6 (4.286)
D13 Italy	0.11392e-6 (1.773)	0.019555 (0.3399)	-0.85698e-7 (-0.5754)
D14 Netherlands	0.16023e-5 (21.16)	0.58527 (10.08)	0.14005e-5 (9.181)
D15 Norway	0.21165e-5 (22.16)	0.70429 (11.96)	0.19295e-5 (12.31)
D16 Portugal	-0.62421e-7 (-1.794)	-0.14394 (-3.57)	-0.14919e-6 (-1.799)
D17 Spain	-0.40145e-7 (-0.7483)	-0.11077 (-2.127)	-0.19885e-6 (-1.662)
D18 Sweden	0.19703e-5 (14.99)	0.6556 (11.14)	0.17203e-5 (10.95)
D19 Switzerland	0.69329e-6 (7.9)	0.28219 (4.764)	0.48643e-6 (3.108)
D20 Canada	0.39422e-5 (29.93)	1.0344 (17.47)	0.37148e-5 (24.05)
D21 UK	0.6383e-6 (9.516)	0.26243 (4.545)	0.43732e-6 (2.901)
CONSTANT Turkey	0.33781e-7 (0.6201)	-40.498 (-13.71)	-0.11087e-6 (-0.951)
Buse R^2 / R^2	0.9906	0.9936	0.991
D.W.		0.7604*	0.8288*
B.P.		243.441 23 df*	202.543 23 df*
B.P.G.		77.625 24 df*	77.698 23 df*
HARVEY		35.259 24 df*	103.88 23 df*
GLEJSER		77.873 24 df*	144.403 23 df*
22 COUNTRIES, 13 YEARS = 286 OBSERVATIONS			

CFCs AND HALONS 1986	OLS LEVELS QUADRATIC	OLS LOG LINEAR	OLS LEVELS LINEAR
Y	0.1189e-06 (2.825)	1.6706 (13.15)	0.88314e-07 (10.08)
Y^2	-0.18119e-11 (-0.7433)		
DNeth	0.0019282 (7.079)	1.1157 (1.697)	0.0019562 (7.3)
DUK	0.01116 (4.094)	0.79551 (1.21)	0.0011455 (4.276)
CONSTANT	-0.17404e-03 (-1.309)	-22.62 (-20.7)	-0.93077e-04 (-1.228)
R^2	0.865	0.8533	0.8627
B.P.G.	3.974 2 df	1.6451 1 df	3.344 1 df
HARVEY	8.611 2 df*	1.797 1 df	6.721 1 df*
GLEJSER	11.261 2 df*	1.712 1 df	11.945 1 df*
38 COUNTRIES			

CFCs AND HALONS 1990	OLS LEVELS QUADRATIC
Y	0.86956E-07 (3.315)
Y^2	-0.28268E-11 (-1.968)
DNeth	0.62144E-03 (3.398)
DUK	0.71523E-03 (3.913)
CONSTANT	-0.95833E-04 (-1.131)
R^2	0.7488
B.P.G.	9.658 2 df*
HARVEY	6.389 2 df*
GLEJSER	16.353 2 df*
39 COUNTRIES	

METHANE late 1980s	OLS LEVELS QUADRATIC
Y	0.28477e-05 (0.7429)
Y^2	-0.26751e-11 (-0.01116)
CONSTANT	0.046852 (4.989)
R^2	0.0833
B.P.G.	3.759 2 df
HARVEY	1.75 2 df
GLEJSER	5.4352 2 df
88 COUNTRIES	

ENERGY CONSUMP. TRANSPORT	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC	OLS LOGS LINEAR	OLS LEVELS LINEAR
Y	2.113 (0.7942)	0.67022e-10 (1.237)	1.2006 (13.43)	0.77008e-10 (6.45)
Y^2	-0.051428 (-0.3432)	0.51247e-15 (0.189)		
D1 N.America	0.64266 (4.714)	0.81673e-6 (5.203)	0.62729 (4.895)	0.82815e-6 (5.747)
D2 Oceania	0.069717 (0.6719)	0.51436e-7 (0.4547)	0.070687 (0.6848)	0.49384e-7 (0.4409)
CONSTANT W.Europe	-29.408 (-2.496)	-0.69293e-7 (-0.2638)	-25.374 (-30.9)	-0.11232e-6 (-0.8613)
R^2	0.7452	0.5677	0.7449	0.5676
D.W.	0.9086	1.1116	0.9087*	1.1083*
B.P.	69.066 23 df*	49.406 23 df*	67.236 23 df*	50.326 23 df*
B.P.G.	0.437 4 df	5.077 4 df	0.16 3 df	4.72 3 df
HARVEY	16.826 4 df*	42.006 4 df*	11.436 3 df*	30.567 3 df*
GLEJSER	4.993 4 df	17.512 4 df*	4.035 3 df	16.269 3 df*
24 COUNTRIES, 4 YEARS = 96 OBSERVATIONS				

ENERGY CONSUMP. TRANSPORT	**GLS LEVELS QUADRATIC**	**GLS LEVELS LINEAR**
Y	0.66069e-10 (7.647)	0.64446e-10 (36.73)
Y^2	-0.72735e-16 (-0.1829)	
D1 N.America	0.95916e-6 (4.741)	0.94582e-6 (4.453)
D2 Oceania	0.19022e-6 (3.369)	0.18333e-6 (3.301)
CONSTANT W.Europe	-0.45984e-7 (-1.179)	-0.30891e-7 (-1.208)
Buse R^2	0.9463	0.9389
24 COUNTRIES, 4 YEARS = 96 OBSERVATIONS		

MUNICIPAL WASTE	**GLS LEVELS QUADRATIC**	**OLS LOGS QUADRATIC**	**OLS LEVELS QUADRATIC**
Y	-0.35046e-04 (-5.408)	-19.671 (-3.126)	-0.37065e-04 (-1.61)
Y^2	0.22128e-08 (8.892)	1.0912 (3.222)	0.24023e-08 (2.469)
D1 W.Europe	0.035754 (1.034)	0.48541 (1.535)	0.02796 (0.4665)
D2 N.America	0.2318 (6.539)	0.84862 (2.776)	0.20985 (3.5)
D3 Oceania	0.10468 (2.59)	0.70357 (2.178)	0.095709 (1.515)
CONSTANT E.Europe	0.37807 (10.18)	86.844 (3.0)	0.38406 (4.599)
D.W.		1.102*	1.091*
B.P.		16.729 16 df	19.117 16 df
B.P.G.		3.678 5 df	1.558 5 df
HARVEY		5.537 5 df	8.569 5 df
GLEJSER		5.365 5 df	3.795 5 df
Buse R^2 / R^2	0.9939	0.7442	0.8198
13 COUNTRIES, 4 YEARS = 52 OBSERVATIONS			

TRAFFIC VOLUMES	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC	OLS LOGS LINEAR	OLS LEVELS LINEAR
Y	7.4129 (2.012)	0.63027 (4.916)	1.2858 (7.875)	0.58188 (22.21)
Y^2	-0.33617 (-1.665)	-0.20803e-5 (-0.3855)		
D1 USA	1.0708 (3.105)	3761.4 (7.633)	1.3415 (4.399)	3861.2 (9.221)
D2 Japan	0.34092 (1.022)	-1414.6 (-2.892)	0.6948 (2.696)	-1275.2 (-3.876)
D3 Australia	0.43759 (1.281)	1238.7 (2.42)	0.77291 (2.792)	1379.5 (3.851)
D4 New Zealand	0.76246 (2.266)	758.78 (1.522)	1.1344 (4.495)	906.89 (2.856)
D5 Austria	0.66314 (1.986)	228.28 (0.4643)	1.031 (4.108)	373.04 (1.177)
D6 Belgium	0.54329 (1.616)	-477.14 (-0.9568)	0.90662 (3.533)	-331.44 (-1.02)
D7 Denmark	0.65017 (1.916)	48.793 (0.09627)	0.99922 (3.733)	192.68 (0.5626)
D8 Finland	0.79373 (2.357)	955.6 (1.912)	1.1518 (4.434)	1100.1 (3.331)
D9 France	0.66667 (1.965)	171.41 (0.3378)	1.0186 (3.829)	316.64 (0.9323)
D10 W.Germany	0.63231 (1.863)	-56.435 (-0.1113)	0.97946 (3.648)	86.851 (0.2524)
D11 Greece	0.79575 (2.985)	655.69 (1.958)	1.1225 (6.205)	740.59 (2.939)
D12 Ireland	1.2296 (4.144)	2604.6 (6.653)	1.5923 (7.883)	2715.4 (10.23)
D13 Italy	0.5569 (1.674)	-297.39 (-0.6103)	0.92676 (3.731)	-153.71 (-0.4903)
D14 Netherlands	0.59509 (1.763)	-192.01 (-0.3821)	0.95865 (3.713)	-44.938 (-0.1376)
D15 Norway	0.36799 (1.087)	-1582.1 (-3.158)	0.69921 (2.544)	-1446.8 (-4.051)
D16 Portugal	0.94975 (3.925)	866.87 (2.802)	1.2346 (7.193)	937.84 (3.776)
D17 Spain	0.12295 (0.3997)	-1261.3 (-3.049)	0.49714 (2.361)	-1141.2 (-4.198)

TRAFFIC VOLUMES (continued)	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC	OLS LOGS LINEAR	OLS LEVELS LINEAR
D18 **Sweden**	0.59976 (1.755)	-269.77 (-0.527)	0.93564 (3.381)	-128.83 (-0.36)
D19 **Switzerland**	0.52374 (1.522)	-964.49 (-1.902)	0.81615 (2.82)	-840.08 (-2.151)
D20 **Canada**	0.77962 (2.276)	730.6 (1.472)	1.0749 (3.657)	846.45 (2.145)
D21 **UK**	0.60535 (1.806)	-61.457 (-0.1241)	0.97059 (3.818)	83.644 (0.2601)
CONSTANT **Turkey**	-31.963 (-1.927)	-1589.4 (-4.068)	-4.4304 (-3.361)	-1457.6 (-7.719)
R^2	0.759	0.9343	0.7568	0.9343
D.W.	1.9114	1.2995*	1.9131	1.3014*
B.P.	12.825 23 df	109.051 23 df*	13.257 23 df	107.555 23 df*
B.P.G.	24.88 23 df	25.222 23 df	24.499 22 df	24.939 22 df
HARVEY	172.953 23 df*	94.444 23 df*	206.842 22 df*	95.017 22 df*
GLEJSER	184.264 23 df*	108.164 23 df*	186.617 22 df*	108.32 22 df*
22 COUNTRIES, 15 YEARS = 330 OBSERVATIONS				

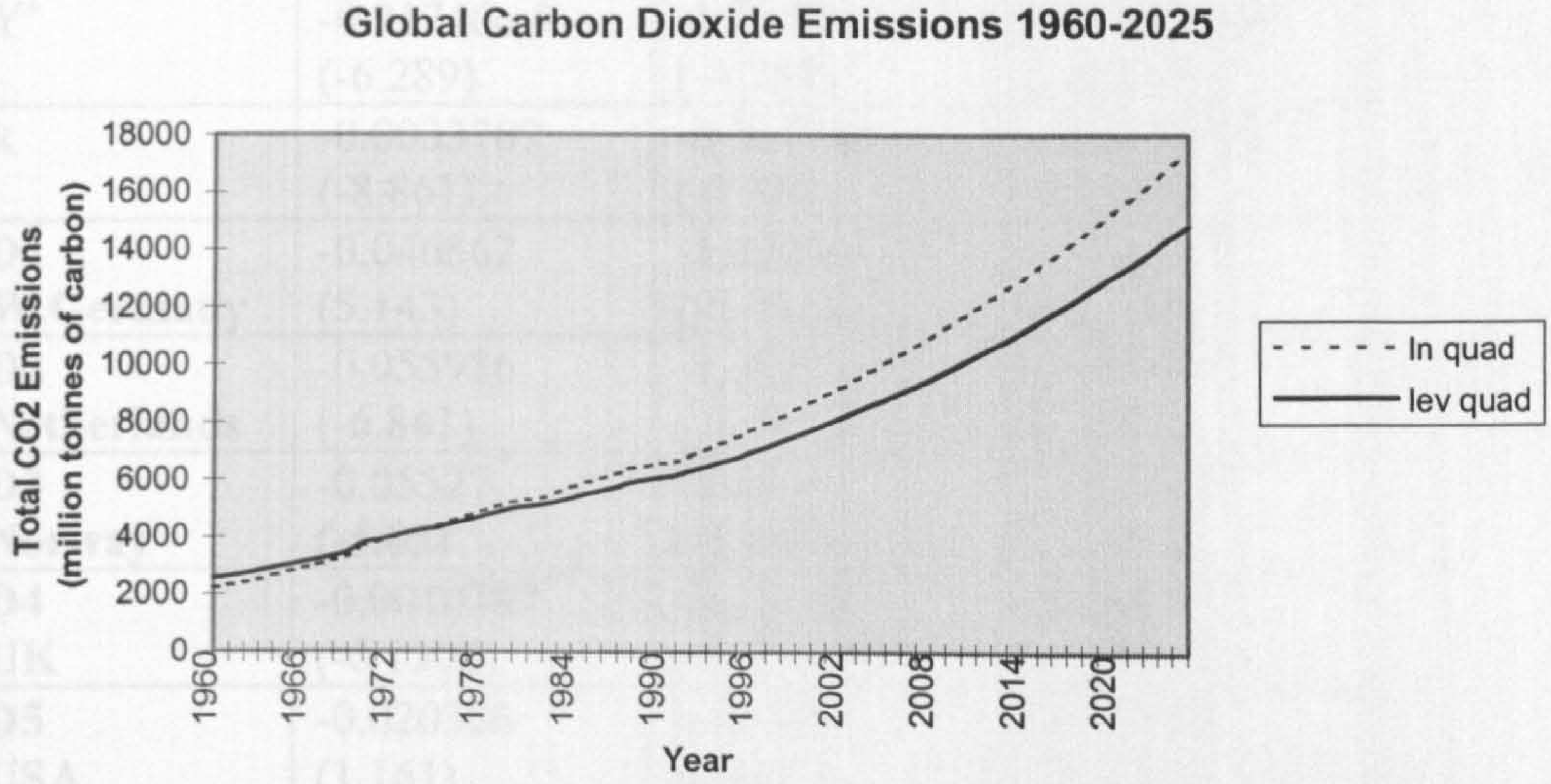
TRAFFIC VOLUMES	GLS LEVELS QUADRATIC	GLS LEVELS LINEAR
Y	0.56269 (7.982)	0.49364 (33.78)
Y^2	-0.26014e-5 (-0.7924)	
D1 **USA**	4722.5 (6.325)	4965 (7.793)
D2 **Japan**	-773.33 (-2.34)	-539.13 (-2.064)
D3 **Australia**	1722 (1.978)	1985.8 (2.266)
D4 **New Zealand**	1417 (3.897)	1671.4 (5.655)
D5 **Austria**	857.4 (2.252)	1097.9 (3.299)

TRAFFIC VOLUMES (continued)	GLS LEVELS QUADRATIC	GLS LEVELS LINEAR
D6 Belgium	145.61 (0.5324)	398.46 (2.396)
D7 Denmark	848.72 (2.564)	1107.2 (4.387)
D8 Finland	1887 (3.799)	2130.8 (4.471)
D9 France	855.13 (2.782)	1114.3 (5.077)
D10 W.Germany	628.64 (2.209)	891.1 (4.716)
D11 Greece	909.14 (1.856)	1025.4 (2.019)
D12 Ireland	2903.2 (11.08)	3080.5 (14.63)
D13 Italy	356.94 (1.085)	602.49 (2.392)
D14 Netherlands	406.77 (1.435)	664.62 (3.64)
D15 Norway	-727.63 (-2.1)	-477.29 (-1.639)
D16 Portugal	979.56 (4.01)	1089.1 (5.901)
D17 Spain	-991.04 (-3.053)	-801.24 (-3.853)
D18 Sweden	811.58 (1.361)	1071.7 (1.895)
D19 Switzerland	-185.47 (-0.4597)	79.715 (0.2354)
D20 Canada	1696.9 (3.639)	1945.9 (3.853)
D21 UK	820.48 (1.484)	1068.3 (2.046)
CONSTANT Turkey	-1355.1 (-5.499)	-1167.1 (-11.1)
Buse R^2	0.9	0.9328
22 COUNTRIES, 15 YEARS = 330 OBSERVATIONS		

Appendix J.

A Forecast of Global Carbon Dioxide Emissions.

The diagram below illustrates projected total carbon dioxide emissions for each of the two functional forms.



The projections were made by forecasting per capita income and then estimating per capita carbon dioxide emissions. These per capita emissions estimates were then multiplied by population for each region, and the regions were then aggregated. UN Department for Economic and Social Information and Policy Analysis (1993) population forecasts for 1992-2025 were used, and World Bank (1994) GDP growth forecasts for 1994-2003. These GDP growth forecasts were then extended, unchanged, to 2025 with the exception of the growth rate for Asia which, after 2003, was reduced from 6.5% to 5.5%.[1]

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[1] A GDP growth rate of 6.5% for 1992-2003 was used for Asia, following the World Bank (1994) forecast of 7.6% for East Asia, 8.5% for China and 5.3% for South Asia. This was then reduced to 5.5% for 2003-2025 since it was felt such high growth rates are unlikely to be maintained.

Appendix K.

Alternative GLS and OLS Results.

SULPHUR DIOXIDE	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.25204e-4 (6.508)	23.774 (5.018)	0.17213e-4 (3.194)
Y^2	-0.91746e-9 (-6.289)	-1.2359 (-4.757)	-0.78351e-9 (-4.597)
k	-0.0033709 (-8.861)	-0.067746 (-7.368)	-0.0024913 (-3.818)
D1 W.Germany	-0.046862 (5.143)	-1.0328 (-5.031)	-0.020379 (-1.408)
D2 Netherlands	-0.055986 (-6.841)	-1.3822 (-7.745)	-0.034517 (-2.758)
D3 Norway	-0.05527 (-5.05)	-1.4534 (-6.445)	-0.029158 (-1.855)
D4 UK	-0.0010787 (-0.1308)	-0.11699 (-0.6943)	0.016273 (1.379)
D5 USA	-0.020326 (1.161)	0.013097 (0.0427)	0.057755 (2.673)
D6 Finland	-0.0051188 (-0.4464)	-0.17555 (-0.925)	0.020739 (1.554)
D7 France	-0.046517 (-5.113)	-0.99287 (-4.996)	-0.021558 (-1.539)
D8 Canada	0.094237 (4.477)	0.55387 (2.013)	0.12054 (6.22)
D9 Denmark	-0.020625 (-2.314)	-0.40627 (-2.001)	0.0054238 (0.3793)
D10 Italy	-0.033875 (-4.709)	-0.65863 (-4.277)	-0.015687 (-1.461)
CONSTANT Ireland	-0.039878 (-2.129)	-115.74 (-5.328)	0.35083e-3 (0.01368)
Buse R^2 /R^2	0.8344	0.9332	0.9173
D.W.		0.8136*	0.9704*
B.P.		116.422 23 df*	86.207 23 df*
B.P.G.		38.532 13 df*	40.297 13 df*
HARVEY		21.233 13 df	32.37 13 df*
GLEJSER		40.645 13 df*	96.649 13 df*
11 COUNTRIES, 15 YEARS = 165 OBSERVATIONS			

SUSPENDED PARTICULATE MATTER	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.61607e-5 (4.245)	18.458 (5.012)	0.12906e-4 (5.641)
Y^2	-0.21864e-9 (-3.827)	-0.90889 (-4.451)	-0.45645e-9 (-6.219)
k	-0.73265e-3 (-5.443)	-0.070473 (-9.512)	-0.001087 (-3.798)
D1 Netherlands	0.0019114 (0.7125)	0.42078 (6.585)	0.0032841 (1.315)
D2 Ireland	0.030161 (7.563)	2.6718 (14.84)	0.041784 (6.042)
D3 UK	0.0048221 (1.818)	0.78078 (11.14)	0.0067095 (2.457)
D4 USA	0.033224 (7.677)	1.654 (18.15)	0.032889 (8.989)
D5 W.Germany	0.0039888 (1.533)	0.60638 (12.22)	0.0042815 (2.213)
D6 France	0.65418e-3 (0.2105)	0.1488 (2.843)	0.72157e-3 (0.3528)
CONSTANT Norway	-0.025763 (-2.885)	-97.498 (-5.837)	-0.06814 (-4.156)
Buse R^2 / R^2	0.7652	0.9742	0.878
D.W.		0.6657*	1.3701*
B.P.		154.288 23 df*	42.207 23 df*
B.P.G.		11.537 9 df	25.238 9 df*
HARVEY		25.913 9 df*	27.985 9 df*
GLEJSER		22.819 9 df*	70.942 9 df*
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

CARBON MONOXIDE	**GLS LEVELS QUADRATIC**	**OLS LOGS QUADRATIC**	**OLS LEVELS QUADRATIC**
Y	0.10374e-3 (12.74)	25.63 (3.154)	0.13805e-3 (11.58)
Y^2	-0.39199e-8 (-14.6)	-1.2793 (-2.923)	-0.46638e-8 (-11.35)
k	-0.006374 (-8.131)	-0.046821 (-6.041)	-0.0088282 (-6.91)
D1 **W. Germany**	0.051721 (2.72)	0.25433 (4.26)	0.023352 (2.369)
D2 **Netherlands**	-0.0087356 (-0.7325)	-0.091148 (-1.897)	-0.013973 (-1.765)
D3 **Norway**	0.11247 (6.301)	0.57601 (7.848)	0.083816 (6.955)
D4 **Denmark**	0.019053 (0.6345)	0.15458 (2.654)	0.0053421 (0.556)
D5 **USA**	0.34163 (16.97)	0.95554 (6.335)	0.27563 (11.09)
D6 **France**	0.041871 (3.359)	0.2941 (5.273)	0.025081 (2.723)
CONSTANT **UK**	-0.4743 (-8.712)	-129.39 (-3.425)	-0.73206 (-9.472)
Buse R^2 / R^2	0.9855	0.9393	0.9661
D.W.		0.635*	0.9041*
B.P.		156.362 23 df*	105.461 23 df*
B.P.G.		33.291 9 df*	28.184 9 df*
HARVEY		39.289 9 df*	32.307 9 df*
GLEJSER		47.601 9 df*	43.248 9 df*
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

NITROGEN DIOXIDE	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.86285e-5 (4.026)	27.534 (4.662)	0.94421e-5 (2.634)
Y^2	-0.27316e-9 (-3.386)	-1.4568 (-4.606)	-0.3951e-9 (-3.213)
k	-0.10185e-3 (-0.5198)	0.006723 (1.271)	0.58526e-3 (1.739)
D1 W.Germany	-0.0092068 (-2.052)	-0.14331 (-3.252)	-0.007483 (-2.673)
D2 Netherlands	-0.010538 (-3.122)	-0.25381 (-5.377)	-0.012794 (-4.264)
D3 Norway	-0.89801e-3 (-0.3346)	0.00614 (0.1314)	-0.22562e-3 (-0.07637)
D4 Sweden	-0.011881 (-5.288)	-0.24667 (-5.27)	-0.011236 (-3.777)
D5 UK	-0.0040262 (-1.307)	-0.12081 (-2.42)	-0.0077199 (-2.431)
D6 USA	0.034364 (8.771)	0.62691 (7.337)	0.043446 (8.004)
D7 Finland	0.0065942 (1.575)	0.048987 (1.062)	0.0039341 (1.343)
D8 France	-0.022059 (-4.21)	-0.62722 (-14.21)	-0.024594 (-8.772)
D9 Canada	0.022752 (6.989)	0.45921 (6.809)	0.029552 (6.919)
CONSTANT Denmark	-0.01272 (-0.9192)	-133.16 (-4.822)	-0.012457 (-0.5122)
Buse R^2 / R^2	0.8053	0.8891	0.8506
D.W.		1.0976*	1.4436*
B.P.		66.085 23 df*	39.067 23 df*
B.P.G.		25.446 12 df*	23.772 12 df*
HARVEY		29.328 12 df*	24.598 12 df*
GLEJSER		61.032 12 df*	51.836 12 df*
10 COUNTRIES, 15 YEARS = 150 OBSERVATIONS			

SULPHUR DIOXIDE TRANSPORT	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.72062e-6 (3.143)	29.605 (4.247)	0.95019e-6 (3.319)
Y^2	-0.28884e-10 (-3.507)	-1.586 (-4.181)	-0.36298e-10 (-3.745)
k	-0.55211e-4 (-2.46)	-0.012635 (-1.028)	-0.52653e-4 (-1.852)
D1 W.Germany	-0.68035e-3 (-1.317)	-0.40331 (-1.446)	-0.001234 (-1.886)
D2 Netherlands	0.37816e-3 (0.7735)	0.1792 (0.7346)	-0.20361 (-0.3556)
D3 Norway	0.001556 (2.448)	0.72392 (2.404)	0.0012742 (1.817)
D4 Denmark	0.0012861 (1.602)	0.6777 (2.456)	0.0013318 (2.058)
D5 UK	0.20308e-3 (0.4375)	0.092394 (0.4009)	-0.34996e-3 (-0.6478)
D6 Finland	-0.59964e-3 (-1.304)	-0.30827 (-1.237)	-0.0010297 (-1.763)
D7 France	-0.38196e-4 (-0.06362)	0.10118 (0.3741)	-0.44534e-3 (-0.7007)
D8 Canada	0.0023206 (3.655)	0.92826 (2.511)	0.0018751 (2.211)
CONSTANT Ireland	-0.001561 (-1.453)	-144.23 (-4.487)	-0.0028488 (-2.08)
Buse R^2 / R^2	0.6559	0.7741	0.7958
D.W.		0.8289*	0.8436*
B.P.		127.944 23 df*	133.606 23 df*
B.P.G.		24.797 11 df*	29.812 11 df*
HARVEY		31.492 11 df*	32.294 11 df*
GLEJSER		49.49 11 df*	56.141 11 df*
9 COUNTRIES, 15 YEARS = 135 OBSERVATIONS			

SPM TRANSPORT	**GLS LEVELS QUADRATIC**	**OLS LOGS QUADRATIC**	**OLS LEVELS QUADRATIC**
Y	0.42738e-6 (3.927)	5.331 (1.479)	0.44872e-6 (3.553)
Y^2	-0.1455e-10 (-3.771)	-0.23804 (-1.196)	-0.11655e-10 (-2.876)
k	0.38194e-5 (0.3101)	-0.0048068 (-0.6655)	-0.10822e-4 (-0.6849)
D1 Netherlands	0.55466e-3 (2.793)	0.56333 (11.5)	0.7359e-3 (6.831)
D2 Ireland	0.002157 (8.31)	1.4517 (9.38)	0.0026024 (7.74)
D3 UK	0.0020049 (3.988)	1.1243 (21.24)	0.0019808 (17.02)
D4 USA	0.0048084 (19.44)	1.607 (14.58	0.0044206 (17.63)
D5 W.Germany	0.12573e-3 (0.7652)	0.12428 (2.732)	0.87916e-4 (0.879)
D6 Norway	0.71343e-3 (5.446)	0.55923 (10.96)	0.67291e-3 (5.959)
CONSTANT France	-0.0020576 (-2.932)	-35.795 (-2.196)	-0.0026211 (-2.997)
Buse R^2 / R^2	0.9173	0.9607	0.9734
D.W.		0.6738*	0.5843*
B.P.		181.606 23 df*	275.644 23 df*
B.P.G.		16.536 9 df	31.642 9 df*
HARVEY		40.304 9 df*	18.179 9 df*
GLEJSER		34.925 9 df*	37.113 9 df*
7 COUNTRIES, 15 YEARS = 105 OBSERVATIONS			

NITROGEN DIOXIDE TRANSPORT	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.85311e-5 (8.268)	32.359 (7.627)	0.1111e-4 (10.9)
Y^2	-0.282e-9 (-7.457)	-1.7 (-7.482)	-0.36566e-9 (-10.62)
k	-0.3524e-4 (-0.4161)	0.0078089 (1.906)	-0.14001e-3 (-1.38)
D1 W.Germany	0.0085402 (10.57)	0.44251 (14.03)	0.0091166 (11.68)
D2 Netherlands	0.0066445 (7.26)	0.32714 (9.891)	0.0075104 (9.162)
D3 UK	0.0064114 (10.67)	0.27475 (7.847)	0.0069857 (8.048)
D4 USA	0.022137 (13.85)	0.91685 (14.11)	0.021636 (13.44)
D5 Finland	0.016374 (16.97)	0.66246 (20.45)	0.016193 (20.19)
D6 Denmark	0.0083812 (4.643)	0.43078 (13.72)	0.009388 (12.08)
D7 Canada	0.02883 (17.45)	1.0612 (20.74)	0.029023 (22.97)
D8 Norway	0.021955 (12.84)	0.85748 (25.03)	0.021604 (25.61)
CONSTANT France	-0.044472 (-6.723)	-158.15 (-7.97)	-0.061946 (-8.98)
Buse R^2 / R^2	0.9298	0.9463	0.9617
D.W.		1.2865*	1.1906*
B.P.		36.975 23 df*	53.303 23 df*
B.P.G.		28.844 11 df*	30.593 11 df*
HARVEY		20.886 11 df*	24.639 11 df*
GLEJSER		52.816 11 df*	51.192 11 df*
9 COUNTRIES, 15 YEARS = 135 OBSERVATIONS			

NITRATES	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.16765e-03 (1.63)	7.7531 (0.79)	0.26645e-03 (0.3889)
Y^2	-0.11021e-07 (-3.722)	-0.43314 (-0.8422)	-0.14371e-07 (-0.6555)
k	0.28814 (6.885)	0.13324 (1.191)	0.27239 (1.011)
D1 **Spain**	1.4717 (1.854)	2.1443 (2.94)	1.4968 (0.8135)
D2 **W.Germany**	2.34 (3.753)	2.6473 (8.921)	2.3362 (2.862)
D3 **Norway**	-0.16685 (-1.323)	0.55845 (1.815)	-0.12135 (-0.1408)
D4 **Switzerland**	1.2352 (6.563)	1.813 (9.534)	0.99216 (1.789)
D5 **UK**	5.2701 (8.211)	3.1896 (8.362)	4.7287 (4.687)
D6 **USA**	1.1697 (9.038)	1.8591 (8.299)	1.091 (1.686)
D7 **Italy**	1.2065 (6.116)	2.2237 (4.807)	1.2898 (1.05)
D8 **Denmark**	3.7243 (1.464)	2.8638 (9.446)	3.5745 (4.297)
D9 **Finland**	-0.10391 (-0.7446)	0.92077 (2.492)	-0.011111 (-0.011)
D10 **Greece**	0.47555 (1.182)	1.7495 (1.656)	0.70062 (0.277)
D11 **Netherlands**	3.3034 (11.69)	2.8981 (8.741)	3.0516 (3.416)
D12 **Czech.**	3.1915 (4.99)	3.1636 (1.838)	3.8178 (1.077)
D13 **Hungary**	1.0953 (1.718)	2.0268 (1.57)	1.1583 (0.3931)
D14 **Belgium**	2.5446 (4.804)	2.6959 (7.464)	2.5094 (2.59)
CONSTANT **Canada**	-0.53203 (-0.6475)	-36.582 (-0.7733)	-1.2368 (-0.24)

NITRATES (Continued)	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Buse R^2 / R^2	0.9208	0.8484	0.6651
D.W.		1.332*	1.2935*
B.P.		62.612 23 df*	58.64 23 df*
B.P.G.		37.583 17 df*	32.877 17 df*
HARVEY		29.921 17 df*	98.499 17 df*
GLEJSER		46.652 17 df*	96.87 17 df*
30 RIVERS, 4 YEARS = 120 OBSERVATIONS			

PHOSPH-OROUS	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.72036e-4 (2.579)	41.846 (4.593)	0.15392e-3 (3.008)
Y^2	-0.47001e-8 (-3.925)	-2.3915 (-4.701)	-0.93432e-8 (-3.95)
k	0.053339 (4.912)	0.28825 (2.824)	0.10877 (3.139)
CONSTANT	0.17713 (1.097)	-183.98 (-4.508)	-0.24144 (-0.8242)
Buse R^2 / R^2	0.2816	0.2296	0.2151
D.W.		0.6355*	1.0772*
B.P.		102.42 23 df*	77.809 23 df*
B.P.G.		2.049 3 df	6.507 3 df
HARVEY		0.367 3 df	2.227 3 df
GLEJSER		1.696 3 df	7.688 3 df
28 RIVERS, 4 YEARS = 112 OBSERVATIONS			

CARBON DIOXIDE	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.23745e-3 (7.109)	4.2557 (15.64)	0.32011e-3 (11.9)
Y^2	-0.3803e-8 (-2.224)	-0.21023 (-13.38)	-0.89855e-8 (-8.147)
k	-0.0012468 (-0.6278)	-0.0013591 (-0.7692)	-0.0053322 (-2.257)
D1 **Asia**	0.098943 (0.834)	0.16901 (6.788)	0.050225 (1.094)
D2 **E.Europe**	1.9524 (15.44)	1.0991 (11.92)	1.7968 (20.61)
D3 **N.America**	2.4953 (9.32)	1.0767 (6.985)	2.6091 (14.36)
D4 **Oceania**	0.12921 (0.7194)	0.27286 (2.179)	0.012822 (0.0943)
D5 **S.&C.America**	-0.21843 (-2.022)	-0.42056 (-5.197)	-0.37362 (-5.18)
D6 **W.Europe**	0.2672 (1.252)	0.31962 (2.531)	0.074505 (0.5417)
CONSTANT **Africa**	0.010275 (0.1195)	-20.87 (-18.08)	-0.0056717 (-0.1283)
Buse R^2 / R^2	0.9413	0.9926	0.9885
D.W.		0.2303*	0.2436*
B.P.		637.39 23 df*	616.565 23 df*
B.P.G.		140.104 9 df*	113.312 9 df*
HARVEY		73.261 9 df*	107.655 9 df*
GLEJSER		140.776 9 df*	170.368 9 df*
7 REGIONS, 32 YEARS = 224 OBSERVATIONS			

TOTAL ENERGY CON	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	0.22915e-9 (7.876)	5.5893 (8.466)	0.23434e-9 (5.125)
Y^2	-0.51567e-14 (-4.551)	-0.27845 (-7.603)	-0.6129e-14 (3.874)
k	-0.20029e-8 (-0.6619)	0.0028765 (1.9)	0.53447e-8 (1.17)
D1 USA	0.31608e-5 (17.13)	1.0675 (10.55)	0.33322e-5 (12.14)
D2 Japan	0.24806e-6 (1.803)	0.24763 (2.907)	0.31595e-6 (1.398)
D3 Australia	0.11774e-5 (7.19)	0.60232 (6.648)	0.12734e-5 (5.202)
D4 New Zealand	0.75564e-6 (3.129)	0.42269 (5.198)	0.76e-6 (3.567)
D5 Austria	0.77689e-6 (5.799)	0.45938 (5.592)	0.8454e-6 (3.914)
D6 Belgium	0.14364e-5 (9.943)	0.67135 (8.01)	0.14894e-5 (6.712)
D7 Denmark	0.66528e-6 (4.175)	0.41691 (4.758)	0.72266e-6 (3.076)
D8 Finland	0.23201e-5 (11.12)	0.88888 (10.43)	0.23272e-5 (10.26)
D9 France	0.49829e-6 (3.468)	0.35992 (4.13)	0.57159e-6 (2.447)
D10 W.Germany	0.1029e-5 (6.604)	0.55994 (6.353)	0.11319e-5 (4.781)
D11 Greece	0.11002e-6 (1.488)	0.076574 (1.484)	0.11839e-6 (1.069)
D12 Ireland	0.56787e-6 (6.421)	0.36367 (5.805)	0.5934e-6 (4.072)
D13 Italy	0.30084e-7 (0.2378)	0.12924 (1.59)	0.92043e-7 (0.4327)
D14 Netherlands	0.1514e-5 (11.09)	0.70084 (8.355)	0.15895e-5 (7.155)
D15 Norway	0.20168e-5 (12.65)	0.83793 (9.154)	0.21534e-5 (8.705)
D16 Portugal	-0.94706e-7 (-1.652)	-0.099646 (-2.147)	-0.85681e-7 (-0.8648)

TOTAL ENERGY CON (Continued)	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
D17	-0.98115e-7 (-1.045)	-0.034409 (-0.5247)	-0.8217e-7 (-0.5277)
D18 Sweden	0.18753e-5 (10.28)	0.78646 (8.699)	0.19388e-5 (7.946)
D19 Switzerland	0.58753e-6 (3.592)	0.42671 (4.435)	0.73134e-6 (2.798)
D20 Canada	0.38363e-5 (20.46)	1.1828 (12.09)	0.3967e-5 (14.96)
D21 UK	0.55098e-6 (4.223)	0.37576 (4.538)	0.62218e-6 (2.85)
CONSTANT Turkey	-0.55178e-8 (-0.07357)	-41.217 (-13.91)	-0.60965e-7 (-0.4914)
Buse R^2 / R^2	0.9865	0.9937	0.991
D.W.		0.8002*	0.8609*
B.P.		233.772 23 df*	191.801 23 df*
B.P.G.		64.579 24 df*	75.842 24 df*
HARVEY		27.273 24 df	92.49 24 df*
GLEJSER		62.587 24 df*	142.203 24 df*
22 COUNTRIES, 13 YEARS = 286 OBSERVATIONS			

MUNICIPAL WASTE	GLS LEVELS QUADRATIC	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC
Y	-0.30774e-4 (-4.435)	-19.312 (-2.665)	-0.35536e-4 (-1.509)
Y^2	0.19582e-8 (6.809)	1.0713 (2.732)	0.22935e-8 (2.25)
k	0.0060091 (1.523)	0.0026429 (0.1036)	0.0030589 (0.3978)
D1 W.Europe	0.03226 (1.089)	0.47762 (1.455)	0.029942 (0.4933)
D2 N.America	0.24225 (6.612)	0.84599 (2.728)	0.21783 (3.417)
D3 Oceania	0.10363 (2.737)	0.69531 (2.069)	0.0972 (1.522)
CONSTANT E.Europe	0.34967 (10.37)	85.219 (2.567)	0.37189 (4.148)

MUNICIPAL WASTE (Continued)	**GLS LEVELS QUADRATIC**	**OLS LOGS QUADRATIC**	**OLS LEVELS QUADRATIC**
Buse R^2 / R^2	0.9919	0.7442	0.8205
D.W.		1.095*	1.0607*
B.P.		16.683 16 df	18.995 16 df
B.P.G.		5.254 6 df	3.183 6 df
HARVEY		7.305 6 df	10.676 6 df
GLEJSER		7.154 6 df	5.552 6 df
13 COUNTRIES, 4 YEARS = 52 OBSERVATIONS			

ENERGY CON TRANSPORT	**OLS LOGS QUADRATIC**	**OLS LEVELS QUADRATIC**	**OLS LOGS LINEAR**	**OLS LEVELS LINEAR**
Y	1.7034 (0.5732)	0.58918e-10 (1.053)	1.2199 (12.2)	0.8089e-10 (5.667)
Y^2	-0.027456 (-0.1628)	0.11937e-14 (0.4064)		
k	-0.0019053 (-0.3158)	-0.41549e-08 (-0.6151)	-0.0023474 (-0.438)	-0.31201e-08 (-0.501)
D1 N.America	0.62886 (4.373)	0.77764e-06 (4.578)	0.61912 (4.76)	0.81021e-06 (5.435)
D2 Oceania	0.067773 (0.6488)	0.48514e-07 (0.427)	0.067734 (0.6519)	0.45141e-07 (0.4002)
CONSTANT W.Europe	-27.65 (-2.113)	-0.17902e-07 (-0.06475)	-25.525 (-28.58)	-0.11667e-06 (-0.8891)
R^2	0.7455	0.5696	0.7454	0.5688
D.W.	0.9066*	1.0986*	0.9057*	1.0957*
B.P.	68.78 23 df*	50.261 23 df*	68.015 23 df*	51.84 23 df*
B.P.G.	1.911 5 df	5.745 5 df	1.9 4 df	4.897 4 df
HARVEY	14.152 5 df*	36.619 5 df*	12.673 4 df*	27.131 4 df*
GLEJSER	8.214 5 df	20.118 5 df*	7.77 4 df	16.456 4 df*
24 COUNTRIES, 4 YEARS = 96 OBSERVATIONS				

ENERGY CON TRANSPORT	GLS LOGS QUADRATIC	GLS LEVELS QUADRATIC	GLS LEVELS LINEAR
Y	1.1185 (1.96)	0.63836e-10 (8.914)	0.72685e-10 (24.73)
Y^2	0.0066768 (0.2068)	0.33399e-15 (0.9643)	
k	-0.0032888 (-3.771)	-0.19754e-08 (-2.584)	-0.24221e-08 (-3.858)
D1 N.America	0.62849 (5.161)	0.91097e-06 (4.649)	0.89366e-06 (4.354)
D2 Oceania	0.24375 (2.008)	0.19583e-06 (2.934)	0.17851e-06 (2.71)
CONSTANT W.Europe	-25.161 (-9.969)	-0.4598e-07 (-1.594)	-0.81773e-07 (-4.749)
Buse R^2	0.9794	0.9577	0.9786
24 COUNTRIES, 4 YEARS = 96 OBSERVATIONS			

TRAFFIC VOLUMES	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC	OLS LOGS LINEAR	OLS LEVELS LINEAR
Y	7.4999 (2.009)	0.10683 (0.6605)	1.3942 (3.261)	0.30702 (4.935)
Y^2	-0.34439 (-1.646)	0.74134e-05 (1.341)		
k	0.0016063 (0.1539)	80.609 (5.008)	-0.0027768 (-0.2745)	73.213 (4.836)
D1 USA	1.1671 (1.633)	8180.5 (8.165)	1.1635 (1.623)	7461.1 (8.808)
D2 Japan	0.41398 (0.7133)	1821.1 (2.278)	0.55354 (0.9614)	1086.0 (1.864)
D3 Australia	0.51984 (0.8192)	4952.8 (5.562)	0.61655 (0.9731)	4169.2 (6.199)
D4 New Zealand	0.83257 (1.469)	3836.3 (4.919)	0.99749 (1.784)	3088.2 (5.662)
D5 Austria	0.73271 (1.303)	3281.7 (4.251)	0.89522 (1.613)	2546.3 (4.683)
D6 Belgium	0.6156 (1.065)	2717.5 (3.404)	0.76627 (1.339)	1966.2 (3.454)
D7 Denmark	0.72794 (1.196)	3527.6 (4.155)	0.85005 (1.403)	2755.9 (4.411)

TRAFFIC VOLUMES (Continued)	OLS LOGS QUADRATIC	OLS LEVELS QUADRATIC	OLS LOGS LINEAR	OLS LEVELS LINEAR
D8 Finland	0.86765 (1.479)	4234.9 (5.212)	1.0089 (1.733)	3479.6 (5.935)
D9 France	0.74362 (1.23)	3609.5 (4.284)	0.87068 (1.448)	2837.3 (4.608)
D10 W.Germany	0.71052 (1.162)	3446.6 (4.041)	0.8296 (1.363)	2674.6 (4.246)
D11 Greece	0.82908 (2.412)	1930.8 (4.7)	1.0511 (3.315)	1546.8 (5.245)
D12 Ireland	1.2746 (3.058)	4422.5 (8.451)	1.4992 (3.797)	3907.3 (10.99)
D13 Italy	0.62521 (1.127)	2688.6 (3.544)	0.79305 (1.45)	1962.8 (3.688)
D14 Netherlands	0.66813 (1.147)	3039.5 (3.769)	0.81703 (1.416)	2280.5 (3.966)
D15 Norway	0.44948 (0.715)	2091.3 (2.382)	0.54436 (0.8671)	1328.8 (1.984)
D16 Portugal	0.97778 (3.225)	1929.3 (5.275)	1.1741 (4.2)	1608.7 (5.807)
D17 Spain	0.17228 (0.3876)	762.57 (1.344)	0.39605 (0.9332)	199.21 (0.5218)
D18 Sweden	0.68195 (1.075)	3439.6 (3.866)	0.77936 (1.231)	2656.0 (3.955)
D19 Switzerland	0.61403 (0.9026)	3161.2 (3.301)	0.65728 (0.9642)	2391.4 (3.117)
D20 Canada	0.8705 (1.275)	4878.2 (5.102)	0.90528 (1.323)	4133.3 (5.305)
D21 UK	0.6765 (1.184)	3073.2 (3.906)	0.83216 (1.473)	2329.3 (4.17)
CONSTANT Turkey	-32.154 (1.93)	-1180.9 (-3.067)	-5.2634 (-1.59)	-1632.9 (-8.785)
R^2	0.759	0.9393	0.7569	0.939
D.W.	1.9148	1.39*	1.9069	1.3738*
B.P.	12.407 24 df	76.602 24 df*	13.988 23 df	83.734 23 df*
B.P.G.	28.496 24 df	29.226 24 df	28.49 23 df	27.834 23 df
HARVEY	170.504 24 df*	125.77 24 df*	187.755 23 df*	107.597 23 df*
GLEJSER	192.649 24 df*	146.865 24 df*	195.137 23 df*	141.035 23 df*
22 COUNTRIES, 15 YEARS = 330 OBSERVATIONS				

TRAFFIC VOLUMES	**GLS LEVELS QUADRATIC**	**GLS LEVELS LINEAR**
Y	0.031378 (0.5376)	0.18313 (7.338)
Y^2	0.6357e-05 (2.799)	
k	100.17 (15.34)	93.059 (14.67)
D1 USA	9262.8 (11.5)	8882.9 (10.96)
D2 Japan	2456.5 (5.102)	2013.1 (4.611)
D3 Australia	5347.3 (5.1)	4896.6 (4.642)
D4 New Zealand	4439.3 (9.188)	3958.2 (9.088)
D5 Austria	3861.9 (7.319)	3404.1 (6.777)
D6 Belgium	3357.2 (6.772)	2886.3 (6.494)
D7 Denmark	4359.0 (8.419)	3886.6 (8.138)
D8 Finland	5000.2 (8.935)	4540.6 (8.376)
D9 France	4295.0 (8.77)	3818.5 (8.586)
D10 W.Germany	4147.5 (8.417)	3674.4 (8.206)
D11 Greece	2092.6 (4.07)	1842.8 (3.954)
D12 Ireland	4659.7 (10.12)	4302.2 (10.21)
D13 Italy	3364.9 (6.471)	2894.8 (6.106)
D14 Netherlands	3650.1 (7.621)	3169.1 (7.376)
D15 Norway	2897.6 (5.645)	2456.7 (5.133)

TRAFFIC VOLUMES (Continued)	**GLS LEVELS QUADRATIC**	**GLS LEVELS LINEAR**
D16 **Portugal**	1979.3 (4.791)	1759.3 (4.567)
D17 **Spain**	1044.3 (2.029)	664.57 (1.442)
D18 **Sweden**	4498.8 (7.326)	4037.0 (6.673)
D19 **Switzerland**	4050.3 (7.478)	3604.5 (7.065)
D20 **Canada**	5773.5 (8.971)	5362.0 (8.695)
D21 **UK**	3998.7 (5.92)	3520.3 (5.437)
CONSTANT **Turkey**	-1051.1 (-2.517)	-1366.0 (-3.62)
Buse R^2	0.9511	0.9366
22 COUNTRIES, 15 YEARS = 330 OBSERVATIONS		

Appendix L:

Summary of Francois, McDonald and Nordstrom (1995).

Francois, McDonald and Nordstrom (1995) estimate the impact of the Uruguay Round on the pattern of world production and on the world level of income (GDP). Using a nineteen-sector, thirteen-region numerical model of the world economy, and incorporating imperfect competition and increasing returns to scale, Francois *et al.* use 1992 benchmark data and estimate how these data would differ if the final Uruguay Round agreement had been in place. The model also incorporates the medium run dynamic effects of the Uruguay Round, whereby static income gains lead to greater saving and investment, thus compounding the overall welfare gains. In one version the regional rate of savings is allowed to be endogenous.

Whilst not reporting actual trade effects, Francois *et al.* estimate larger output changes with the imperfect competition, increasing returns to scale model compared with the perfect competition constant returns to scale model. The model estimates that, due to the liberalisation of the Multifibre Arrangement, there will be a contraction of textile and clothing production in the developed world, matched by an expansion in this sector in the developing world. As a result of these changes, the developing world is estimated to see a contraction in manufacturing sectors as resources are shifted into textiles and clothing, whilst the developed world is then likely to expand its manufacturing sectors.

With regard to the agricultural sector, agricultural production is estimated to expand in all developing regions and also in Canada, Australia and New Zealand. The EU and EFTA are estimated to experience a reduction in such production.

Income effects are largest in the increasing returns, imperfect competition model. As a percentage of 1992 GDP, the developing world, and particularly East Asia, South Asia and China, are estimated to experience the largest increases in income. The United States narrowly recieves the largest absolute increase in income, closely followed by East Asia.

Appendix M.

Estimated Income Effects of the Uruguay Round.

Francois, McDonald and Nordstrom (1995).

Billions of 1992 US $	Dynamic IRTS: Monopolistic Competition (endogenous savings rate)
CANADA	3.79
UNITED STATES	36.62
EFTA	1.69
EUROPEAN UNION	31.85
AUSTRALIA & NEW ZEALAND	1.46
JAPAN	14.23
CHINA	17.64
AFRICA	10.72
EAST ASIA	31.02
SOUTH ASIA	10.27
LATIN AMERICA	20.26
TRANSITION ECONOMIES	3.41
REST OF WORLD	31.49
TOTAL	214.46

Appendix N:

New Regression Results.

The total energy consumption, traffic volumes and transport energy consumption data of Chapters 5 and 6 have been used to generate regressions but the data have been aggregated into regions which are more compatible with those of Francois, McDonald and Nordstrom (1995). Sulphur dioxide and nitrogen dioxide regressions use data from UNEP (1994). Carbon monoxide and suspended particulate matter use income coefficients and the intercept for the USA from the regressions in Chapter 5, whilst the other intercepts have been estimated as explained in the main body of Chapter 7. The final table compares turning points from the new regressions with those from Chapter 5.

TOTAL ENERGY USE	GLS LOGS QUADRATIC
Y	3.4461 (5.72)
Y^2	-0.16154 (-4.734)
D1 European Union	0.45944 (7.58)
D2 USA	1.1722 (14.57)
D3 EFTA (1994)	0.80422 (11.99)
D4 Canada	1.2953 (16.59)
D5 Oceania	0.44881 (6.653)
CONSTANT Turkey	-31.52 (-11.89)
Buse (1973) R^2	0.9978
6 COUNTRIES/ REGIONS, 13 YEARS = 78 OBSERVATIONS	

TRAFFIC VOLUMES	GLS LOGS QUADRATIC
Y	5.872 (5.35)
Y^2	-0.24988 (-4.21)
D1 European Union	0.63447 (5.96)
D2 USA	1.091 (10.26)
D3 EFTA (1994)	0.63747 (5.567)
D4 Canada	0.83324 (6.81)
D5 Oceania	0.46218 (4.489)
CONSTANT Turkey	-25.151 (-5.04)
Buse (1973) R^2	0.9932
6 COUNTRIES/ REGIONS, 15 YEARS = 90 OBSERVATIONS	

TRANSPORT ENERGY USE	GLS LOGS QUADRATIC
Y	1.1073 (50.82)
D1 N.America	0.86778 (6.482)
D2 Oceania	0.44358 (3.50)
D3 W.Europe	0.199 (6.0)
CONSTANT Turkey	-24.716 (-142.0)
Buse (1973) R^2	0.9939
24 COUNTRIES/ REGIONS, 4 YEARS = 96 OBSERVATIONS	

SULPHUR DIOXIDE	**GLS LOGS QUADRATIC**
Y	5.6356 (6.92)
Y^2	-0.32942 (-6.7)
D1 European Union	2.5989 (6.45)
D2 N.America	3.9652 (8.6)
D3 Oceania	1.5008 (3.53)
D4 East Asia	2.2438 (6.15)
D5 China	1.7392 (4.53)
CONSTANT South Asia	-29.725 (-8.87)
Buse (1973) R^2	0.6755
27 COUNTRIES/ REGIONS, 4 YEARS = 108 OBSERVATIONS	

NITROGEN DIOXIDE	**GLS LOGS QUADRATIC**
Y	4.8626 (8.79)
Y^2	-0.24512 (-7.45)
D1 European Union	1.5474 (11.09)
D2 N.America	2.3908 (16.21)
D3 Oceania	1.002 (5.29)
D4 East Asia	1.3664 (14.31)
D5 China	0.86275 (8.78)
CONSTANT South Asia	-18.959 (-10.47)
Buse (1973) R^2	0.9772
26 COUNTRIES/ REGIONS, 4 YEARS = 104 OBSERVATIONS	

CARBON MONOXIDE	GLS LOGS QUADRATIC
Y	31.084 (6.84)
Y^2	-1.6885 (-6.97)
USA	-143.5346 (13.33)
EUROPEAN UNION	-145.0674
LOW INCOME	-154.4900
MIDDLE INCOME	-147.1361

SUSPENDED PART.MATTER	GLS LOGS QUADRATIC
Y	31.449 (8.53)
Y^2	-1.7674 (-8.70)
USA	-142.0912 (13.47)
EUROPEAN UNION	-144.11965
LOW INCOME	-153.55628
MIDDLE INCOME	-146.24682

Estimated Turning Points of the New Regressions, Compared to those from Chapter 5 (1985 US $).

ENVIRONMENTAL INDICATOR:	Turning Point:	Chapter 5 Turning Points:
Total Energy Use	$42,900	$34,700
Traffic Volumes	$126,700	$65,300
Transport Energy Use	No Turning Point	$4 million
Sulphur Dioxide	$5,200	$6,900
Nitrogen Dioxide	$20,300	$14,700
Carbon Monoxide	$9,900	
Suspended Particulate Matter	$7,300	

Data Appendix

CARBON DIOXIDE AND INCOME DATA

AFRICA

YEAR	per cap y	per cap e
1960	815.34	0.16
1961	818.25	0.16
1962	831.84	0.16
1963	867.83	0.16
1964	893.69	0.17
1965	905.3	0.19
1966	907.62	0.19
1967	905.01	0.2
1968	931.71	0.21
1969	982.53	0.22
1970	1034.58	0.22
1971	1106.84	0.25
1972	1107.67	0.25
1973	1128.31	0.27
1974	1177.56	0.27
1975	1191.64	0.26
1976	1213.55	0.27
1977	1247.82	0.27
1978	1271.84	0.28
1979	1270.66	0.29
1980	1282.28	0.3
1981	1320.88	0.3
1982	1301.82	0.29
1983	1262.91	0.29
1984	1232.67	0.3
1985	1220.88	0.3
1986	1216.56	0.3
1987	1192.74	0.29
1988	1196.51	0.30
1989	1206.33	0.29
1990	1199.77	0.29
1991	1205.3	0.29

ASIA

YEAR	per cap y	per cap e
1960	747.68	0.21
1961	712	0.17
1962	711.1	0.15
1963	745.18	0.15
1964	790.17	0.16
1965	806.07	0.17
1966	812.09	0.18
1967	816.06	0.17
1968	822.43	0.18
1969	880.65	0.2
1970	958.05	0.23
1971	966.02	0.26
1972	974.15	0.26
1973	1014.99	0.28
1974	1040.53	0.28
1975	1077.31	0.3
1976	1093.42	0.31
1977	1141.37	0.34
1978	1188.9	0.36
1979	1230.81	0.37
1980	1305.67	0.36
1981	1316.21	0.35
1982	1339.93	0.36
1983	1396.41	0.38
1984	1456.13	0.39
1985	1524.85	0.42
1986	1525.36	0.43
1987	1566.72	0.45
1988	1633.19	0.48
1989	1684.54	0.5
1990	1687.24	0.52
1991	1735.03	0.58

CARBON DIOXIDE AND INCOME DATA

E.EUROPE

YEAR	per cap y	per cap e
1960	2186.39	2.23
1961	2321.88	2.29
1962	2415.79	2.38
1963	2451.17	2.5
1964	2608.01	2.62
1965	2775.67	2.7
1966	2962.95	2.79
1967	3141.4	2.85
1968	3385.23	2.92
1969	3488.56	3.03
1970	3704.17	2.54
1971	3896.92	2.64
1972	4041.22	2.73
1973	4352.42	2.81
1974	4609.68	2.88
1975	4810.13	3
1976	5031.26	3.1
1977	5256.19	3.18
1978	5460.43	3.26
1979	5518.63	3.25
1980	5566.03	3.26
1981	5667.37	3.16
1982	5782.3	3.2
1983	5984.8	3.22
1984	6167.81	3.24
1985	6285.65	3.42
1986	6447.24	3.41
1987	6531.76	3.5
1988	6800.94	3.52
1989	6744.74	3.56
1990	6778.68	3.28
1991	6738.74	3.03

N.AMERICA

YEAR	per cap y	per cap e
1960	9657.17	4.29
1961	9703.1	4.23
1962	10108.21	4.33
1963	10390.08	4.48
1964	10813.24	4.63
1965	11374.5	4.75
1966	11879.76	4.94
1967	12030.46	5.09
1968	12428.77	5.25
1969	12693	5.44
1970	12695.57	5.55
1971	12984.92	5.53
1972	13500.07	5.74
1973	14140.81	5.89
1974	13902.57	5.65
1975	13549.34	5.38
1976	14142.98	5.68
1977	14674.5	5.67
1978	15267.14	5.71
1979	15491.64	5.71
1980	15184.05	5.48
1981	15411.42	5.21
1982	14786.37	4.91
1983	15176.85	4.87
1984	16130.96	4.98
1985	16476.65	5.02
1986	16770.23	5.03
1987	17130.49	5.17
1988	17666.92	5.41
1989	18040.45	5.43
1990	17969.61	5.28
1991	17474.46	5.21

CARBON DIOXIDE AND INCOME DATA

OCEANIA

YEAR	per cap y	per cap e
1960	3484.38	0.84
1961	3816.07	0.96
1962	4038.71	0.99
1963	4372.15	1.07
1964	4824.32	1.17
1965	4960.48	1.25
1966	5370.88	1.31
1967	5804.97	1.47
1968	6442.81	1.65
1969	6998.14	1.84
1970	7579.88	2.01
1971	7780.16	2.06
1972	8245.91	2.18
1973	8740.84	2.36
1974	8533.94	2.27
1975	8603.18	2.16
1976	8878.27	2.21
1977	9123.32	2.3
1978	9466.14	2.27
1979	9830.34	2.33
1980	10124.87	2.29
1981	10411.07	2.26
1982	10563.27	2.22
1983	10805.49	2.14
1984	11200.62	2.32
1985	11676.77	2.24
1986	11871.3	2.19
1987	12285.45	2.19
1988	12953.99	2.34
1989	13432.71	2.44
1990	13892.76	2.53
1991	14358.87	2.53

SOUTH & CENTRAL AMERICA

YEAR	per cap y	per cap e
1960	2435.46	0.4
1961	2520.5	0.4
1962	2554.98	0.41
1963	2557.6	0.4
1964	2687.1	0.42
1965	2736.17	0.42
1966	2790.74	0.44
1967	2848.51	0.46
1968	2974.37	0.48
1969	3080.11	0.51
1970	3215.37	0.52
1971	3371.08	0.54
1972	3509.01	0.55
1973	3687.89	0.58
1974	3851.78	0.6
1975	3871.33	0.59
1976	3998.2	0.63
1977	4082.21	0.62
1978	4150.16	0.66
1979	4345.67	0.68
1980	4522.04	0.7
1981	4464.77	0.68
1982	4239.7	0.7
1983	4001.9	0.65
1984	4056.03	0.63
1985	4103.3	0.62
1986	4192.23	0.63
1987	4235.53	0.65
1988	4186.59	0.65
1989	4168.79	0.65
1990	4136.58	0.66
1991	4223.05	0.69

CARBON DIOXIDE AND INCOME DATA

W.EUROPE

YEAR	per cap y	per cap e
1960	5184.18	1.6
1961	5428.06	1.62
1962	5616.85	1.7
1963	5824.97	1.8
1964	6108.05	1.84
1965	6304.78	1.86
1966	6495.94	1.88
1967	6666.28	1.89
1968	6960.14	1.98
1969	7319.01	2.09
1970	7637	2.14
1971	7815.42	2.16
1972	8086.77	2.2
1973	8506.48	2.3
1974	8621.72	2.22
1975	8471.48	2.1
1976	8816.8	2.24
1977	9003.03	2.17
1978	9197.68	2.23
1979	9476.88	2.33
1980	9551.88	2.23
1981	9456.26	2.11
1982	9487.89	2.01
1983	9604.26	1.97
1984	9790.3	1.95
1985	9990.48	1.99
1986	10275.89	1.96
1987	10549.63	1.95
1988	10939.43	1.92
1989	11257.04	1.98
1990	11540.18	1.99
1991	11637.8	2.23

Where per cap y = per capita income
per cap e = per capita emissions

Sources: Carbon dioxide data from Marland, Andres and Boden (1994)
Income data from Summers and Heston (1991)

NITROGEN DIOXIDE AND INCOME DATA

DENMARK

YEAR	per cap y	per cap e
1970	9670	0.02678
1975	10236	0.038933
1980	11342	0.053289
1981	11153	0.046661
1982	11526	0.05041
1983	11828	0.049472
1984	12419	0.051839
1985	12969	0.057489
1986	13474	0.061121
1987	13449	0.059294
1988	13571	0.057505
1989	13663	0.05377
1990	13909	0.052519
1991	14015	0.060341
1992	14091	0.051838

NETHERLANDS

YEAR	per cap y	per cap e
1970	9199	0.034972
1975	10255	0.035197
1980	11284	0.041272
1981	11079	0.0405
1982	10869	0.039335
1983	10983	0.0387
1984	11288	0.039725
1985	11539	0.039884
1986	11797	0.040351
1987	11858	0.040846
1988	12087	0.040718
1989	12591	0.039733
1990	13029	0.038456
1991	13196	0.038168
1992	13281	0.037291

W.GERMANY

1970	9425	0.038664
1975	10094	0.040919
1980	11920	0.047529
1981	11806	0.046078
1982	11666	0.045705
1983	11956	0.046596
1984	12302	0.04778
1985	12535	0.047627
1986	12839	0.048095
1987	13017	0.046748
1988	13456	0.045174
1989	13837	0.042216
1990	14341	0.038906
1991	14746	0.038366
1992	14709	0.037254

NORWAY

1970	8034	0.041011
1975	9773	0.047916
1980	12141	0.044977
1981	12206	0.043171
1982	12177	0.044471
1983	12714	0.045488
1984	13449	0.049275
1985	14144	0.05177
1986	14683	0.054929
1987	14812	0.056604
1988	14674	0.054407
1989	14630	0.054885
1990	14902	0.05422
1991	15047	0.051854
1992	15518	0.05133

NITROGEN DIOXIDE AND INCOME DATA

SWEDEN

YEAR	per cap y	per cap e
1970	10766	0.037548
1975	11958	0.037837
1980	12456	0.039952
1981	12370	0.039303
1982	12475	0.038559
1983	12682	0.03685
1984	13198	0.037663
1985	13451	0.039162
1986	13725	0.039427
1987	14128	0.038695
1988	14408	0.037459
1989	14681	0.045187
1990	14762	0.04393
1991	14363	0.043428
1992	13986	0.042406

USA

YEAR	per cap y	per cap e
1970	12963	0.092464
1975	13682	0.094132
1980	15295	0.094263
1981	15502	0.092618
1982	14897	0.08847
1983	15290	0.085039
1984	16255	0.086607
1985	16570	0.084997
1986	16848	0.083659
1987	17186	0.084832
1988	17710	0.087046
1989	18095	0.085803
1990	18054	0.085365
1991	17594	0.084056
1992	17945	0.082357

UK

1970	8537	0.041217
1975	9312	0.039928
1980	10167	0.042517
1981	10017	0.041418
1982	10217	0.041168
1983	10625	0.041369
1984	10892	0.041002
1985	11237	0.042743
1986	11726	0.044184
1987	12283	0.046197
1988	12969	0.04742
1989	13241	0.048117
1990	13217	0.047569
1991	12818	0.045723
1992	12724	0.043977

FINLAND

1970	8108	0.02475
1975	9609	0.033963
1980	10851	0.05523
1981	10903	0.051667
1982	11228	0.050756
1983	11477	0.0486
1984	11746	0.047726
1985	12051	0.051408
1986	12261	0.052054
1987	12730	0.054733
1988	13377	0.055746
1989	14227	0.057235
1990	14059	0.058163
1991	12663	0.056472
1992	12000	0.130923

NITROGEN DIOXIDE AND INCOME DATA

FRANCE

YEAR	per cap y	per cap e
1970	9200	0.026038
1975	10297	0.030513
1980	11756	0.030549
1981	11746	0.028515
1982	11970	0.028157
1983	11936	0.027353
1984	12034	0.026753
1985	12206	0.025376
1986	12507	0.025201
1987	12744	0.02531
1988	13259	0.025893
1989	13642	0.026366
1990	13904	0.02621
1991	13870	0.026907
1992	13918	0.026476

CANADA

YEAR	per cap y	per cap e
1970	10124	0.063965
1975	12287	0.077367
1980	14133	0.081479
1981	14555	0.078342
1982	13740	0.077167
1983	14105	0.076008
1984	14954	0.074906
1985	15589	0.07884
1986	16029	0.076283
1987	16602	0.079493
1988	17258	0.08158
1989	17524	0.080857
1990	17173	0.075371
1991	16368	0.072381
1992	16362	0.07065

Where per cap y = per capita income
per cap e = per capita emissions

Sources: Nitrogen dioxide data from OECD (1993, 95)
Income data from Summers and Heston (1991)

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