Curtin Business School

The Environment, Growth and Foreign Aid: An Analysis with Energy and Carbon Emissions Intensities

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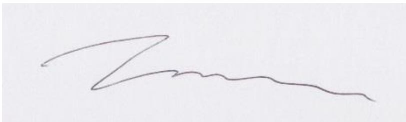
Declaration

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.



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Abstract

This thesis is the first to simultaneously examine interrelationships between the environment, economic growth and foreign aid in developing countries. Drawing from the Kaya Identity and Environmental Kuznets Curve (EKC) hypothesis, a simultaneous equations model was used to analyse the relationships between energy intensity, carbon emissions intensity and GDP per capita in a sample of aid-receiving countries. The impact of foreign aid disbursements, both in aggregate and on a sectoral basis, were also considered in the context of these relationships.

The results provide support for the EKC hypothesis in terms of the carbon emissions over GDP-GDP per capita relationship. This result was determined by the underlying relationship between carbon emissions intensity and GDP per capita, which also describes an inverted U-shape. The other underlying relationship, between energy intensity and GDP per capita, was found to be monotonic negative in nature for the observed income range.

Foreign aid results were mixed. Aggregate aid disbursements were found to reduce environmental impact overall at lower income levels, but increase environmental impact at higher income levels. No confident conclusions could be drawn from the results for sectoral aid disbursements however. This was attributed to the relatively low level of significance of these sectoral disbursements to recipient economies, as well as data coverage issues affecting the source dataset.

While the support for an EKC relationship is encouraging, the detailed results from the analysis present a complex picture of the environment, growth and aid relationships. This study ultimately shows that there is still significant need for improvement in regards to the environmental impact of growth and the potential influence of foreign aid on the environment.

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Chapter 1

Introduction

1.1 Environmental Concerns

One of the biggest issues presently facing world governments and policy makers is climate change. While countries around the world are increasingly adopting strategies to mitigate the environmental impact of economic activity, statistics indicate that this impact continues to increase. Global CO_2 emissions were nearly 36 million kilotons in 2013, up from just over 32 million kilotons five years earlier, and compared to approximately 22.4 million kilotons in 1990 (World Bank 2016a). Of particular note is the contribution of developing nations towards these figures, whose emissions accounted for 63% of the total in 2011 according to the Center for Global Development (2015). The significant contribution to global emissions by developing nations could be considered to be driven by a push for increased growth and development, with the 1991 Beijing Ministerial Declaration on Environment and Development identifying poverty as a significant source of pressure on the environment within the developing world (Ministerial Conference of Developing Countries on Environment and Development 1992).

The association of environmental degradation with the pursuit of economic objectives stems from the fact that the expansion of economic activity over time is considered to be the primary driver of increasing environmental impact (Blanco et al. 2014). Consequently, it has been stressed that environmental mitigation efforts must be considered in the context of economic growth and development (Ministerial Conference of Developing Countries on Environment and Development 1992). The 1992 Rio de Janeiro Earth Summit bought the role of developing countries in this regard to prominent attention, with many developed countries vowing to provide significant assistance in helping those less developed to improve environmental standards, without adversely affecting economic growth and development objectives (Roberts et al. 2009). More recently, the UN Intergovernmental Panel on Climate Change (IPCC)'s Fourth Assessment Report further reinforced the continuing importance of such assistance with its discussion of the significant need for transition to more environmentally sustainable development pathways if the worst effects of climate change are to be avoided (Sathaye et al. 2007). In this context, obtaining a detailed understanding of the relationship between economic growth and environmental impact in developing countries is an important step in ensuring the effectiveness of any action taken.

1.2 The Role of Foreign Aid

An additional element of significance to the developing world and environmental impact discussion is the role of Official Development Assistance (ODA), referred to hereafter as foreign aid. Foreign aid is defined by the OECD as flows from governments to developing countries that are of a concessional nature, for the purposes of promoting economic growth and development (OECD 2016a). Foreign aid may be provided bilaterally (directly from donor to recipient government), or multilaterally (indirectly via an organisation such as the World Bank) and may take the form of financial flows or technical assistance. In 2015, aid disbursements totalled over $131 billion US dollars (OECD 2016a). Given that the intention of aid is to promote economic growth and development in recipient nations, it may play an indirect, though important role in influencing the environmental impact of these nations over time. Furthermore, as highlighted by the aforementioned pledges of financial assistance to emerge from the 1992 Rio Earth Summit, aid may also have a direct role in mitigating the environmental impact of developing nations and helping them to transition towards the environmentally sustainable development pathways identified by the IPCC. This direct pursuit of environmental objectives with aid also appears to be of continuing relevance, with Kretschmer et al. (2013) noting that environmental concerns continue to be an important focus for donors.

The pursuit of environmental objectives through aid (in addition to the traditional economic objectives) reflects the view that developing nations can less afford to devote resources to environmental protection and should not be expected to do so, given that already developed nations achieved such status through their own environmentally damaging process of growth and development (Roberts et al. 2009). Such policies may also be considered a reflection of the perceived importance of developing countries in the ongoing mitigation of climate change.

1.3 Research Gap

Given the significance of environmental concerns amongst world governments and policy makers, it is unsurprising to note that a considerable body of research has accumulated over time examining various aspects of economic activity and its associated environmental impact. A strand of research has focused on the causality between economic growth and measures of environmental impact such as carbon emissions and energy use, typically using Granger causality tests on vector autoregression or vector error correction models. Results obtained from these studies vary, but many have determined causality running between measures of growth and environmental impact of either a uni- or bi-directional nature (Omri 2013).

Another significant branch of economic growth and environmental impact research has been the examination of potential dynamics in the environment-growth relationship in the form of the Environmental Kuznets Curve (EKC) hypothesis. The EKC hypothesis is a theoretical construct describing a hypothetical inverted U-shaped relationship between a country's wealth and pollution intensity. The EKC has been studied extensively with a variety of different measures of environmental impact (Stern 2004). While results vary considerably across the literature, a significant body of studies has accumulated finding support for the EKC's hypothesised relationship between income and pollution. Building from this research, there are two more recent subsets of the environment-growth literature identified by Stern (2004). These subsets focus on decomposing the drivers of pollution and examining environmental efficiency respectively. These branches of the literature expand on the existing EKC literature by offering a more detailed examination of the factors driving changes in environmental impact and the overall environment-growth relationship.

From all of this literature, a number of important insights into the environment-growth relationship can be identified; that there may be a two-way relationship between economic growth and environmental impact (particularly in terms of energy use and carbon emissions), that the environment-growth relationship is potentially non-linear in nature and that decomposing this relationship may provide new insight over earlier studies. Notably however, there are relatively few studies that attempt to consider all of these factors together. A number of more recent studies have attempted to ascertain causality between environmental measures and both linear and squared GDP variables (e.g. Apergis and Payne

2009; Lean and Smyth 2010). Additionally, Liou and Wu's (2011) efficiency-based study is notable for considering linear, quadratic and cubic income measures. However, causality studies typically only consider the relationship between the factors of interest at a higher level, while decomposition and efficiency-based studies such as Liou and Wu (2011) do not capture the potential bi-directionality between environmental impact measures and economic growth.

Adding to this is the matter of foreign aid. A substantial body of literature has accumulated in regards to foreign aid and its effectiveness in achieving its primary objective of promoting economic growth in recipient countries. However, despite more than fifty years of investigation, this literature is still characterised by a distinct lack of certainty regarding the core research question, with even more recent examinations of the literature producing inconsistent results (Glennie and Sumner 2014). This lack of certainty has led to the emergence of alternative approaches to the examination of aid effectiveness, with some of the most notable of these being the examination of aid in terms of specific non-growth objectives such as health and educational outcomes, as well as examination of the growth performance of aid disaggregated by the sector targeted in the recipient economy (Arndt et al. 2010; Glennie and Sumner 2014). The examination of aid in an environmental impact context could be categorised with these branches of the aid effectiveness literature, though unlike its growth-focussed counterpart, studies on aid and the environment remain relatively scarce.

Of the handful empirical studies on aid and environmental impact that have been identified, perhaps the most significant is Kretschmer et al. (2013), who examined foreign aid's impact on energy and carbon emissions intensity.[1] They additionally examined aid both at the aggregate level as well as aid that specifically targets industry and the energy sector of recipient economies. Their results found aid in aggregate reduced energy intensity but had no effect on carbon emission intensity, while aid for the energy sector had a modest negative impact on energy intensity. However, they made no attempt to incorporate the EKC hypothesis into their analysis, or to examine the possible indirect environmental impact of aid via economic growth. In fact, none of the identified empirical aid and environment studies

[1] Energy intensity is defined as energy use over GDP and carbon emission intensity as carbon emissions over energy use.

consider these latter two factors, preventing a complete picture of aid’s environmental impact from being obtained.

Despite the extent of the combined literature relating to economic growth, the environment and foreign aid, there remains a distinct lack of research that bridges the key areas within each literature. Specifically, there are presently no studies that simultaneously consider the relationships between the environment, growth and aid, while also taking into consideration the EKC hypothesis, potential bi-directionality of the environment-growth relationship and insight offered by decomposition approaches to analysing this relationship.

1.4 Research Aims

Given the identified gap in the existing literature, the present research features the following aims:

1. To investigate the relationship between economic growth and environmental impact in the context of the EKC hypothesis while additionally:
    a. Decomposing the environment-growth relationship into two sub-relationships in the form of the intensity of energy use and carbon emissions; and
    b. Accounting for the potentially bi-directional nature of effect between the environment and growth.
2. Simultaneously analysing the role of foreign aid in both aggregate and sectorally disaggregated forms in terms of its influence on the environmental impact of developing countries, capturing both a potential direct and indirect effect.

1.5 Theoretical and Empirical Framework

While the EKC hypothesis forms the primary theoretical basis for this study’s view of the environment-growth relationship, additional theoretical views were also considered to provide definition to environmental impact and allow for more detailed insight. Specifically, these theoretical views were the Kaya Identity and related Scale, Composition and Technique (SCT) effects framework.

Following the example of Kretschmer et al. (2013), the Kaya Identity was used as a basis for defining environmental impact in this study. The identity is considered a more concrete form of the IPAT equation (Impact = Pollution, Affluence and Technology) equation (IPCC 2017). It is defined as follows (Kaya and Yokobori 1997):

$$\frac{CO_2\ Emissions}{Population} = \frac{CO_2\ Emissions}{Energy\ Use} \times \frac{Energy\ Use}{GDP} \times \frac{GDP}{Population}$$

where human environmental impact is considered to be the product of carbon emissions intensity, energy intensity and GDP per capita, respectively.

Relating to the Kaya Identity, the SCT effects framework first defined by Grossman and Krueger (1991), describes the specific means by which economic growth may influence environmental impact. The framework refers to three effects, the first of which is Scale. Scale captures the view of the expansion of economic activity as a key driver of environmental degradation. The second effect is Composition, which reflects the fact that not all economic sectors affect the environment as adversely as others. For instance, it could be said that the manufacturing sector has a significantly greater adverse impact on the environment than does the services sector. Finally, the Technique effect refers to productivity and efficiency improvements that allow output to increase without an associated Scale effect, or alternatively, reductions in the environmental impact associated with a given level of economic activity. The Technique effect also captures the adoption of "green" technologies that directly reduce the environmental impact of economic activity. The SCT effects were used here to describe the means by which changes in GDP per capita and the provision of foreign aid may impact on energy and emissions intensity, and the nature of that effect.

Consideration of the growth effect of aid was also necessary to achieve the research objectives. The theoretical view of this relationship was drawn from the example of Ekanayake and Chatrna (2010). Under this view, aid in aggregate is considered an additional input into the production function for recipient countries, implying a positive relationship between aid and economic growth as per the prevailing expectation in the literature. However, as this research also considers aid in a sectorally disaggregated form, each individual aid sector is associated with its own specific mechanisms of effect on growth. The specific targeted aid sectors analysed in this research were drawn from the OECD's Creditor Reporting System (CRS) database and are as follows:

- Economic Infrastructure and Services
- Health
- Production Sectors
- Environmental Aid
- Other

With the Other category constituting the remaining defined sectors in the database which were not explicitly examined in this analysis.

1.6 Research Significance

There is no doubt regarding the global significance of issues relating to the environmental impact of economic activity, and specifically the response of developing countries to these issues. The present lack of attempts to thoroughly bridge the major bodies of literature relating to these issues however, means that an important degree of relevant insight is lacking. This study attempts to provide this insight. In doing so, it is hoped that the research will work toward providing a more complete view of economic activity and environmental impact specifically as it relates to developing countries, and the role of foreign aid in this context. Accumulation of such insight could be considered beneficial in terms of determining ongoing strategies for mitigating the anticipated impact of climate change.

1.7 Outline of the Thesis

The remainder of this thesis is presented as follows. The relevant strands of literature from which the present study is drawn are explored in Chapter 2, with a discussion of the methodology used for the data analysis in Chapter 3. Information on the data sources used for the analysis, along with some exploration of relevant background statistics derived from this data are then presented in Chapter 4. Finally, the results of the analysis are presented along with discussion of these in Chapter 5, followed by the conclusion in Chapter 6.

Chapter 2

Literature Review

2.1 Introduction

By investigating the link between the environment, growth and aid, the present research draws together three distinct strands of literature. These strands examine the relationship between the environment and growth, the effectiveness of aid in promoting growth and the impact of aid on the environment, respectively.

2.2 The Environment-Growth Literature

The literature on the relationship between environmental impact and economic growth is broad and multi-faceted with a variety of distinct theoretical and empirical foci and approaches. Two of the most significant distinct aspects of the literature relevant to the present research can be identified as the empirical literature on energy-emissions-growth causality and the Environmental Kuznets Curve (EKC) hypothesis.

The Focus on Causality

One of the earliest key studies to examine the relationship between economic growth and environmental impact was Kraft and Kraft (1978)'s study of energy consumption and Gross National Product (GNP). This study was specifically concerned with the nature of causality running between energy use and GNP. Findings were that changes in GNP causes changes in energy use, but not the other way around. This study incited numerous similar research efforts continuing into the present, with varied results in terms of causality and direction between energy use and economic growth variables (e.g. Stern 1993; Ghali and El-Sakka 2004; Shiu and Lam 2004; Yuan et al. 2007; Belloumi 2009). Over time, some authors began to expand on this work by adding an additional variable in the form of carbon emissions into the causality analysis (e.g. Ang, 2007; Soytas and Sari, 2009; Lean and Smyth, 2010). These latter studies examined the nexus of causality running between energy use, carbon emissions and economic growth, with diverse findings that variously provided evidence for causality running between all three factors in either direction.

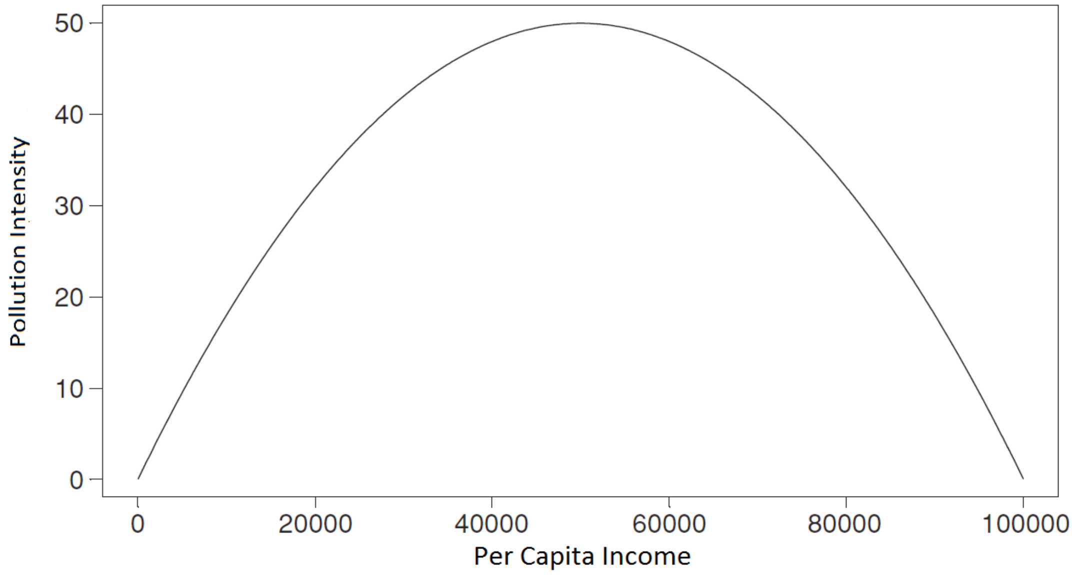
Since Kraft and Kraft's original study, the Granger causality test has been a commonly used technique for establishing causality between the key variables in this literature when using time series data (Omri 2013). However, alternative approaches such as autoregressive distributed lag (ARDL) model bounds testing have also been popular (Al-Mulali et al. 2015). Some studies have also extended these approaches to the use of panel data for multi-country samples (e.g. Lean and Smyth 2010). The study by Omri (2013) however, notably departs from these commonly used techniques. Omri instead employed the unique approach of using a simultaneous equations model to examine the potential causal relationships between energy use, carbon emissions and economic growth. Omri's model utilised three equations for each of the key variables respectively, with each variable hypothesised to have a causal effect on the others. Omri found bi-directional causality running between energy use and economic growth, as well as carbon emissions and economic growth. Additionally, unidirectional causality running from energy use to carbon emissions was also found. Support for all of Omri's findings can also be found elsewhere in the causality literature.

While many of the energy-emissions-growth causality studies could be said to exist strictly within their own distinct branch of the literature, there has been some crossover with other aspects of environment-growth research. Specifically, a number of causality based studies such as Apergis and Payne (2009), Ozturk and Acaravci (2010), Lau et al. (2014) amongst others also attempted to test the EKC hypothesis, which itself has generated a substantial and distinct body of literature.

The Environmental Kuznets Curve

One of the most commonly used theoretical constructs to inform the literature on the relationship between environmental impact and growth has been the Environmental Kuznets Curve (EKC) hypothesis (Liou and Wu 2011). Initially proposed by Grossman and Krueger (1991), the EKC was popularised by the World Bank's 1992 World Development Report (Stern 2004). The hypothesis refers to the idea that pollution intensity (the measure of a pollutant per unit of GDP) may initially rise with increasing income, but begin falling against it after a certain level of income is reached (World Bank 1992; Sun 1999). This would effectively result in an apparent inverted U-shaped relationship between pollution intensity and income as illustrated in Figure 2.1.

Figure 2.1. Relationship between income and pollution intensity hypothesised by the EKC



Adapted from Carson (2010).

This inverted U-shaped relationship is explained by wealthier countries, having achieved a sufficient level of income and thus standard of living, now being able to concern themselves more with objectives other than growth. This may therefore result in them placing a higher priority on environmental concerns relative to growth and development objectives (Grossman and Krueger 1991). The EKC hypothesis has generated a substantial body of literature since its introduction, with a variety of different perspectives and approaches.

One important preliminary note should be made however, prior to discussion of the EKC literature. This note is in regards to the diversity of EKC definitions in use. As discussed by Carson (2010), there have been numerous environmental measures used to define the pollution intensity aspect of the EKC in both theoretical and empirical literature, with none necessarily being any more or less valid than any other.[2] The issue of how to define the EKC for the purposes of this study will however be addressed in the next chapter, with the following discussion considering the EKC in its diversity of definitions.

Over time, the EKC literature has developed to encompass a broad range of environmental impact measures and results. Grossman and Krueger's original study utilised the ecological indicators sulphur dioxide, dark matter and suspended particles as dependent variables,

[2] There is even ambiguity surrounding the use of intensity measures of pollution - many EKC studies define intensity on a per capita, rather than per GDP basis. Some EKC studies do not consider intensity at all, employing aggregate measures of environmental impact instead.

finding a roughly N-shaped relationship between each of these and GDP per capita. Many studies following Grossman and Krueger's work took a similar line by examining the EKC relationship using various ecological pollution indicators such as sulphur dioxide, suspended particulate matter and deforestation (e.g. Selden and Song 1994; Shafik 1994). One problem with using such indicators however - if taken as a per capita measure - is that there is considerable variation in terms of the impact these types of pollution may have on an individual unit (Carson 2010). For instance, sulphur dioxide pollution may adversely affect one city to a significant degree, but leave another city entirely unaffected. According to Carson, this has resulted in per capita ecological measures having only weak links with most theoretical EKC models.

The issues with using ecological indicators to measure pollution have been addressed in the EKC literature through the use of alternative dependent variables such as energy use, which implicitly incorporates a range of different pollution impacts (Stern 2004). Studies incorporating such a dependent variable have included Cole et al. (1997) - who failed to find evidence of an EKC - and Suri and Chapman (1998), who did confirm an EKC. Additionally, Galli (1998) took a somewhat different approach by examining energy intensity (energy consumption per GDP), instead of the per capita measures more commonly employed. The results provided support for an EKC with this measure in Asian countries. Aside from energy use variables however, measures of carbon emissions have also been used as a dependent variable to capture a broader environmental impact in EKC studies e.g. Holtz-Eakin and Selden (1995), Du et al. (2012) and Jebli et al. (2016). According to Al-Mulali et al.'s (2015) review of the more recent EKC literature, carbon emissions appears to have emerged as highly popular pollution measure.

Looking at the empirical models employed by EKC studies in more detail, the standard form of model conventionally used in the EKC literature has been a reduced form equation with assumed exogenous per capita income variables and relevant control variables regressed against the environmental impact measures (Stern 2004; Carson 2010). Equation (2.1) illustrates this conventional form (Stern 2004):

$$\text{(2.1)} \qquad \ln(E/P) = \alpha_i + \gamma_t + \beta_1 ln(GDP/P)_{it} + \beta_2 (ln(GDP/P))^2_{it} + \varepsilon_{it}$$

where *E* is the environmental impact measure used, *P* is population and *ln* represents that the variables are expressed as natural logarithms. The first two terms on the right hand side are country or region (*i*) and yearly (*t*) intercepts respectively. An issue with the implementation of this form of model however, has been that many EKC studies made no attempt to account for the endogeneity of the income variables suggested by the environment-growth causality research.[3] The standard approach to dealing with this endogeneity is to instrument for the problematic variables (e.g. Lin and Liscow 2013 - one of the few reduced form studies to do so). Aside from endogeneity concerns, issues with omitted variables was noted by Stern (2004) as another significant econometric flaw affecting the reliability of results for a number of EKC studies employing the conventional reduced form model.

The issue of omitted variables relates to the potential bias in the results obtained from a model due to unobserved factors that may influence the examined relationships. The original Grossman and Krueger study included a number of additional variables such as trade, urbanisation and political factors, aimed at reducing issues with omitted variable bias. Thus effectively attempting to minimise the extent of unobserved factors that may bias the results. Panayotou (1997) similarly attempted to mitigate the omitted variable issue by including an additional variable representing institutional quality into the model specification - a now commonly included control variable which has been shown to significantly impact on the EKC relationship (Carson 2010). An alternative to this variable in the form of private sector credit as a share of GDP has also been used more recently by Salahuddin et al. (2016) and Uddin et al. (2017) in their studies of internet usage and carbon emissions, and income growth and ecological footprint respectively.

Aside from the econometric concerns affecting the conventional reduced form models used in EKC analysis, these models still suffer from a significant limitation in that they fail to provide much insight into the underlying mechanics of the environment-income/growth relationship they examine (de Bruyn 1997; Liou and Wu 2011). Alternative approaches that have emerged from the EKC literature however, have helped to address this concern.

[3] As discussed earlier, a finding of bi-directional causality has been found in some studies between income and energy use or carbon emissions. The possibility also exists that such causality also applies between income and other measures of environmental impact. The implication of this for empirical EKC models is that the income variables used on the right hand side may therefore be at least partly determined by the model. If steps are not taken to deal with this endogeneity it will result in biased and inconsistent coefficient estimates.

Decomposition and Efficiency-Based Approaches

As identified by Stern (2004), a more recent trend in the EKC literature has been the emergence of decomposition and efficiency-based approaches that provide greater insight into the mechanics of the studied relationship. The decomposition approach breaks down environmental impact into specific underlying drivers, while the efficiency-based approach typically employs a linear programming based efficiency frontier method.

The decomposition approach originated with Grossman (1995), who formulated an identity for the pollution impact of a country as the result of total economic activity (GDP), the relative size of each individual economic sector relative to GDP and the pollution intensity of each respective economic sector. Grossman accounted for changes in total pollution impact in terms of a Scale, Composition and Technique (SCT) effects framework. This framework breaks down changes in environmental impact within a country to those resulting from the scale of economic activity, the structural composition of the economy and the efficiency of production and adoption of environmentally friendly technologies and processes (Grossman and Krueger 1991). Grossman's decomposition was subsequently utilised as the basis for a variety of studies such as de Bruyn (1997), Viguier (1999) and Bruvoll and Medin (2003), who each applied statistical techniques to determine index values measuring the changes in pollution resulting from the decomposed elements of the identity. Amongst the findings of these studies, de Bruyn, applying the decomposition to changes in sulphur dioxide emissions, determined technological change to be the biggest driver of emissions intensity reductions. Viguier (1999) used a modified decomposition involving fuel quality, fuel mix, industrial structure and energy intensity, applied to a range of pollution measures. Findings were that energy intensity was overall, the most significant factor driving changes in pollution across the different measures. Bruvoll and Medin (2003) similarly used a modified decomposition and range of emissions-based pollution indicators, finding energy intensity and intra-sectoral factors affecting emissions intensity (emissions per energy use) to be the most significant contributors to changes in pollution levels.

As noted by Stern (2004) however, studies based on the Grossman decomposition are hampered by a need to obtain industry level data from sample countries, which is often collected on a sectoral basis that differs from output. This makes the approach unviable for many countries (a problem evidenced by the limited samples employed by many such studies). Zhang (2000) proposed an alternative decomposition approach, in effect based on the Kaya Identity, which avoids this issue by eliminating the need for industry level data. Zhang's decomposition utilised carbon emissions as a pollution impact measure, which was decomposed into fossil fuel intensity (fossil fuel use relative to total energy use), total energy intensity (total energy use relative to GDP), GDP per capita and population. When using the decomposition in the case of China, Zhang found that economic growth (increases in GDP per capita) was the most significant driver of carbon emissions increases historically. However, historical reductions in energy intensity were also found to have significantly mitigated this increase in emissions. Hamilton and Turton (2002) followed Zhang, using a similar decomposition applied to a sample of OECD countries. Like Zhang, Hamilton and Turton found that economic growth was the largest contributor to carbon emissions increases historically, while falling energy intensity was determined to be the most significant factor mitigating these increases.

An alternative view of decomposition studies has also emerged in the form of sectorally-based EKC studies. Such studies attempt to ascertain the presence of an EKC within particular economic sectors of a country. Hamit-Haggar (2012) for instance, investigated the EKC with greenhouse gas emissions for a broad range of industrial sectors in Canada, with mixed results. Following this, Fuji and Managi (2016) also tested the EKC for a range of different industrial sectors. Their analysis employed a sample of 39 countries, and a range of different environmental impact measures. Their results confirmed an overall EKC for the industrial sector in general, though mixed results on a sectoral basis. Finally, a similar study by Wang et al. (2017), focussing on China, found evidence for an EKC for carbon emissions within the electricity and heat production sector, though not in the manufacturing or mining sectors.

Aside from the decomposition approach, the other key trend drawing from the EKC literature are the efficiency frontier studies. These studies are most significantly represented in the literature by the Data Envelopment Analysis (DEA) technique, which uses mathematical programming to examine environmental efficiency (Ramanathan 2006). The DEA approach involves computing a function that determines the input-output ratio for pollution (of which various measures are taken, and treated as inputs) and overall economic output in various Decision Making Units (DMUs). These DMU's can take the form of individual firms, regions or countries. The most efficient DMUs in terms of their input-output ratio are allocated a score of one. This places them on the efficiency frontier, an enveloping line that encompasses all DMUs under investigation (Ramanathan 2006). DMUs with a score of less than one are located within the frontier, indicating that they are relatively less environmentally efficient.

There have been numerous examples of the implementation of the DEA approach in both its standard form, as well as with various modifications and extensions (Zhou et al. 2008). A recent example by Chen and Jia (2017) for instance, employed the DEA approach on a regional basis for China, using solid industrial waste and sulphur dioxide emissions as outputs.

One DEA study of particular relevance to the present research is Liou and Wu (2011). Their study used the DEA method to construct indices for the overall efficiency of energy use and carbon emissions, with each of these indices being broken down into sub-indices accounting for technical and scale based efficiency respectively. The technical sub-index being concerned with technology related efficiencies and the scale sub-index with scale based efficiencies. Liou and Wu utilised the Two Stage Least Squares econometric estimation method for their analysis, with a sample of 57 countries, including all signatories of the Kyoto Protocol. A significant N-shaped relationship was found between almost all of the efficiency indices and GDP per capita. The one exceptional index being the scale sub-index for energy use, where an inverted N-shaped relationship was determined.

The results of Liou and Wu’s analysis, along with those of other decomposition studies, show that the underlying environmental efficiency of output has an important role to play in providing insight into the overall environment-income relationships examined by studies of the EKC. Attempts to ascertain causality between pollution measures and growth, or to test the existence of an EKC relationship between these pollution measures and income, can only communicate so much about the relationships of interest without the more detailed consideration of these decomposition approaches.

Bearing this conclusion in mind, we now turn attention to the literature on foreign aid. The consideration of the role of foreign aid in the context of the environment-growth relationship is a key secondary objective of this research. As such, examination of the literature on foreign aid effectiveness and its environmental impact will provide important insight on which to base the subsequent analysis.

2.3 The Aid-Growth Literature

A substantial body of literature investigating the relationship between foreign aid and economic growth has developed over a period of more than fifty years. The primary concern of this research has been to determine the means by which aid may promote economic growth in developing countries and its effectiveness in doing so. However, despite the extent of investigation into the impact of aid on growth, the results for the effectiveness of aid at a macroeconomic level has proven consistently inconclusive (Hansen and Tarp 2000). More recent analysis has not improved this situation; one meta-analysis of the literature performed by Doucouliagos and Paldam (2008) using 68 different aid-growth studies, determined an overall insignificant relationship between aid and growth. However, a subsequent meta-analysis of the same set of studies by Mekasha and Tarp (2013) concluded that there is actually a significant and positive relationship. The absence of a solid theoretical basis to underpin views of the aid-growth relationship has also been inhibitive (Hansen and Tarp 2000; Easterly 2003). In spite of these issues, development of the aid-growth literature over time has provided insight into the nature of this relationship and the factors that may affect it.

The earliest studies examining aid effectiveness frequently used the Harrod-Domar model as their primary theoretical basis (Hansen and Tarp 2000). Under this model, the rate of economic growth was determined solely by the quantity of capital and labour (which were held in fixed ratios), and in the absence of foreign inflows, investment was determined solely by savings (Harrod 1939; Domar 1946). The receipt of foreign aid would therefore supplement domestic savings and allow an increase in the level of investment, which would in turn raise the growth rate (Hansen and Tarp 2000; McGillivray et al. 2006). This theoretical view of aid and growth would be formalised and expanded on by Chenery and Strout (1966) with their highly influential “two-gap” model. This model formally defined the so-called “savings gap” and additionally introduced the idea of a “trade gap”, which could alternatively serve as a constraining factor on growth for developing countries. This “trade gap” referred to the fact that developing countries may experience inadequate levels of foreign currency due to low net exports, which would inhibit their ability to import capital goods necessary to achieve a desired level of growth. Under the “two-gap” model, foreign aid could work to fill either of these two “gaps” as necessary, allowing the recipient nation to overcome their resource constraints and raise their level of economic growth (Chenery and Strout 1966).

Though its relevance has declined significantly over time, Chenery and Strout's model proved to have a significant influence over subsequent literature, with many early studies utilising the model as a theoretical basis for their analysis e.g. Host-Madsen (1967), Sengupta (1968), Chenery and Eckstein (1970) and Robinson (1971).[4]

These early empirical aid-growth studies faced a number of issues in terms of the reliability of their analysis. Many of them did not attempt to isolate aid inflows (using aggregate foreign inflows instead), reducing the potential insight they could provide into aid effectiveness. Even for those studies that did isolate aid, such as Griffin and Enos (1970) and Robinson (1971), data availability and reliability were also major concerns. Studies from this era typically used only very limited sample sizes and time periods with reliable data being difficult to obtain. The model specifications for many of these studies also featured relatively few control variables, thus leading to the potential for omitted variable bias (McGillivray et al. 2006). Finally, these model's also failed to account for the potential endogeneity of aid, an issue that would be addressed in later studies.

The first attempt to address the endogeneity of aid - an issue arising due to potential reverse causation between the aid and growth variables came from Mosley (1980). Mosley's study was also notable for the consideration of longer timeframes for aid's impact on growth. This was achieved by lagging the aid variable. In spite of these advancements however, a surprising negative correlation between aid and growth was obtained by Mosley, with the lagging of aid failing to alter this result.

Following Mosley's study, Dowling and Heimenz (1983) employed a similar model and a focus on Asian countries. They made an additional notable contribution with the inclusion of various economic and policy factors which were thought to influence the aid-growth relationship as control variables in their model specification. Contrary to Mosley's findings, Dowling and Heimenz determined a significant positive correlation between aid and growth, regardless of whether or not economic and policy factors were controlled for. However, later empirical studies from this era (Rana and Dowling 1988; Reichel 1995) produced only inconclusive results, with aid found to have no statistically significant impact on growth.

[4] Despite its earlier influence, the "two gap" model is largely no longer considered a relevant theoretical basis for empirical aid-growth analysis, with Easterly (2003) presenting an influential critique of the model.

Further development in the aid-growth literature came from a study by Burnside and Dollar (2000) which determined that aid was effective in promoting economic growth in developing countries dependent on a sound economic and policy environment. The key aspect of Burnside and Dollar's model was the inclusion of an interaction term between aid and a composite policy indicator constructed specifically for the analysis. The indicator comprised a range of macroeconomic and government effectiveness indicators designed to provide an accurate representation of the social stability, quality of government and economic management in sample countries. However, though Burnside and Dollar's positive finding was widely reported, subsequent studies in response to it failed to confirm the result. In particular, Easterly et al. (2004) did not achieve a significant result for the crucial aid and policy interaction term when repeating the Burnside and Dollar analysis with an expanded dataset, leading them to conclude that the result was highly sensitive to the underlying data. Hansen and Tarp (2000) had also previously commented on the sensitivity of Burnside and Dollar's aid and policy result. Despite this, the Burnside and Dollar study played an important role in highlighting the various factors that would likely need to be controlled for when analysing the aid-growth relationship, with studies from this period onwards routinely including such control variables in their models (e.g. Moreira 2005; Rajan and Subramanian 2008; Ekanayake and Chatrna 2010 amongst many others). However, these studies continued to achieve mixed and inconclusive results regarding aid effectiveness.

The next major development in the aid-growth literature came from Clemens et al.'s (2004) study which disaggregated aid based on expected impact timeframe. It has been argued that disaggregating aid better accounts for its heterogeneous nature and may thus provide more reliable insight into aid effectiveness (Harms and Lutz 2004; Mavrotas and Ouattara 2006). Taking into account the fact that aid is often provided for a wide variety of specific purposes, Clemens et al. specifically divided aid into a "short impact" form including budget support aid and aid for infrastructure, a "long-impact" form including aid for health and education, and a non-economic form including humanitarian aid amongst other types. They found a positive and significant relationship between "short impact" aid and economic growth over a four year time horizon, but no significant impact for "long impact" or non-economic aid over any measured timeframe. According to Dalgaard and Hansen (2010), Clemens et al.'s study was the first to utilise the disaggregated aid approach in a cross-country context and has been subsequently followed by further such efforts. Dovern and Nunnenkamp (2007) for instance, also achieved a similar positive finding with short impact aid. Minoiu and Reddy (2010) on the other hand, separated aid into "developmental" and "non-developmental" forms based on whether or not it was intended to achieve economic objectives. They found a significant and positive relationship for the developmental form. Kaya et al. (2012) instead examined aid by targeted sector, finding a positive and significant relationship between agricultural aid and economic growth in the short run. Though this finding did not hold for other types of aid such as that targeting social infrastructure.

One other more recent development in the aid-growth literature has been the examination of the properties of aid which may influence its effectiveness. These properties have included the volatility of aid flows received by recipient countries (Hudson and Mosley 2008; Kodama 2012), with findings that aid volatility adversely affects the effectiveness of aid in promoting growth. The level of aid provided in terms of the recipient country's GDP or GNI has also been examined. This factor came into specific focus in studies such as Islam (2005), Alvi et al. (2008) and Clemens et al. (2012), who all determined an upper threshold or turning point for aid effectiveness ranging from 4%-25% of GDP (Glennie and Sumner 2014).[5] Gyimah-Brempong et al. (2012) however, took an alternative approach. They determined that aid is not effective at promoting growth below 6.6%-14.4% of GNI, while Kalyvitis et al. (2012) determined this lower threshold to be at 3.4% of GDP.

Ultimately, while still affected by mixed and inconclusive results regarding its core objectives, the aid-growth literature has experienced considerable development over time that has nonetheless produced valuable insight into the aid-growth relationship. The disaggregation of aid to account for its heterogeneous nature, and examination of the properties of aid itself constitute the most recent of these developments, with the former being of particular relevance to the present research. However, it is in an environmental impact context that the aid-growth relationship and the developments informing it are to be examined. As such it is also important to consider the literature concerning the direct impact of aid on the environment.

[5] The idea of absorptive capacity and diminishing returns for aid has been considered in earlier studies through the inclusion of a square term for aid (for instance Ghura and Hadjmichael 1995; Burnside and Dollar 2000; Ekanayake and Chatrna 2010). However, the level of aid provided was not a specific focus of these studies.

2.4 The Aid-Environment Literature

In contrast to the extensive research effort into the aid-growth relationship, investigation into possible linkages between aid and the environment has attracted relatively little attention. One of the earliest significant studies to be conducted in this area is that of Chao and Yu (1999), who developed a general equilibrium model describing the means by which aid may affect the environment in developing countries. Considering pollution as a by-product of production, Chao and Yu determined via their theoretical model that aid for environmental clean-up would ultimately have an ambiguous impact on pollution levels in the recipient country. Assuming that the environmental clean-up effort utilises domestic factors of production which must be diverted from private production, then such environmentally tied aid would be expected to reduce output and thus pollution. This effect would be in addition to the active pollution reduction efforts financed by the aid. However, the reduction in output would also increase prices, thus stimulating an increase in output. According to Chao and Yu's model, this would leave the net impact on output (and thus pollution) indeterminate.

Following the work of Chao and Yu, Chao et al. (2012) produced their own theoretical model for aid and the environment. Expanding on the previous effort, they developed an endogenous growth model considering untied aid as well as aid tied to public inputs and the environment respectively. Their analysis did not account for environmental effect, but rather the relative impact of each type of aid on the long run economic growth rate of the recipient country. Treating untied aid as a lump sum transfer to households, Chao et al. found that it increased the long-run balanced economic growth rate of the recipient economy. They also found a similar impact for aid tied to public inputs, resulting from an increase in public investment. However, aid tied to the environment was found to reduce the long run growth rate due to its tendency to crowd out public inputs.

One other significant attempt to develop a theoretical model of aid and the environment is Baranano and Martin (2015). Their model allowed for substitution between private and public inputs in production and the Intertemporal Elasticity of Substitution (IES) in consumption. Along similar lines to Chao et al. (2012), they considered untied aid, aid tied to the environment and aid tied to infrastructure in terms of economic and also environmental impact. They found that overall, environmentally tied aid had the smallest positive impact on economic growth in recipient countries, though the greatest positive (improving) impact on the environment. Conversely, untied aid was found to be most detrimental to the environment overall and aid tied to infrastructure most positively associated with growth. However, these results were also found to be sensitive to the IES and impact of environmental quality on utility.

In addition to the body of theoretically focussed studies on aid and the environment, some attempts to empirically examine the relationship between these factors also exist. One such attempt is that of Arvin and Lew (2009), who examined the relationship between foreign aid and various ecological outcomes. Their model utilised panel data from 1990-2002 and the Two Stage Least Squares estimation method. Carbon dioxide emissions levels, water pollution and deforestation in recipient countries were used as dependent variables. Findings were that aid significantly reduced carbon dioxide emissions in their sample, but increased water pollution and deforestation.

Following Arvin and Lew, a study by Kretschmer et al. (2013) empirically examined the relationship between aid and energy and carbon intensities (energy use relative to GDP and carbon emissions relative to energy use respectively) in developing countries. Their study utilised Kaya and Yokobori's (1997) Kaya Identity along with Grossman and Krueger's (1991) Scale Composition and Technique Effects framework as a theoretical basis for their empirical analysis. Aid was considered in aggregate, and also disaggregated in terms of aid targeting industry and the energy sector. Kretschmer et al.'s analysis utilised panel data and a mixture of the Least Squares Dummy Variable Corrected with country specific fixed effects and Generalised Method of Moments (GMM) estimation methods.[6] Results showed that aid measured in aggregate form reduced energy intensity (though with an admittedly small quantitative impact), while having no significant effect on emissions intensity. Kretschmer et al. also concluded that their findings in relation to aid disaggregated by targeted sector were ambiguous, with aid for the energy sector having a modest effect in reducing energy intensity, but no effect on emissions intensity. No significant impact was determined at all for industrial aid.

[6] Both the Anderson-Hsiao and Arellano-Bond estimators are used for the GMM estimations, with the authors noting no significant difference between these results.

Of note regarding the Kretschmer et al. study however, is that they did not attempt to capture the indirect effect of aid on the environment via growth. According to the authors, this was on account of the prevailing uncertainty surround the aid-growth relationship. Additionally, the study did not accommodate any potential non-linearity in the environment-growth relationship as per the EKC, including only a linear term for GDP per capita in the model specification. These omissions leave key factors relevant to the aid-environment relationship unexplored.

2.5 Conclusion

The environment-growth, aid-growth and aid-environment literature represent a complex, substantial body of research on which the present study is based. The present research bridges these three research areas, drawing from the more recent developments in the environment-growth and aid-growth literature in order to provide greater insight into the relationships between these factors. It also draws from and adds to the relatively limited body of empirical literature on aid and the environment, particularly the study by Kretschmer et al.

Chapter 3

Methodology

3.1 Theoretical Model

The three distinct branches of literature discussed in Chapter 2 form the basis for constructing the theoretical framework underlying the environment-growth-aid relationships. Specifically, the underlying mechanisms of these relationships can be explained via theoretical constructs such as the Environmental Kuznets Curve Hypothesis, Kaya Identity and Scale, Composition and Technique effects framework.

3.1.1 The Environment and Growth

The Environmental Kuznets Curve Hypothesis

The key implication of the EKC in the context of this research is that the environment-growth relationship may be non-linear in nature, hypothetically describing an inverted U shape when pollution is plotted against economic growth. Equation (3.1) expresses this relationship:

$$(3.1) \quad CARBON = f(Y, X_1)$$

where carbon emissions, serving as a proxy for pollution, is a non-linear function of output, Y and a set of exogenous factors, X_1.

Additionally, as discussed, there is considerable evidence in the literature to suggest a bi-directional relationship between pollution and growth. This means that output Y also depends non-linearly on carbon emissions:

$$(3.2) \quad Y = g(CARBON, K, L, X_2)$$

Where K and L represent capital and labour respectively, and X_2 is a set of relevant exogenous factors. Furthermore, equations (3.1) and (3.2) imply that both *CARBON* and Y are determined simultaneously as functions of X_1 and X_2 respectively.

These two functions present a generalised view of the environment-growth relationship. In order to examine the mechanics of the relationship, the following section develops a more detailed definition of environmental impact.

The Kaya Identity

Following the example of Zhang (2000), Hamilton and Turton (2002) and Kretschmer et al. (2013), the Kaya Identity is used to describe environmental impact. This identity provides a definition of anthropogenic environmental impact derived from the influential IPAT (Impact = Pollution, Affluence and Technology) equation (IPCC 2017).[7] The Identity is defined as follows (Kaya and Yokobori 1997):

$$(3.3) \quad \frac{CO_2\ Emissions}{Population} = \frac{CO_2\ Emissions}{Energy\ Use} \times \frac{Energy\ Use}{GDP} \times \frac{GDP}{Population}$$

The identity decomposes environmental impact - measured by carbon emissions per capita - into carbon emissions intensity (CEI, the first term on the right hand side), energy intensity (EI, the second term) and GDP per capita (the final term). This decomposition allows for a more detailed examination of the environment-growth relationship and EKC hypothesis. This approach also allows foreign aid's environmental impact to be decomposed into a direct (carbon emissions intensity and energy intensity) and indirect (GDP per capita) impact - a key requirement for this study.

Applying the decomposition to equations (3.1) and (3.2) yields:[8]

$$(3.4a) \quad EI = f_1(Y, X_{11})$$
$$(3.4b) \quad CEI = f_2(Y, X_{12})$$
$$(3.5) \quad Y = g(EI, CEI, K, L, X_2)$$

Again, the EKC hypothesis suggests that the functions $f_1()$ and $f_2()$ are potentially non-linear in *Y,* while g() is non-linear in either or both of *EI* and *CEI*. Additionally, EI and CEI may be multiplied together to form carbon emissions per unit of GDP (carbon emissions over GDP) -

[7] The Kaya Identity has been used as basis for papers produced by the UN's Intergovernmental Panel on Climate Change (IPCC) and has also been utilised in various environment-growth and aid-environment studies, of which the most relevant to the present research is Kretschmer et al. (2013).
[8] In equations 3.4a and 3.4b, CEI could also be considered a function of EI and vice versa, as has often been considered in the environment-growth causality literature. However it is not done here for reasons explained in Section 3.2.

an overall measure of pollution intensity. This measure can be used to directly examine the EKC relationship, while energy and emissions intensity provide a decomposed view.

As discussed in Chapter 2, the EKC has been defined in terms of a variety of different - and potentially equally valid - pollution measures. The decision to define it here in terms of carbon emissions - while deriving directly from the use of the Kaya Identity - also offers certain advantages. Specifically, carbon emissions are a relatively ubiquitous form of pollution that can also serve to represent a range of other pollutants (Franklin and Ruth 2012). Furthermore, as noted in Chapter 2, carbon emissions have emerged as one of the more popular choices of pollution measure in the recent EKC literature. However, this measure is most commonly used on a per capita basis e.g. Richmond and Kaufman (2006), Apergis and Payne (2009) amongst many others. According to Carson (2010), the reason for this is that it allows for easy interpretation and comparison between countries. This study measures carbon emissions per GDP instead however, based on the outlined decomposition of the EKC relationship. A per GDP measure of emissions also follows the view of the original World Bank 1992 Development Report (Tisdell 2001). It is also supported by Sun (1999). Additionally, it may be argued that the same advantages applying to per capita measures in terms of ease of interpretation and comparison also apply to the per GDP measure.

The EKC hypothesis and decomposition of the overall environment-growth relationship however, are not by themselves sufficient to describe the underlying mechanics of the environment-growth relationship. As such, an additional theoretical construct is considered

Scale, Composition and Technique Effects

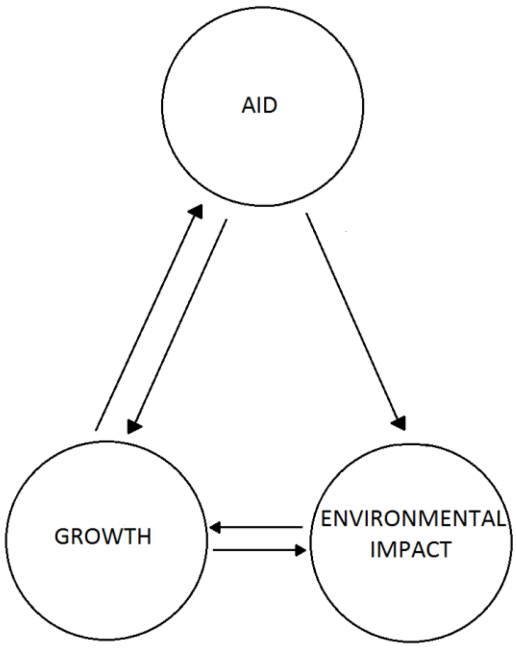
Relating to the Kaya Identity, the Scale, Composition and Technique (SCT) effects framework originally proposed by Grossman and Krueger (1991), provides a means of describing the specific channels through which economic activity may impact on the environment. The Scale effect refers to a direct, positive relationship between economic activity and environmental impact, with a larger scale of economic activity being associated with a larger environmental impact. This effect is accounted for through the measurement of carbon emissions relative to GDP and its component intensities.

The Composition effect refers to the structural breakdown of a particular economy. Not all economic sectors are as environmentally intensive as others e.g. the manufacturing sector has a far greater environmental impact than the services sector. Therefore, any change in the composition of an economy may also change its level of environmental impact, regardless of any changes in scale. In the Kaya Identity, the Composition effect may alter one or both of emissions and energy intensity (the first two terms on the right-hand side) in a direction dependent on the nature of the compositional change.

Lastly, the Technique effect covers efficiency and productivity gains which can allow for a greater scale of economic activity without the corresponding increase in environmental impact. It can additionally account for active efforts to reduce environmental impact, such as the introduction of energy efficiency measures and adoption of "green" technologies (Grossman and Krueger 1991; Kretschmer et al. 2013). Thus, in the Kaya Identity, the Technique effect reduces environmental impact by lowering one or both of energy and emissions intensity. Additionally, the Technique effect may be impacted by GDP per capita as implied by the EKC, where it should increase in line with GDP per capita above a certain level of income.

3.1.2 The Environment, Growth and Aid

Figure 3.1. Environment-growth-aid relationships



When foreign aid is added to the environment-growth relationship, a complex set of interrelationships arises. Figure 3.1 illustrates these relationships in general terms. As can be seen, aid is expected to influence and be influenced by economic growth, and also influence environmental impact.

Looking first at aid's impact on growth, incorporating the bi-directional relationship of *Y* and *A* into the production function (3.2) yields:[9]

$$(3.6) \qquad Y = g(EI, CEI, L, K, X_2, A)$$

where aid (*A*) is considered as an additional input into the production function for recipient economies. The bi-directionality of the aid-growth relationship can be emphasized by expressing aid as a function of GDP, i.e., $A = A(Y)$. This bi-directionality of the aid-growth relationship presents unique issues for the analysis and will be discussed further in Chapter 5.

To accommodate aid's impact on the environment, equations (3.4a) and (3.4b) are expanded as follows:

$$(3.7a) \quad EI = f_1(Y(A), A, X_{11})$$
$$(3.7b) \quad CEI = f_2(Y(A), A, X_{12})$$

while substituting equations (3.7a) and (3.7b) into (3.6) yields:

$$(3.8) \quad Y = g\{\, EI(A, Y(A), X_{11}), CEI(A, Y(A), X_{12}), L, K, X_2, A\}$$

Equations (3.7a) and (3.7b) signify aid's capacity to impact on the environment both directly, and indirectly via economic growth. The direct impact comes through the form of technology and knowledge transfer (essentially the Technique effect) (Kretschmer et al. 2013). Additionally, this direct environmental impact may include a Composition effect if aid is targeted at certain sectors of the recipient economy or is more effective in promoting growth within some target sectors than others. These direct environmental impacts through the Technique and Composition effect are captured by the appearance of the aid variable *A* directly in functions $f_1()$ and $f_2()$.

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[9] Ekanayake and Chatrna (2010) consider aid's impacts on economic growth by specifying the production function as Y=f(L,K,A). Eqn. (3.6) extends their production function by explicitly incorporating two environmental variables.

From our previous discussion on the SCT effects, aid's impact on economic growth (as captured by $Y(A)$) may result in both an indirect Scale effect (though this is accounted for through the environmental measures used), as well as an indirect Technique and Composition effect. The latter two affecting energy and carbon emissions intensity (through $Y(A)$ appearing as the first argument of $f_1()$ and $f_2()$). While the Technique effect is always pollution intensity reducing, the direction of the Composition effect on energy and emissions intensity is ambiguous; being indeterminate without knowing the exact nature of any compositional change.

As per our model, the combined observable effect of aid on the environment therefore consists of a direct and indirect Technique and Composition effect. However, the indirect Technique effect is dependent on the level of GDP per capita as per the EKC, and the direction of the Composition effect (whether direct or indirect) is indeterminate without specific measurement. This ultimately leaves the prior expectation for the impact of aid on energy and emissions intensity as ambiguous, at least when aid is viewed in aggregate.

Disaggregating Aid

To fully accommodate our view of the environment-growth-aid relationships, consideration must be given to the heterogeneous nature of aid. In particular, the different sectors towards which it may be targeted. In this regard, equation (3.8) is modified by disaggregating aid into various targeted aid sectors:

$$(3.9) \qquad Y = f\{(EI(\{A_i\}, Y, X_{11}), CEI(\{A_i\}, Y, X_{12}), \{A_i(Y)\}, L, K, X_2\}$$

where $\{A_i\}$ represents the set of sectoral aid variables, with the subscript i representing that the aid is targeted towards sector i. Specifically, the empirical analysis of this study considers five aid sectors: Economic Infrastructure and Services, Health, Production Sectors, Environmental and Other Aid. A sixth category, Education Aid, was also originally included in the analysis, but was ultimately omitted due to its extremely small size.[10]

Looking at each of the target aid sectors, Economic Infrastructure and Services Aid covers the implementation of infrastructure intended to facilitate economic activity such as roads,

[10] See Chapter 4 for more detail on the relative significance of this aid category to recipient countries in the sample.

bridges, telecommunications networks and energy generation and distribution structures (OECD 2016b). It also includes programs relating to the development and regulation of the financial sector. Therefore, such aid may promote economic growth in recipient countries by increasing the provision of infrastructure, without potential adverse effects associated with increasing public investment such as raised taxes or diversion of funds from other areas (Romp and de Haan 2007). This growth effect implies that infrastructure aid may also indirectly alter energy and emissions intensity via Composition and Technique effects. Though this form of aid may also have a direct Composition and Technique effect if the infrastructure is of benefit to particular economic sectors or improves production efficiency.

Health aid is targeted at various health related projects and programs. This form of aid may promote economic growth as increased investment in health related projects and programs is expected to raise the level of human capital, thus increasing productivity (Knowles and Owen 1997). The growth effect again implies indirect Composition and Technique effects, possibly altering energy and emissions intensity. The associated productivity gains also imply an associated direct Technique effect for Health aid, thus reducing energy and emissions intensity. There may also be a direct Composition effect, given that such gains would be expected to provide greater benefit to labour-intensive sectors.

Production Sectors aid covers projects and programs intended to help expand and support various industries in the recipient country including agriculture, manufacturing and mining (OECD 2016b). This form of aid may directly promote growth through increased investment. As such, Production Sectors aid may also impact on energy and emissions intensity indirectly via Composition and Technique effects. There may also be a direct Composition effect given the focus of this aid on production sectors specifically. A direct Technique effect is also possible through the associated technology and knowledge transfer implied by this form of aid.

Environmental aid includes projects and programs aimed at addressing environmental concerns. As this type of aid is not associated with an intended economic impact, no formal expectations regarding this aid category and growth are considered.[11] This form of aid is

[11] As discussed in Chapter 2, the theoretical aid-environment literature does offer a number of views regarding the possible economic impact of environmental aid. However, these views vary considerably and attempts to incorporate them into the empirical analysis is beyond the scope of this study.

expected to directly reduce energy and emissions intensity however, via the Technique effect.

Finally, Other Aid is a category comprising all remaining targeted aid sectors not explicitly included in the analysis. It is included here to avoid omitted variable bias, though is not of specific analytical interest.

3.1.3 Hypothesis

The preceding theoretical views regarding the environment-growth-aid relationships can be summarised through the following expectations:

1. As per the EKC hypothesis, GDP per capita (as a measure of income) is related to overall pollution intensity (carbon emissions over GDP) positively at low levels of GDP per capita and negatively above a certain level.
2. While the overall carbon emissions over GDP-GDP per capita relationship is expected to describe an inverted U shape as per hypothesis 1, the individual relationships between energy intensity and emissions intensity and GDP per capita are considered ambiguous. It is not necessary for either intensity to individually describe an inverted U-shaped relationship with GDP per capita in order for their combined relationship to do so. The relationship between either of these intensities and income is also not well investigated in the literature, preventing confident expectations from being drawn.
3. Under the assumption that the majority of aid sets its primary objective as the promotion of economic growth in recipient countries (i.e. Environmental and other non-growth promoting types of aid are only minority categories), aid when viewed in aggregate should impact positively on economic growth in those countries, all else being equal.
4. Any sectorally disaggregated forms of aid intending to promote economic growth (i.e. Economic Infrastructure and Services, Production Sectors and Health aid) should impact positively on economic growth in recipient countries, all else being equal.
5. Aid targeting environmental rather than economic objectives (i.e. Environmental aid) should have little or no impact on economic growth in recipient countries.

6. Total Aid, Economic Infrastructure and Services, Health and Production Sectors aid should have an ambiguous impact on energy and emissions intensity due to the following factors:
    a. Growth-promoting aid may have a negative or positive impact on energy and emissions intensity through direct and indirect Composition effects, with the extent and direction of effect being determined by the specific sectors that experience relative expansion on account of aid.
    b. Aid may have a negative impact on energy and emissions intensity through the direct and indirect Technique effect due to efficiency and productivity improvements bought about by increased investment in physical and human capital, technology and knowledge transfer from donor countries and active pollution reducing efforts stimulated by rising income as per the EKC.
7. Environmental aid should have a negative impact on energy and emissions intensity in recipient countries due to the associated direct Technique effect.

3.2 Empirical Model

A panel-based simultaneous equations model is employed to examine the hypotheses outlined in the preceding section. A model of this form has also been employed by Omri (2013) in his study of energy use, carbon emissions and economic growth. This modelling approach is highly suitable here as it allows for the simultaneous examination of the relationships between the multiple variables of interest. The model consists of three equations as follows:

(3.10) $lnGDP_{r,t} = \alpha_0 + \alpha_1 AID_{r,t} + \alpha_2 AID_{r,t-1} + \alpha_3 lnENERGY_{rt} + \alpha_4 (lnENERGY_{rt})^2 + \alpha_5 lnEMISSIONS_{r,t} + \alpha_6 (lnEMISSIONS_{rt})^2 + \alpha_7 D_{r,t} + \alpha_8 D_{r,t-1} + \alpha_9 F_{r,t} + \alpha_{10} F_{r,t-1} + \alpha_{11} T_{r,t} + \alpha_{12} I_{r,t} + \varepsilon_{r,t}$

(3.11) $lnENERGY_{r,t} = \beta_0 + \beta_1 AID_{r,t} + \beta_2 AID_{r,t-1} + \beta_3 lnGDP_{r,t} + \beta_4 (lnGDP_{rt})^2 + \beta_5 D_{r,t} + \beta_6 D_{r,t-1} + \beta_7 F_{r,t} + \beta_8 F_{r,t-1} + \beta_9 T_{r,t} + \beta_{10} SI_{r,t} + \beta_{11} EP_{r,t} + \nu_{r,t}$

(3.12) $lnEMISSIONS_{r,t} = \theta_0 + \theta_1 AID_{r,t} + \theta_2 AID_{r,t-1} + \theta_3 lnGDP_{r,t} + \theta_4 (lnGDP_{rt})^2 + \theta_5 D_{r,t} + \theta_6 D_{r,t-1} + \theta_7 F_{r,t} + \theta_8 F_{r,t-1} + \theta_9 T_{r,t} + \theta_{10} SI_{r,t} + \theta_{11} FM_{r,t} + \omega_{r,t}$

where the dependent variables for equations (3.10), (3.11) and (3.12) are logs of real GDP per capita (*GDP*), energy intensity (*ENERGY*) and carbon emissions intensity (*EMISSIONS*), respectively. *AID* is either a scalar representing aggregate aid or vector comprised from the sectoral aid variables. For the set of exogenous factors, *D* is domestic investment, *F* is Foreign Direct Investment (FDI), *T* represents the total value of trade relative to GDP, *I* is the inflation rate, *SI* stands for the share of industry in GDP, *EP* is the Energy Price Index, and *FM* is a variable representing the intensity of fossil fuel use.

In addition to the main model equations, one other equation (3.13) is also estimated in order to directly test for an overall EKC relationship. This equation uses carbon emissions over GDP (*EE*) as the dependent variable and includes all relevant explanatory variables from equations (3.11) and (3.12) as follows:

$$(3.13) \quad lnEE_{r,t} = \phi_0 + \phi_1 AID_{r,t} + \phi_2 AID_{r,t-1} + \phi_3 lnGDP_{r,t} + \phi_4 (lnGDP_{rt})^2 + \phi_5 D_{r,t} + \phi_6 D_{r,t-1} + \phi_7 F_{r,t} + \phi_8 F_{r,t-1} + \phi_9 T_{r,t} + \phi_{10} SI_{r,t} + \emptyset_{11} EP_{rt} + \phi_{12} FM_{r,t} + \varpi_{r,t}$$

For all variables, the subscripts *r* and *t* represent that the variables are for recipient country *r* in year *t*. More detailed descriptions of each variable are provided in Table 3.1, along with the expected signs.

Table 3.1. Variable descriptions

Variable	Description	Expected Sign (equation)
GDP	Real annual Gross Domestic Product per capita, World Bank.	Indeterminate (3.11, 3.12) Positive (3.13)
GDP^2	GDP squared	Indeterminate (3.11, 3.12), Negative (3.13)
ENERGY	Gross annual primary energy use (before transformation) in kg of oil equivalent divided by real GDP, World Bank.	Indeterminate (3.10)
$ENERGY^2$		Indeterminate (3.10)
EMISSIONS	Kg of carbon dioxide emissions per kg of oil equivalent energy use, World Bank.	Indeterminate (3.10)
$EMISSIONS^2$		Indeterminate (3.10)
AID	Aggregate and sectorally disaggregated Official Development Assistance (ODA) disbursements recorded by all donors as a % of recipient GDP, OECD.	Positive (3.10, all except Environmental aid, current and lagged) Neutral (3.10, Environmental aid, current and lagged) Negative (3.11, 3.12, 3.13, all, current and lagged)
D	Gross capital formation as a % of GDP, World Bank	Positive (3.10, current and lagged) Negative (3.11, 3.12, 3.13, current and lagged)
F	Foreign Direct Investment as a % of GDP, World Bank	Positive (3.10, current and lagged) Negative (3.11, 3.12, 3.13, current and lagged)
T	Total exports and imports of goods and services as a % of GDP, World Bank	Positive (3.10) Negative (3.11, 3.12, 3.13)
I	Annual inflation rate, World Bank	Negative (3.10)
SI	Total value added from mining, manufacturing, construction, electricity, water and gas as a % of GDP, World Bank.	Positive (3.11, 3.12, 3.13)
EP	Index of global energy prices, World Bank.	Negative (3.11, 3.13)
FM	Energy use from fossil fuels as a % of gross energy use, World Bank.	Positive (3.12, 3.13)

Notes: All monetary values are expressed in constant 2005 US Dollars. For more detailed information on each variable, see Appendix 3.1.

The GDP per Capita Equation

The purpose of this equation is to capture the indirect environmental impact of aid via its effect on economic growth. The log of real GDP per capita here is considered as a proxy for economic growth. Real GDP per capita is well established as the standard measure of economic growth in the related literature (see for example Al-Mulali et al. 2015 for the EKC literature and Rajan and Subramanian 2011 amongst aid-growth studies).

In addition to the current period aid variables (aggregate and sectoral), equation (3.10) also includes a one year lagged value of each aid variable. This is to allow for a potential lag in observable aid impact with some forms of aid working over a longer time horizon (Clemens et al. 2004). This contrasts with the aid-growth literature, which has conventionally employed panel data with four or more year observation periods to accommodate lagged aid effect (Clemens et al. 2004). Furthermore, it should be noted that a single year lag is unlikely to capture the full extent of impact for certain types of aid.[12] However, deeper lags and multi-year observation periods are not employed here as the impact of aid and growth on energy and carbon emissions intensity is typically not considered to have a deep, if any lagged effect (see for instance Arvin and Lew 2009; Kretschmer et al. 2013; Omri 2013). Additionally, there is an inherent trade-off in allowing for a longer impact horizon in that it reduces the ability of the sample to capture time trends. The inclusion of a single year lag therefore, is at least expected to capture some element of delayed aid impact on growth while still preserving a satisfactory time dimension in the sample. A conventional timeframe for the analysis of the environment-growth and aid-environment relationships may also be preserved.

Aside from the aid variables, energy and carbon emissions intensity are also included on the right-hand side of equation (3.10) as per the functions outlined in section 3.1.2. The additional square terms are included for each of these variables to address the EKC; in particular, to allow a potential non-linear relationship of GDP per capita separately with each of energy and carbon emissions intensity. The inclusion of these variables in the GDP per capita equations is also supported by a number of environment-growth causality studies which find empirical support for a bi-directional relationship between energy use or carbon emissions and economic growth. While this bi-directionality is typically found in relation to

[12] Clemens et al. went so far as to suggest that the extent of observable impact lags for health and education targeted aid may even be too large to feasibly analyse.

per capita measures of energy and emissions, we consider it sensible to also allow for the possibility here with the alternative intensity measures used.

The remaining explanatory variables in equation (3.10) are included for control purposes. These have all been drawn from the existing literature on aid and growth. The equation includes domestic investment to directly capture the impact on growth of capital stock changes as per equation (3.9) in section 3.1.2 (Ekanayake and Chatrna 2010). FDI is also included due its expected potential impact on growth (see for instance de Mello Jr. 1999 and Hansen and Rand 2006). One period lags for both of these variables are also included to capture possible delayed impacts associated with these factors in a similar fashion to aid.[13] Trade is included to account for its potential contribution to growth (see for instance Frankel and Romer 1999 and Wacziarg and Horn Welch 2008). Trade also serves as a measure of trade openness in the recipient country, which is typically used as an indicator of policy soundness in the aid-growth literature (Rajan and Subramanian 2008). Inflation rate is another variable included here as a means to capture the impact of the recipient country's economic management and policy environment on aid effectiveness (Burnside and Dollar 2000).

Of note in regards to equation (3.9) in section 3.1.2, a measure of population growth (the usual proxy for changes in the labour supply as in Ekanayake and Chatrna amongst others) is not explicitly included in the equation given that the dependent variable is already measured relative to the population. It should also be noted that there were a number of other explanatory variables intended to be included in equation (3.10), particularly relating to economic management and policy, which were ultimately omitted for a variety of reasons. The specific details of these omissions are covered in Chapter 5.

The Energy Intensity Equation

The same set of current and lagged aid variables from equation (3.10) appear in both the energy intensity and carbon emissions intensity equations as well, with lags included for similar reasons as in equation (3.10). The inclusion of GDP per capita in linear and squared form on the right-hand side of each of equations (3.11) and (3.12) is to account potential

[13] While panel-based regression analysis of FDI-growth relationships do not necessarily include lags for FDI (see for instance de Mello Jr. 1999 and Alfaro 2003), causality based studies do find empirical support for the use of lagged FDI e.g. one and two years in Hansen and Rand (2006) and up to four years in Chowdhury and Mavrotas (2006).

non-linearity in regards to the relationship between energy and emissions intensity and economic growth. The quadratic function is the standard in the literature on the empirical analysis of the EKC hypothesis (Stern 2004). Here, using the same functional form separately for each of energy and emission intensity will allow a more detailed view on the hypothesized inverted U-shaped relationship of environment and economic growth. Additionally, the inclusion of GDP per capita in (3.11) and (3.12) captures the indirect effect of aid on the environment, leaving the aid variables to capture the direct effect only.

The explanatory variables used in equation (3.11) are largely similar to those in equation (3.10), with domestic investment, FDI, trade and their associated lags all included in this equation. The inclusion of FDI and trade variables is based on the existing literature which suggests a potential influence of these factors on energy use (e.g. Mielnik and Goldemberg 2002 for FDI and Antweiler et al. 2001 for trade).

Equation (3.11) also contains two control variables not included in the GDP per capita equation. The share of industry in GDP is included to explicitly account for the Composition effect as per Kretschmer et al. (2013). The energy price index is also included to account for the impact of price changes on energy use as per standard demand theory.

Finally, as discussed in section 3.1.1, carbon emissions intensity should also be included on the right hand side of equation (3.11). However it is not done here due to a lack of suitable instruments. To include it in only a weakly instrumented form would likely not result in any more reliable a result than to simply omit it. A similar situation applies to the inclusion of energy intensity in the carbon emissions intensity equation. The issue of endogeneity and instrumentation is discussed in more detail in Chapter 5.

The Carbon Emissions Intensity Equation

Equation (3.12) again includes the same aid variables as the other two equations. It also includes a largely identical set of explanatory variables to equation (3.11); the inclusion of a linear and quadratic GDP per capita variable allows for a decomposed view of potential EKC relationships. The only difference in explanatory variables between equations (3.11) and (3.12) is that energy price index is replaced with fossil fuel intensity in (3.12) due to its significant relationship with carbon emissions (Blanco et al. 2014).

Expected Signs

Looking at the key variables of interest in Table 3.1, there is no prior expectation for the signs for the GDP per capita variables in the energy and emission intensity equations (equation 3.11 and 3.12, respectively) as per the hypothesis outlined in section 3.1.3. Similarly, there are no prior expectations for the signs for energy and carbon emissions intensity in either linear or squared form in the per capita GDP equation (equation 3.10). However, when directly examining the EKC in equation (3.13), a positive and negative sign are expected for the standard and square term respectively, thus providing the hypothesised inverted U-shaped relationship.

Aggregate measures of aid should be expected to affect positively on GDP per capita based on the hypothesis outlined in section 3.1.3. The negative expectation for the total aid sign in the energy and emissions intensity equation derives from anticipation that these variables will primarily capture the Technique effect in the estimation. Specifically, as previously discussed, aid in this model is associated with both direct Composition and Technique effects. The inclusion of share of industry in GDP however is intended to control for the Composition effect in both equations. While a Composition effect outside of the industrial sector is still possible, given the relative significance of this sector in contributing to energy use and emissions, any effect outside of this is expected to be more modest in nature. Thus, the Technique effect is expected to be the overriding channel of effect for aid's direct environmental impact in the model.

When considering the sectoral aid categories, those which are ultimately targeting economic growth and development objectives, i.e. Economic Infrastructure and Services, Health, and Production Sectors aid, are expected to have positive signs in the GDP per capita equation as per the hypothesis outlined in section 3.1.3. Environmental aid however, is expected to have no significant effect on GDP per capita given that such aid is not intended to pursue economically related objectives. These signs are expected to be the same across both the current period and lagged terms of each aid variable, with the current period term capturing a more immediate growth effect where applicable. The combined impact of the current and lagged terms for each variable indicates the net effect of aid on growth over both years. In general, it is expected that any given aid category largely features a delayed intended economic impact. However, the current period positive growth impact for economically targeted aid types is also expected to the extent that such aid provides a short-term positive economic stimulus through increases in investment, employment and income.

Regarding environmental impact, Environmental aid is expected to be negative in both the energy and carbon emissions intensity equations as per the hypothesis outlined in section 3.1.3. Similarly, a negative sign is also expected for the other aid categories of interest (Economic Infrastructure and Services, Health and Production Sectors) considering that these aid types are primarily expected to directly affect the environment via the Technique channel as discussed in regards to total aid. All aid variables signs are expected to remain the same in the carbon emissions over GDP equation (3.13).

As for the remaining control variables, as can be seen from Table 3.1, domestic investment, FDI and trade are all expected to be positive in the GDP per capita equation and negative in the environmental equations, with these signs applying to both the current and lagged terms where applicable. The negative expectation for these variables in equation (3.12) and (3.13) is based on the view that they will primarily impact on the environment via the Technique effect, as with the aid variables. Inflation is expected to have a negative impact on GDP per capita, given that it is a representation of overall soundness in economic management and policy in the recipient country. Share of industry in GDP is expected to impact positively on both energy and carbon emissions intensity given that this variable represents the most pollution intensive sectors of the recipient economy (Kretschmer et al. 2013). The Energy Price Index variable is expected to have negative effect on energy intensity under the assumption that energy is an ordinary good. Fossil fuel intensity is expected to have positive effect on carbon emission intensity (Blanco et al. 2014). Where applicable, these signs are expected to remain unchanged in equation (3.13).

Chapter 4

Data and Background

4.1 Data Sources

Data examined in the empirical analysis are obtained from two main sources. First, data on aggregate and sectoral aid values are obtained from the OECD's Creditor Reporting System (CRS) database. This system provides data on ODA (aid) disbursements and commitments for 180 recipient countries and 86 donor countries and organisations for the period 1973-2014 (at time of original collection). Aid flows recorded in the CRS are additionally disaggregated by targeted sector within the recipient country.[14] Of these sectors, this thesis analyses the following four categories: *Total Health Aid*, *Total Economic Infrastructure and Services*, *Total Production Sectors* and *Total General Environment Protection*. All remaining aid flows are included into the fifth category: 'Other Aid'.

For the purpose of this research, aid disbursements were chosen as the measure of aid rather than commitments as has typically been the case with studies utilising this dataset (e.g. Clemens et al. 2004; Kretschmer et al. 2013). Commitments have usually been chosen previously in spite of acknowledged issues, due to lack of a sufficient time frame for disbursement data on the sectors of interest (Clemens et al. 2004; Kretschmer et al. 2013).[15] However, studies using aid commitments must contend with the fact that commitments do not necessarily translate into actual aid disbursed to a recipient country in the time period in which the commitment is recorded, if at all (Kretschmer et al. 2013). Given that the OECD does now offer aid disbursement data in the CRS for a sufficiently long timeframe, this data was considered preferable to that on commitments for the purposes of this study for two reasons: (i) the relatively low levels of data coverage for disbursements are considered less problematic than the potential inaccuracies associated with commitment data, and (ii) commitment data also suffers from significant coverage issues over the full timeframe, only to a lesser extent than for disbursements.

[14] Appendix 4.1 provides a full breakdown of the CRS's constituent sectoral aid categories.

[15] According to Clemens et al. 2004), at the time of their original study, disbursement data was not available for years prior to the 1990's (the one exception being Humanitarian Aid). While this has since changed, data coverage for disbursements prior to 2002 is limited, with the average coverage figure being below 60% for these years (OECD 2016c). This contrasts to commitment data which achieved a 70% coverage ratio in 1995, rising to over 90% in 2000.

One additional point of concern to be highlighted with use of the CRS data, is that the OECD relies on the donor to appropriately classify its aid in accordance with the OECD's provided categories (OECD 2017). This may allow donors to (either intentionally or unintentionally) inaccurately classify their aid. However, the OECD takes steps to mitigate the impact of misclassification through the assessment of donor report's conformity to provided definitions (OECD 2017).

Aside from the CRS aid data, data for GDP per capita, energy and carbon emissions intensity, as well as all other included control variables were obtained from the World Bank.[16] These data are available for a comprehensive range of countries from 1960 onwards. The World Bank compiles this data from various sources, including the International Energy Agency, who provided the data for the energy intensity and fossil fuel intensity variables. Where applicable, figures in the World Bank database where retrieved in constant 2005 US dollars. For consistency, aid figures from the OECD CRS, which were retrieved in the form of constant 2013 US dollars, were converted into the 2005 format to match World Bank data.

4.2 Data and Sample

With the data obtained from the two sources, panel data was constructed for a total of 46 aid-receiving countries over the sample period of 1974-2011.[17] The cross-sectional dimension of the data is reduced from the total of 180 recipient countries available in the CRS to the 46 included in the final sample on the basis of certain criteria. Most importantly, a large number - 103 - of recipient countries from the CRS database are excluded from the final sample, due to their incomplete availability of data on the dependent variables (GDP per capita, energy Intensity and carbon emissions Intensity) for the entire sample period. Additionally, any recipient countries remaining after application of this initial criterion that transitioned from developing to developed status during the sample period were filtered out to avoid skewing the results. These countries were identified as Bahrain, Barbados, Bermuda, Brunei, Croatia, Cyprus, Hong Kong, Kuwait, Malta, Oman, Qatar, Saudi Arabia, Singapore, Trinidad and Tobago and the UAE. This transition was identified on the basis of whether a country was recorded as reaching High Income country status during the sample period, as

[16] See Appendix 3.1 for details on specific indicators and calculation methods used to derive the variables in this study.
[17] Appendix 4.2 shows the 46 aid-receiving countries used in the analysis.

identified by the World Bank.[18] Alternatively, as per the example of Boone (1996), any recipient country with recorded aid flows as a donor in the CRS for the sample period was also omitted.

To further ensure the reliability of the analysis results, any country that did not receive aid on a 'consistent' basis during the sample period was also omitted. This requirement was considered on the basis that, aside from the three dependent variables, aid is a critical variable of interest in the study and thus would ideally have a minimum level of significance to each recipient country's economy. Consistency of aid receipt was defined as having recorded aid disbursements for every year from 2002-2011. Defining consistency in this manner, as opposed to considering the full sample period analysed, was done due to data coverage issues affecting earlier years. Specifically, as discussed in the previous section, the OECD states aid data coverage as being above 90% from 2002 onwards, but increasingly below this figure for prior years (OECD 2016c). As such, a lack of recorded aid figures for countries in years prior to 2002 is not uncommon, and not necessarily the result of a lack of actual aid disbursements. To omit countries due to lack of aid data for these years therefore, would have resulted in an infeasibly small sample.

Lastly, a number of countries which remained after application of the above two criteria were ultimately dropped from the regression sample due to insufficient observations for the additional explanatory variables, making them consistently unable to be included in the regressions.

One final point to note is reduction in the sample period to 1974-2011 from the longer range available with the CRS. This reduction results partly from the inclusion of lagged variables in the model specification, which precludes the use of 1973 in the sample. Additionally, years 2012-2014 were excluded on the basis that data for these years was not available at the time of collection for two of the dependent variables - energy and carbon emissions intensity.

[18] https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups

4.3 Descriptive Analysis of Data

Prior to presenting the results from estimating the equations outlined in the previous chapter, it is worthwhile examining the key statistics of the data relating to this study's primary variables of interest. First, summary statistics for the sample to be used in the regression are presented in Table 4.1, followed by a more detailed examination of the specific variables.

Table 4.1. Summary statistics for the sample

Variable	Obs.	Mean	Std. Dev.	Min	Max
GDP per Capita	1,748	2197.8020	1959.7410	161.0149	13555.9500
Energy Intensity	1,748	0.4998	0.3590	0.1384	3.2665
Carbon Emissions Intensity	1,748	1.8507	1.0299	0.0689	7.9448
Total Aid (% GDP)	1,748	1.4396	3.9744	0.0000	57.9171
Economic Inf. & Serv. Aid (% GDP)	1,748	0.1938	0.3779	0.0000	5.1041
Economic Inf. & Serv. Aid (% Total Aid)	1,607	23.6593	26.7955	0.0000	100.0000
Education Aid (% GDP)	1,748	0.0009	0.0021	0.0000	0.0153
Education Aid (% Total Aid)	1,607	0.0628	0.1092	0.0000	1.0000
Health Aid (% GDP)	1,748	0.0628	0.1869	0.0000	1.9100
Health Aid (% Total Aid)	1,607	3.0884	7.0453	0.0000	100.0000
Production Sectors Aid (% GDP)	1,748	0.1074	0.2172	0.0000	2.2737
Production Sectors Aid (% Total Aid)	1,607	12.9466	18.5937	0.0000	100.0000
Environmental Aid (% GDP)	1,748	0.0173	0.0460	0.0000	0.5332
Environmental Aid (% Total Aid)	1,607	1.5509	3.5761	0.0000	42.3253
Other Aid (% GDP)	1,748	1.0576	3.5005	0.0000	56.1231
Other Aid (% Total Aid)	1,607	58.6921	29.7178	0.0000	100.0000
Domestic Investment	1,694	22.4451	7.8469	-5.7397	73.4946
FDI	1,687	1.7837	2.5426	-12.2084	31.4295
Inflation Rate	1,573	60.9290	720.2542	-11.6861	23773.1300
Trade Relative to GDP	1,686	60.7126	32.9269	6.3203	220.4073
Share of Industry in GDP	1,564	31.6008	10.4888	6.4672	77.4137
Energy Price Index	1,748	53.0574	27.1161	23.7814	125.5648
Fossil Fuel Intensity	1,744	54.0317	28.4639	1.7939	99.9383

Figure 4.1a. Average energy intensity by country

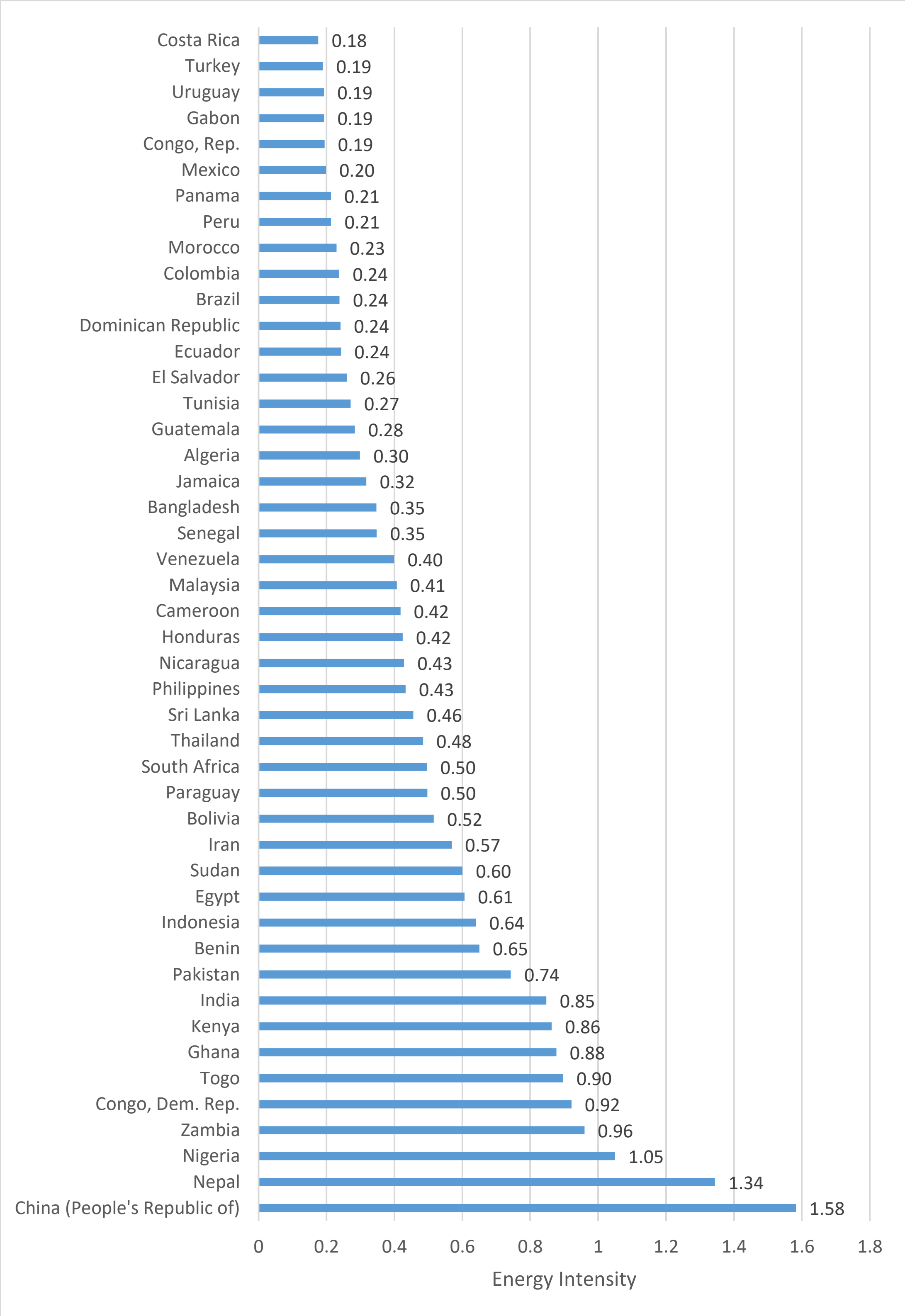


Figure 4.1b. Average energy intensity by year

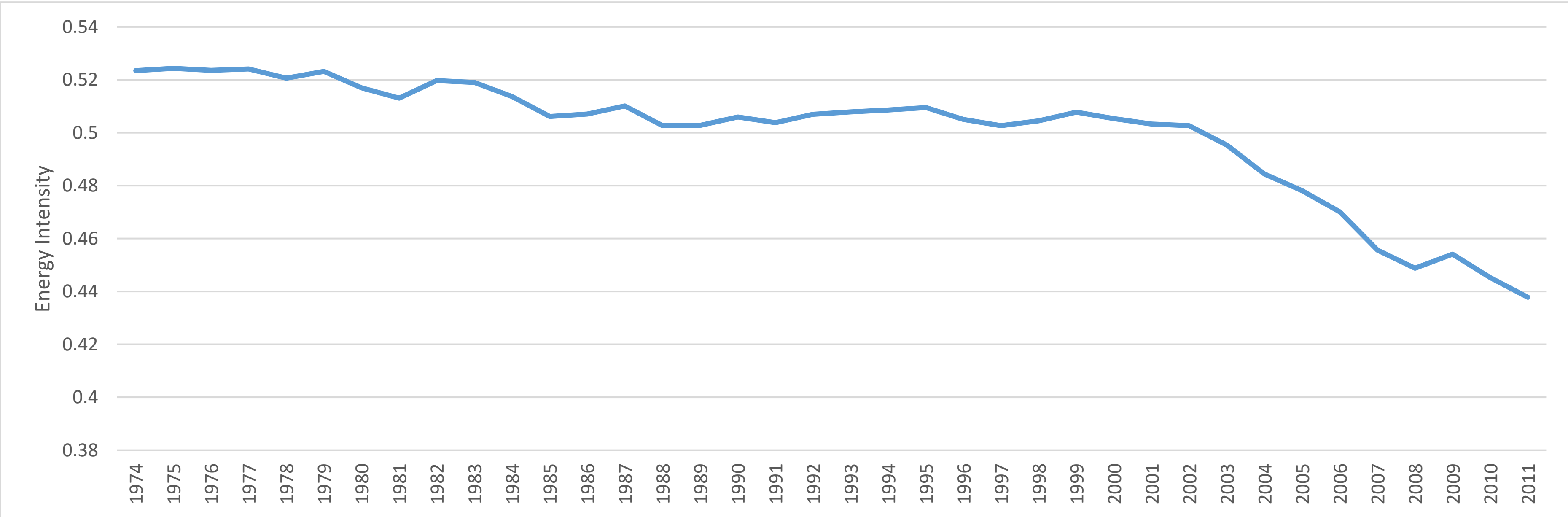


Figure 4.2a. Average carbon emissions intensity by country

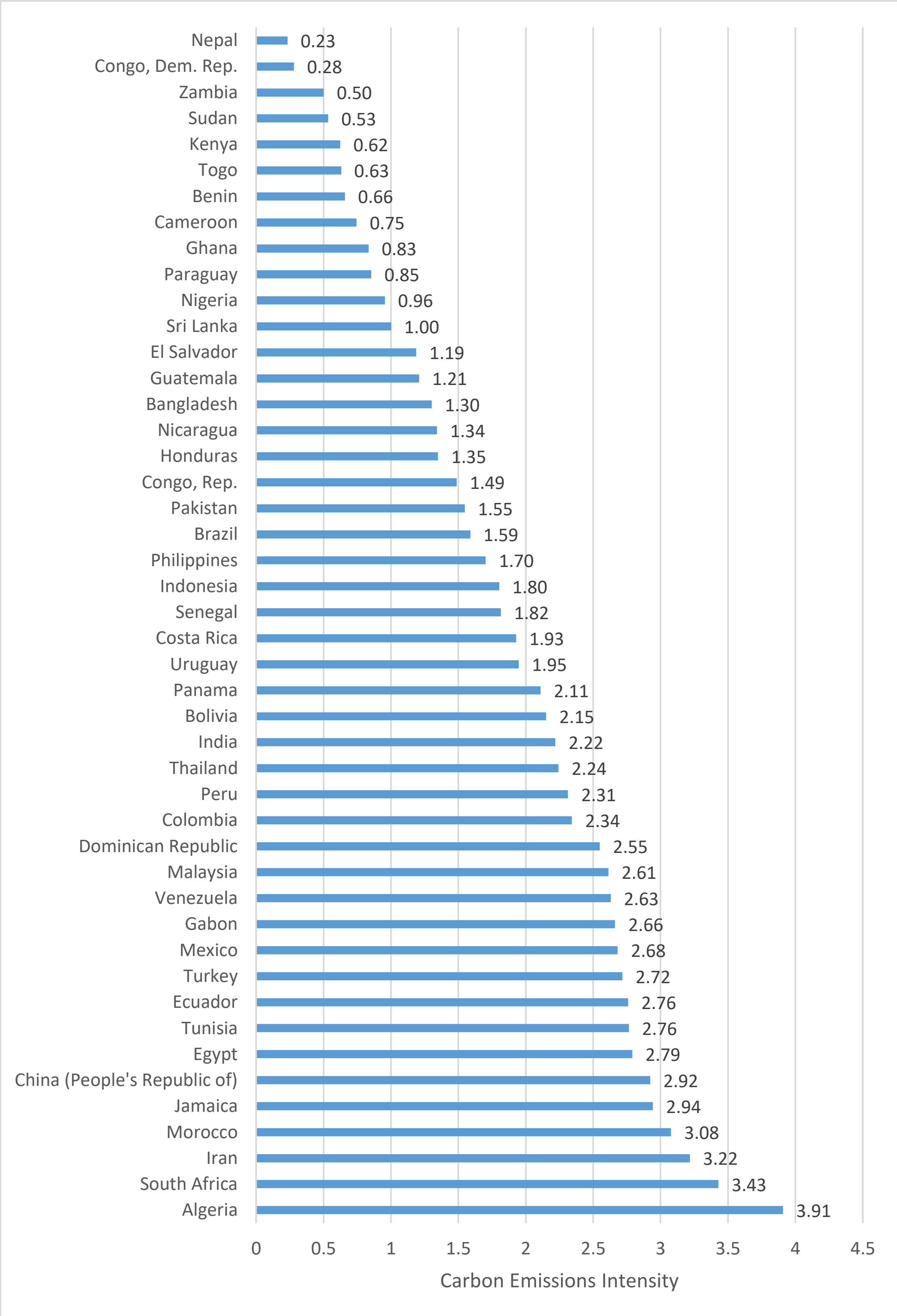


Figure 4.2b. Average carbon emissions intensity by year

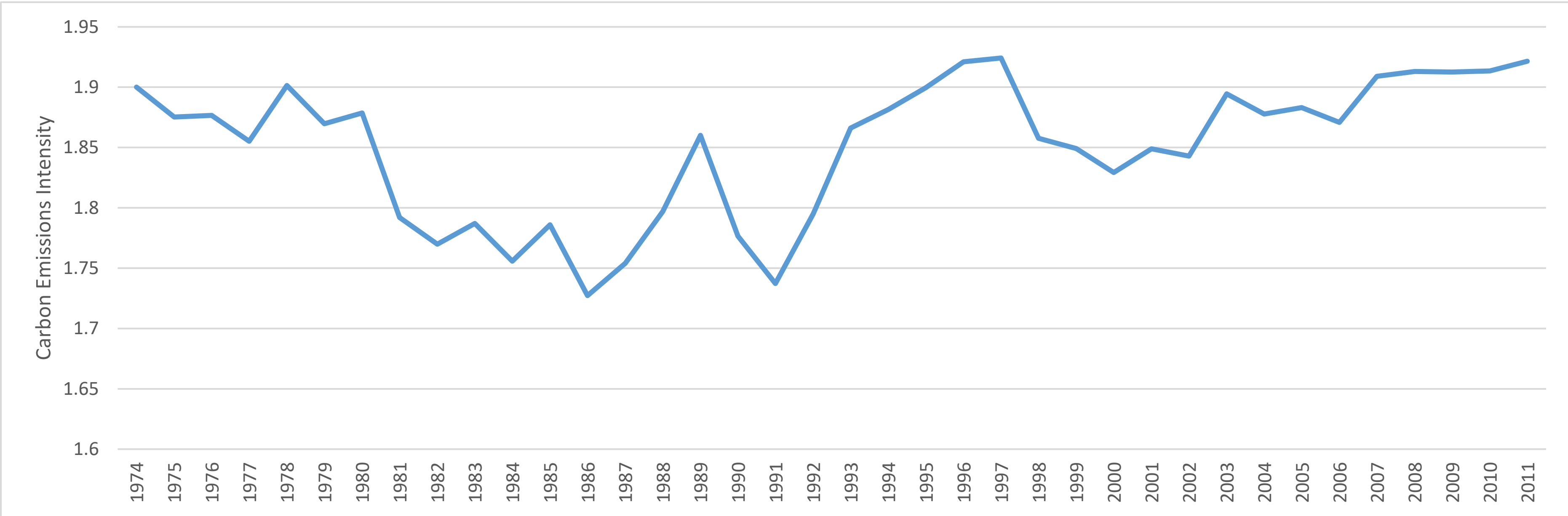


Figure 4.3a. Average carbon emissions over GDP by country

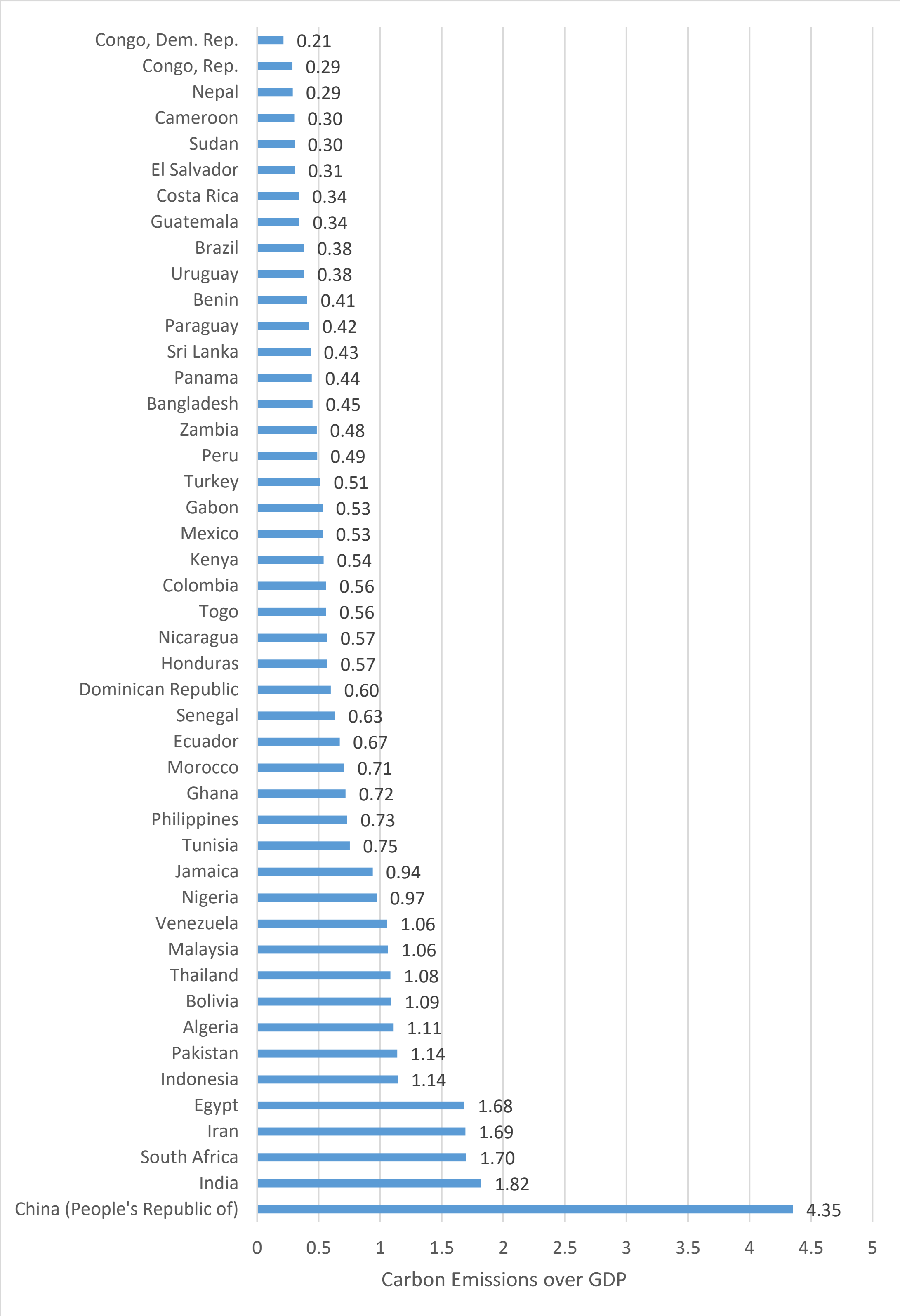


Figure 4.3b. Average carbon emissions over GDP by year

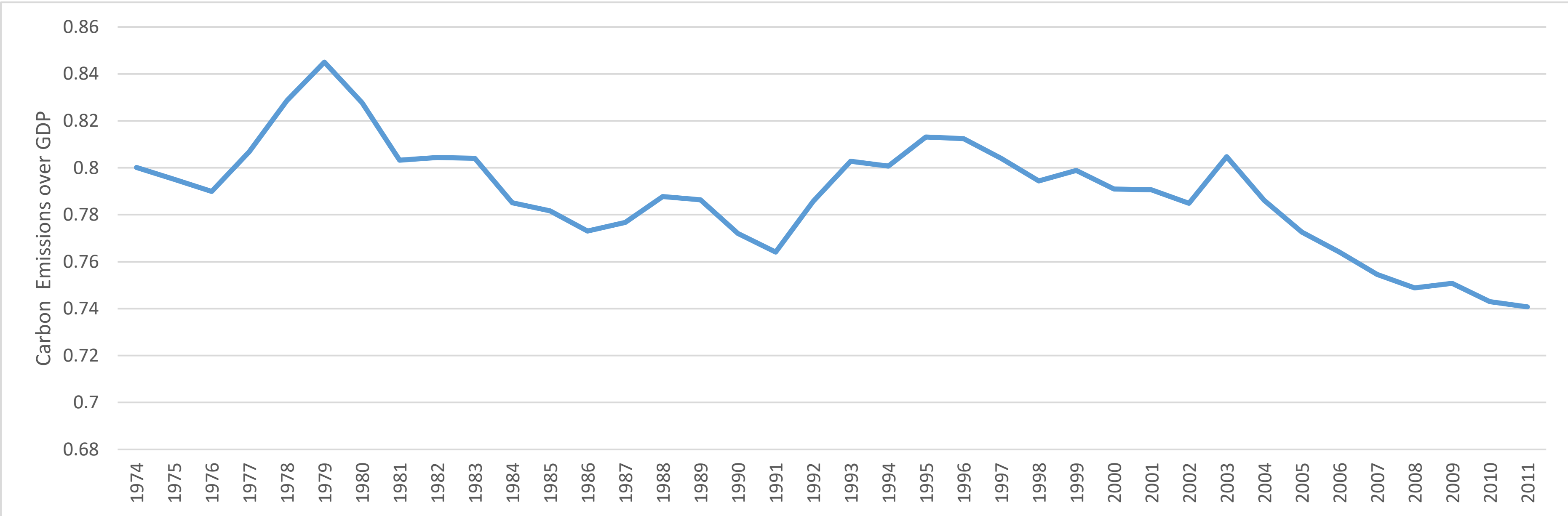


Figure 4.4a. Average GDP per capita by country

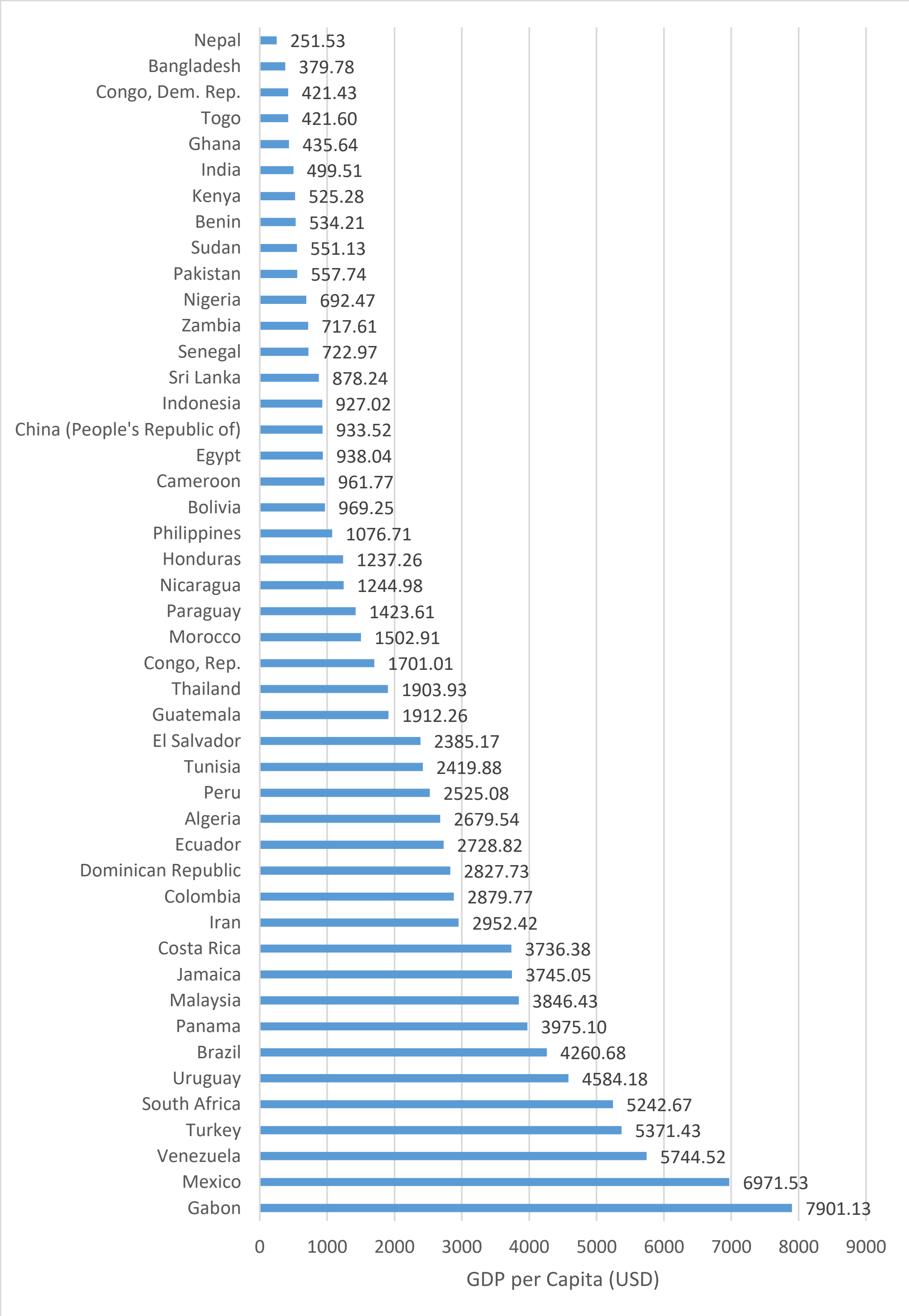
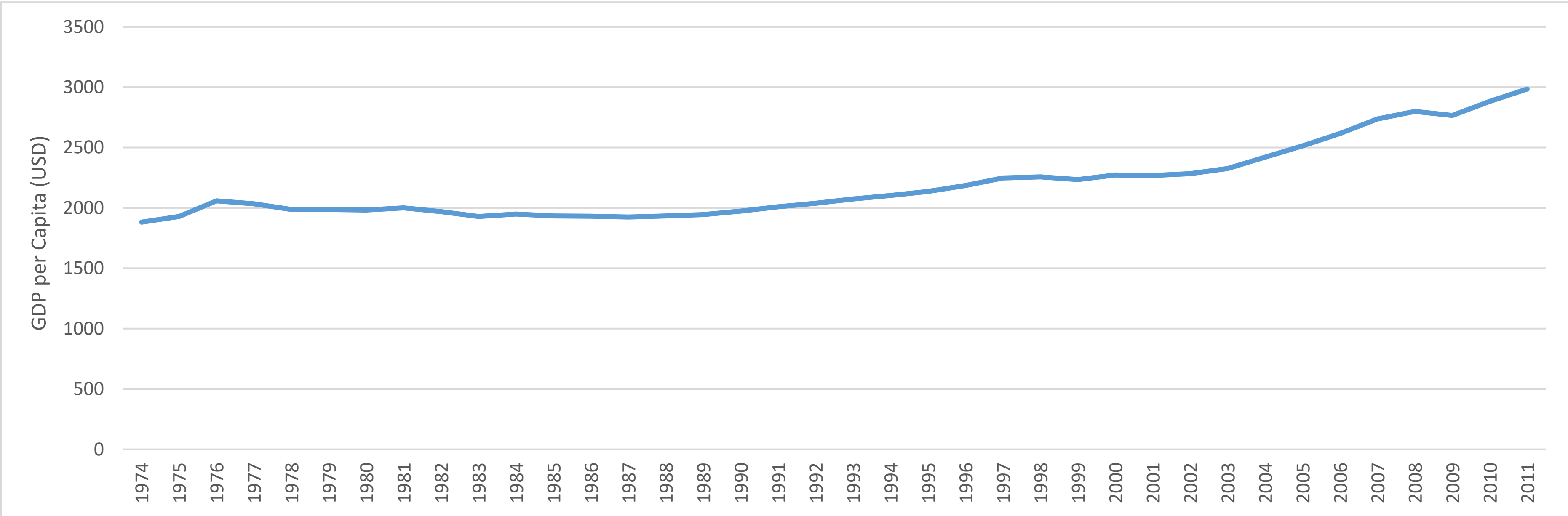


Figure 4.4b. Average GDP per capita by year



Environmental Impact

Starting with the environment-growth dimension of our analysis, Figures 4.1a through 4.4b show the average energy intensity, carbon emissions intensity, carbon emissions over GDP and GDP per capita for the sample by country and year, respectively. Examining the environmental impact and GDP per capita figures by country in Figures 4.1a, 4.2a, 4.3a and 4.4a, considerable variation amongst the sample countries can be observed for the dependent variables. Of these, GDP per capita appears to feature the largest proportional difference between minimum and maximum average values observed for the sample. The highest income country observed - Gabon - has an average GDP per capita approximately 31 times that of Nepal - the lowest. Energy intensity by contrast, features the smallest relative range of values. For this variable China - the most energy intensive country - possesses an average value of around only 9 times that of Costa Rica, the least energy intensive nation in the sample on average. In comparison to both of these variables, carbon emissions intensity sits in the middle. The maximum average country value observed here is exactly 17 times the observed minimum (the maximum and minimum values are possessed by Algeria and Nepal respectively). When combining energy and emissions intensity in the form of carbon emissions over GDP, it can be seen that the most environmentally intensive nation overall in the sample is China. In particular, China features an average value for carbon emissions over GDP that is approximately 21 times that of the Democratic Republic of Congo, who possesses the lowest average value. The maximum environmentally intensive country overall is China by a considerable margin. Looking in between these extremes, with the exception of carbon emissions over GDP, there appears to be a reasonably even distribution of values for each of these variables across the observed range.

Now looking at the temporal variation in the dependent variables, from Figure 4.1b there is an identifiable (albeit weak) downward trend in energy intensity in the sample, particularly in the last decade of the observation period. This trend implies general improvements in energy efficiency over the sample period. By contrast, carbon emissions intensity indicates less discernible patterns in its time trend, as per Figure 4.2b. Interestingly, emissions intensity declined somewhat from 1974 to the mid 1980’s, after which it exhibited a gradual increase until 2011, when the sample period ends. This means that the cleanliness of energy sources worsened during the latter period despite environmental quality attracting increasing concern internationally. Combining these two intensities in Figure 4.3b, a distinct downward trend in carbon emissions over GDP is apparent in the most recent years of the sample. This implies an overriding effect of the energy intensity trend.

Incorporating income trends into the scenario, an increasing trend in GDP per capita is evident for the sample in more recent years, as per Figure 4.4b. This upward trend in GDP per capita appears to coincide with a downward trend in energy intensity as per Figure 4.1b. In order to obtain a clearer view of this scenario, Figures 4.5a-4.5c present scatter plots graphing the environmental impact variables against GDP per capita based on annual averages across all sample countries.

Figure 4.5a. Energy intensity against GDP per capita (average annual figures for entire sample)

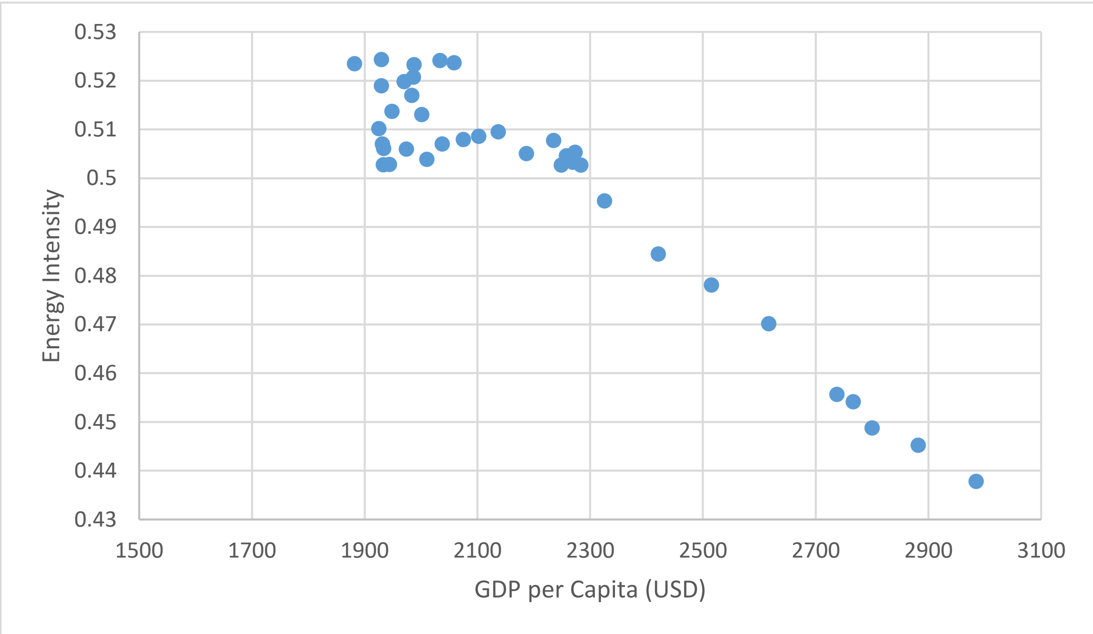


Figure 4.5b. Carbon emissions intensity against GDP per capita (average annual figures for entire sample)

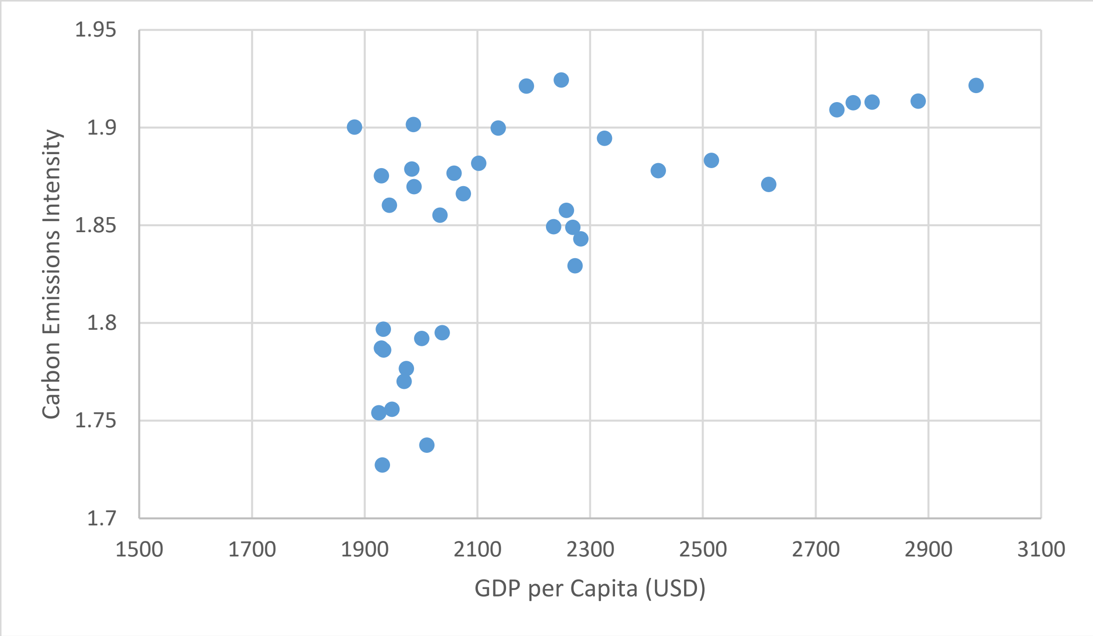
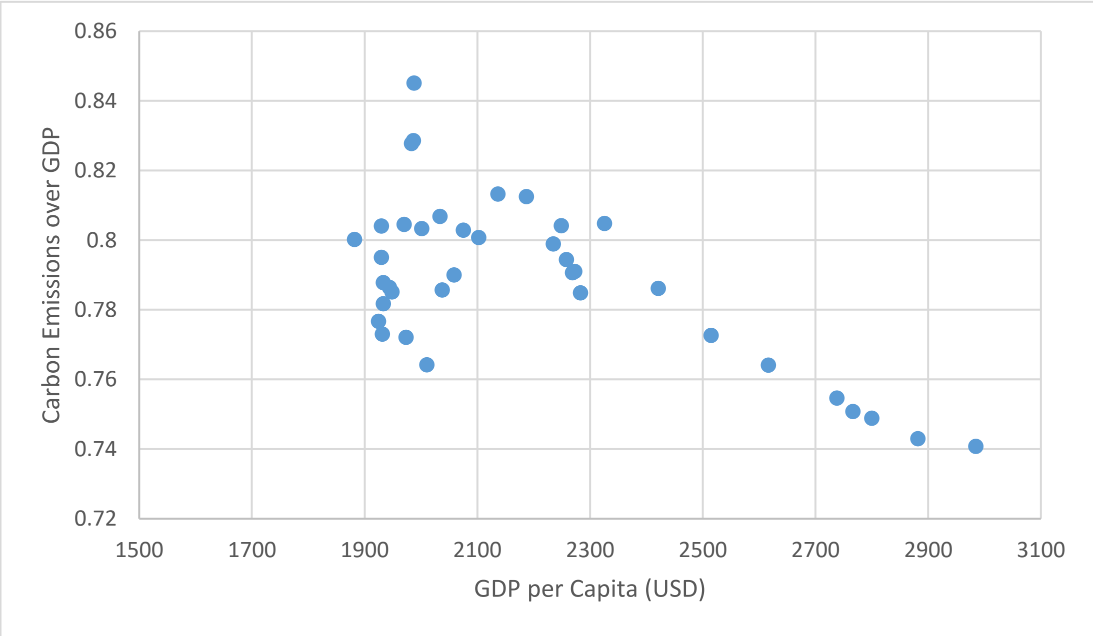


Figure 4.5c. Carbon emissions over GDP against GDP per capita (average annual figures for entire sample)



Consistent with Figures 4.1b and 4.4b, the scatter plots demonstrate an overall negative relationship between energy intensity and GDP per capita. It is also interesting to note that this relationship only becomes apparent above $2000 in GDP per capita. Figure 4.5c demonstrates a similarly negative relationship overall for GDP per capita and carbon over GDP. Though a less distinct, positive relationship is observed in Figure 4.5b between GDP per capita and carbon emissions intensity. This confirms the observations from Figures 4.1b-4.4b that trend observed for carbon emissions over GDP is primarily driven by energy intensity. Furthermore, it is again interesting to note that the relationships observed in 4.5b and 4.5c are also both only apparent above approximately $2000 GDP per capita, as with energy intensity.

While this is only a basic analysis that cannot be relied upon as evidence that the demonstrated relationships exist, the scenario illustrated presents an interesting context in which to examine the results produced by the data analysis itself.

Total Aid

Turning our attention to foreign aid, Figure 4.6a illustrates that the significance of aid varies considerably amongst recipient countries in the sample. Average total aid flows calculated for each country over the sample period range from 0.02% of GDP to 6.46% of GDP annually, with a mean value of 1.44%. This figure is below 1% of GDP for 29 countries and exceeds 3% of GDP for only 8 recipient countries in the sample. A small share of total aid flows in GDP leads to an expectation that aid's overall potential to impact on sample countries' economies should be modest in nature at most.

Figure 4.6a. Average aid received over the sample period by recipient country

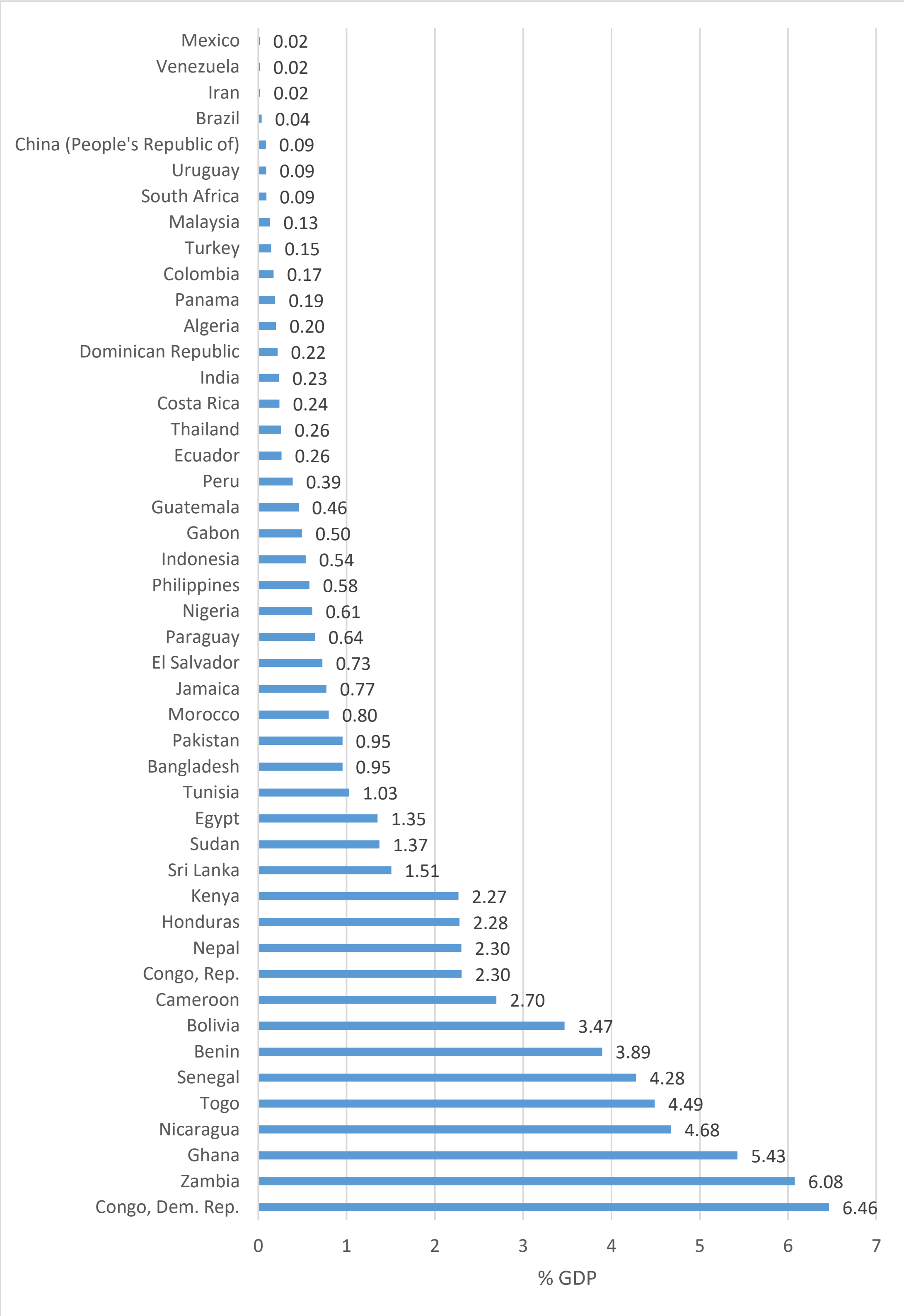
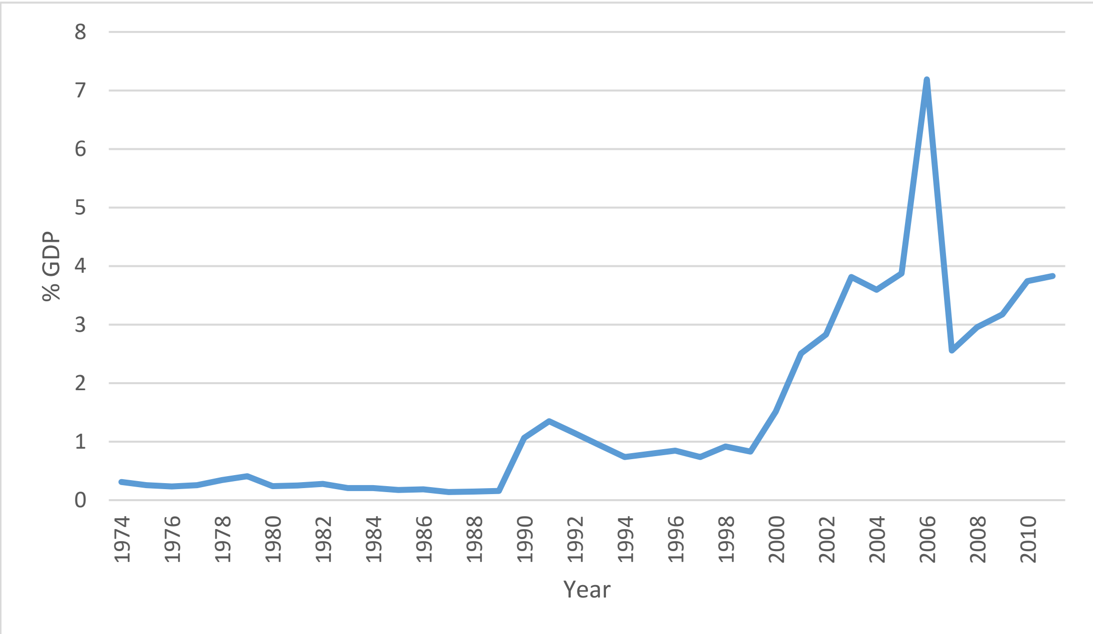


Figure 4.6b presents average total aid received as a percentage of GDP across all sample countries in each year of the sample period. As can be seen, there is a significant increase in the cross-country average from 1990 onwards, with a general upwards trend in the significance of aid for the sample recipients from this point on. The most likely explanation for this trend is due to improving data coverage in the CRS database over time, with coverage rates in earlier decades of the sample period being relatively low as discussed in section 4.1.

One other observation of note from Figure 4.6b is the temporary spike in the significance of aid disbursements to sample countries in 2006. A possible explanation for this spike may be some form of co-ordinated debt cancellation effort amongst donors. A close examination of the underlying data reveals that the Action Relating to Debt aid category increased in 2006 to the average of 4.86% of recipient GDP, which is more than three times its highest level in any other year for the period 2002-2011, and accounts for approximately 68% of total aid disbursed that year on average.

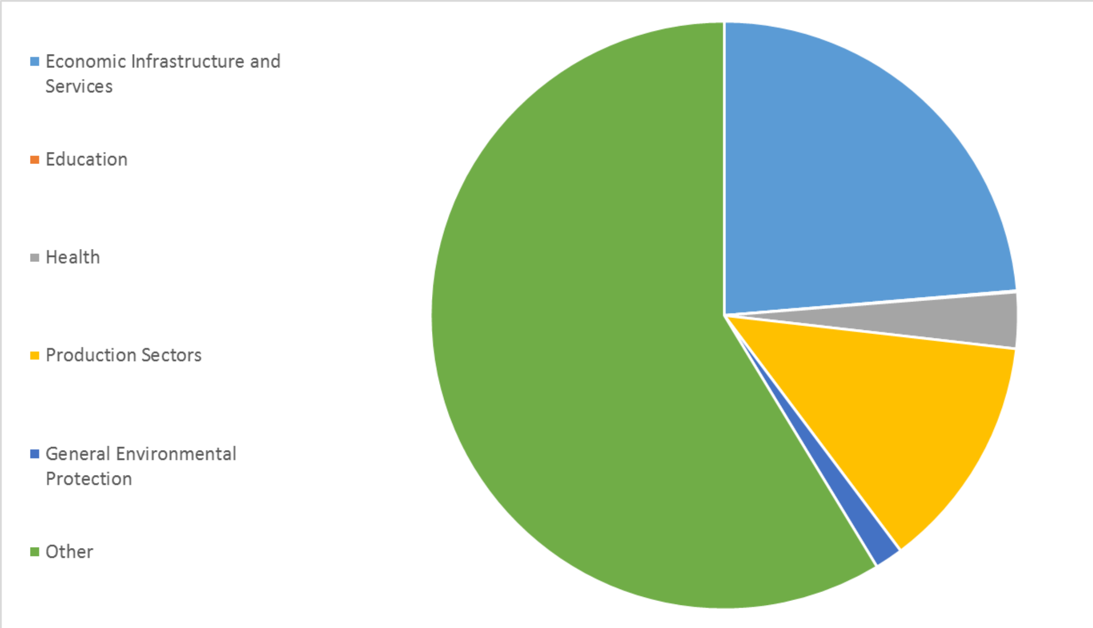
Figure 4.6b. Average aid received annually by all sample countries



Sectoral Aid

Looking at aid in its sectoral form for the sample, the average breakdown of total aid disbursed by measured sector is shown in Figure 4.7a.

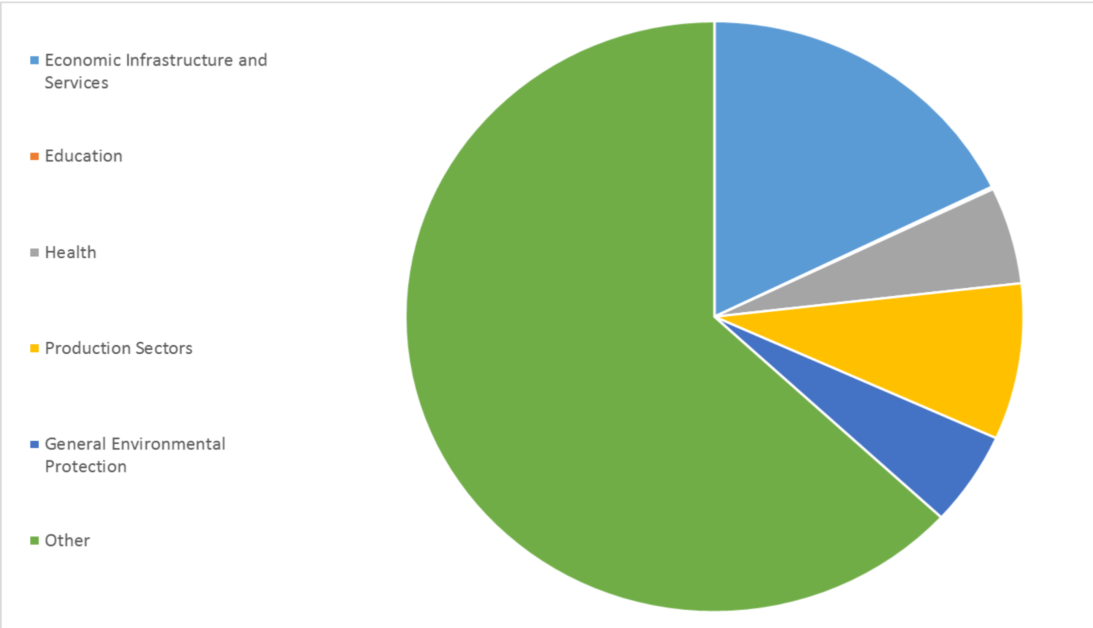
Figure 4.7a. Breakdown of total aid disbursements by sector

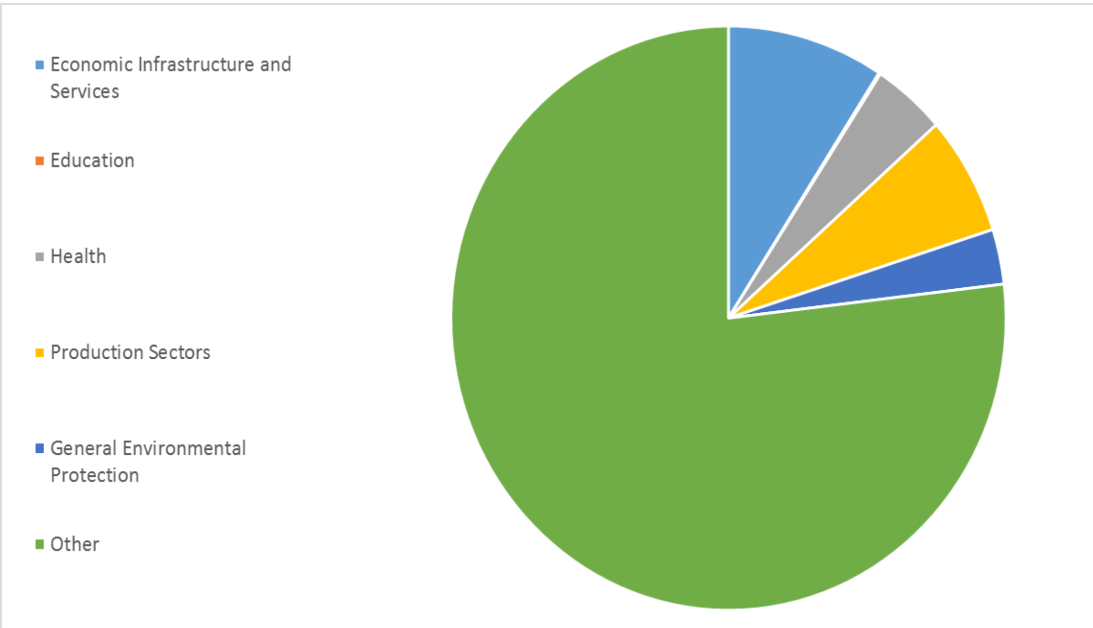


The most prominent observation to be made from Figure 4.7a is the relative significance of the Other Aid category, which accounts for more than half of all aid disbursed for the sample period overall. Of the remaining categories, it can be seen that aid for economic infrastructure and services and production sectors are the two most significant classified aid categories in the sample. Aid for the health sector indicates a more modest share, while Environmental aid was amongst the least significant. One final observation of note is that aid for education is significantly underrepresented, with a smaller reported disbursement relative to the total than even environmental aid. This can also be seen in the previously presented Table 4.1, where Education aid on average, constituted less than 0.001% of recipient GDP for the sample. A frequent failure of donors to classify education related aid disbursements could potentially account for this scenario. However there is no reason to think that this failure would affect Education aid significantly more than any other category. As such, it would appear that Education aid is considered a relatively low priority by donors. Or alternatively, that a lower level of financial investment is required in this sector compared to others to achieve intended objectives. Regardless of cause however, the extremely small size of this aid category in the sample motivated the decision to omit it from the subsequent analysis, as mentioned in the previous chapter.

Another dimension of the sectoral aid breakdown that may be explored is the possibly of time trends in the relative significance of the measured aid categories. This is achieved in Figures 4.7b and 4.7c, which show the sectoral breakdown of aid disbursements in years 2002 and 2011 respectively.

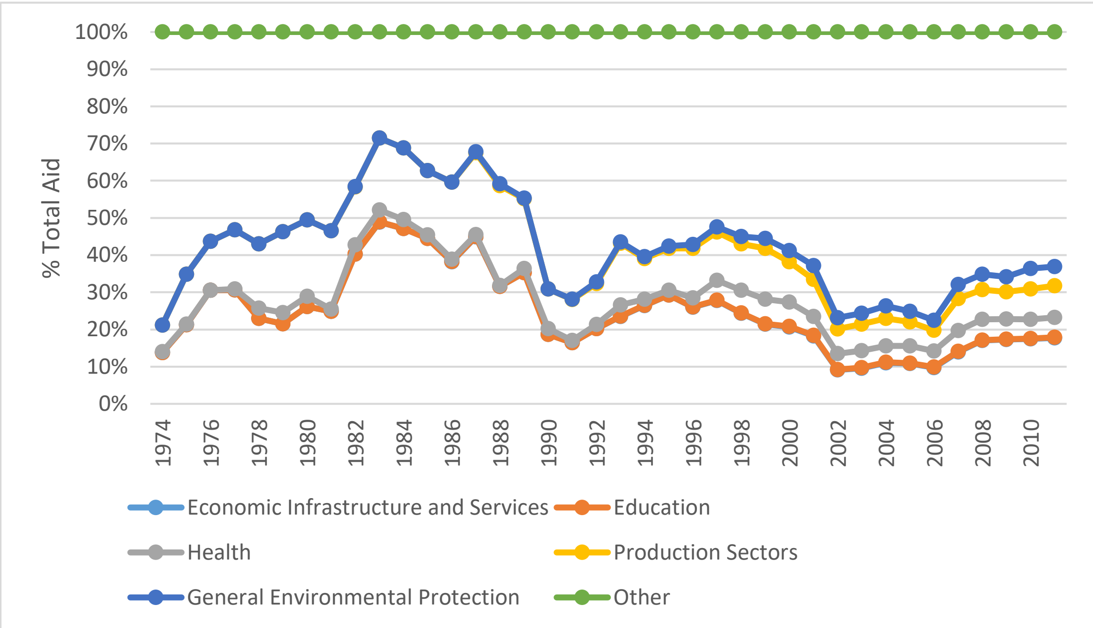
Figure 4.7b. Breakdown of total aid disbursements by sector in 2002





There is a clear increase in the significance of the measured aid categories against the Other Aid category in 2011 as compared to 2002. All measured categories increase in size relative to total aid flows, with Economic Infrastructure and Services aid experiencing the largest increase. Also notable is the significant increase in General Environmental Protection aid, which appears to have roughly doubled in size relative to total aid flows against 2002 levels. This perhaps reflects an increased focus amongst donors on environmental objectives. In order to gain more insight into these observed trends, Figure 4.7d presents the sectoral aid breakdown for the full sample period.

Figure 4.7d. Sectoral aid breakdown by year for full sample period



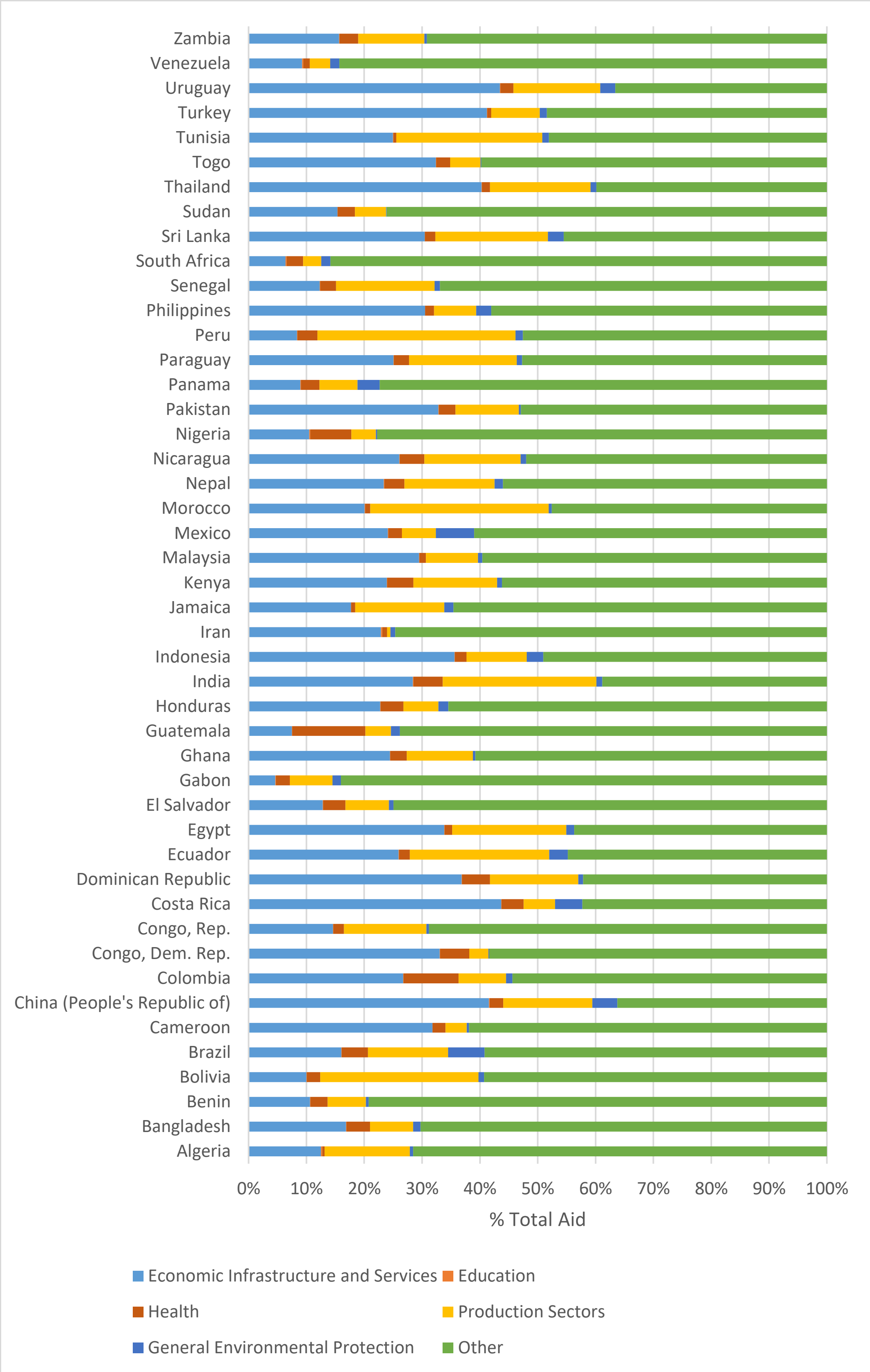
One notable obsevation from Figure 4.7d is that the measured aid categories were of greater relative significance in earlier decades of the sample, falling sharply at the beginning of the 90's, with the re-emergence of an upwards trend in more recent years. One possible explanation for this observed scenario is that it reflects trends amongst donors towards and away from sector specific aid. Or alternatively, the changing popularity of measured aid sectors vs unmeasured ones over time. Whatever the specific reason may be however, the signifcant reduction in relative signficance for measured categories in 1990 parallels a signifcant increase in overall aid flows to recipients that same year, as per Figure 4.7b. Given the likelihood that the scenarion depected in 4.7b is at least partly the result of increased data coverage, it is also possible that coverage increases contributed to the simultaneous decrease in relative significance for the measured aid categories. This would imply that perhaps the relative signficance of the measured aid categories in the sample for the 1970's and 80's is somewhat overstated.

While the examination of these temporal trends is illustrative, it would also be useful to examine the cross-sectional variation in the sectoral aid breakdowns presented. As such, a more detailed view of the variation in relative sectoral disbursements across recipient countries is presented in Figure 4.7e on the following page.

While there is variation in the sectoral aid breakdowns for each sample country, as shown in in Figure 4.7e, countries in the sample nonetheless largely conform to the overall sectoral breakdown illustrated in Figure 4.7a. Specifically, Other Aid typically constitutes the majority of disbursements received with Economic Infrastructure and Services and Production Sectors being the most significant remaining categories. Furthermore, Education aid is typically barely discernible in terms of its relative significance for most countries in the sample.

The overall picture of sectoral aid disbursement for the sample presented in Figures 4.7a-e. suggests a largely consistent view of the relative significance of the various aid categories, with aid for economic infrastructure and services and production sectors typically the largest measured categories and Education Aid being of seemingly minute significance overall. The Other Aid category also typically makes up the majority share of disbursements. When taking into consideration the fact that the majority of recipients had an average level of total aid disbursements below 5% of their GDP in any given year, expectations for the potential impacts of the measured sectoral aid categories on recipient countries must be adjusted accordingly; the impact of sectoral aid disbursements, even more so than total aid disbursements, would be of a modest magnitude at most.

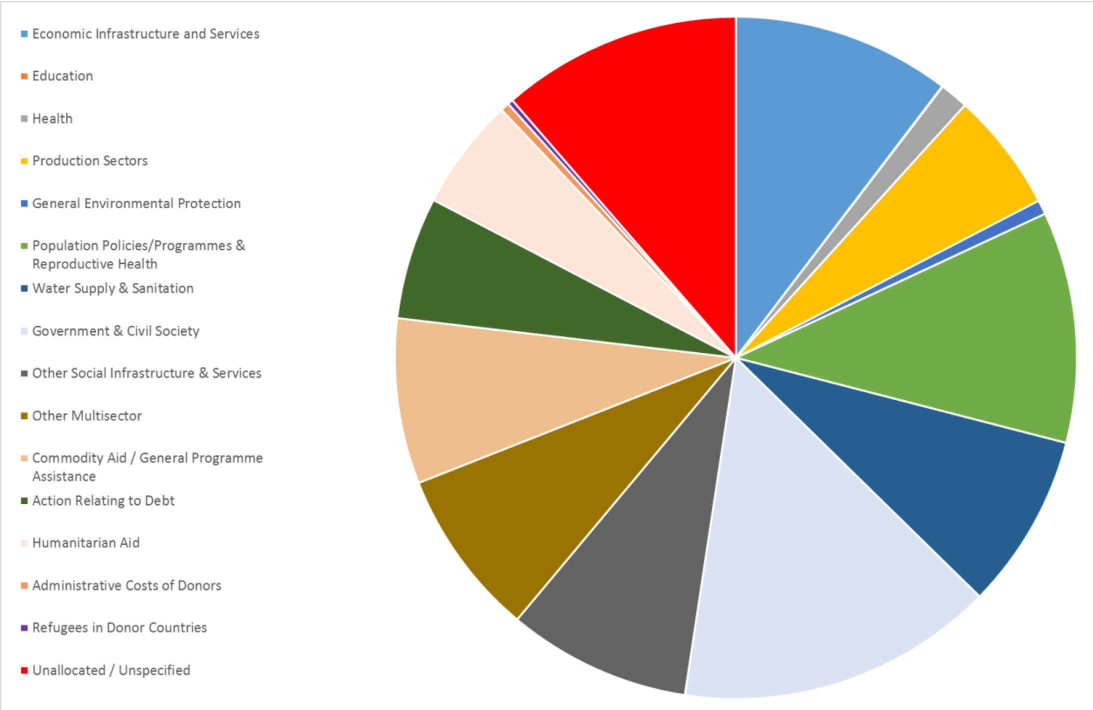
Figure 4.7e Sectoral aid breakdown by country



Other Aid and Aid Sector Selection

Given the relative prominence of Other Aid in Figure 4.7a, it is worth examining this category in more detail. Figure 4.7f presents the sectoral breakdown with Other Aid fully disaggregated into its constituent categories.[19]

Figure 4.7f. Breakdown of total aid disbursements by sector with Other Aid disaggregated



When fully broken down, the largest aid category in the sample from 2002-2011 is Government and Civil Society - a category covering aid aimed at improving political effectiveness and stability, as well as social stability, crime prevention and other related objectives (OECD 2016b). Unallocated or sector unspecified aid follows this category in significance, along with Population Programs/Policies and Reproductive Health - a category covering aid for family planning and reproductive health projects and programs, along with HIV/Aids programs and other related objectives (OECD 2016b). Water Supply and Sanitation targeted aid, Other Social Infrastructure and Services aid and Commodity Aid/General

[19] There are some discrepancies between the breakdowns presented in Figures 4.7a and 4.7f which arise due to changes in the underlying dataset in the interim between collection of the data used in each Figure. Specifically, the data in Figure 4.2f was obtained from the CRS database approximately 12 months after original data collection, with the content of the database appearing to have been significantly updated during this time. Therefore it should be noted that the breakdown presented in Figure 4.7f differs from that of the actual dataset used in the analysis.

Program Assistance are the other most significant aid categories in the sample. Other Social Infrastructure and Services aid covers areas such as social welfare programs, culture and recreation and narcotics control. Commodity Aid/General Program Assistance includes budget support and support for commodity and capital imports (OECD 2016b). Despite the relative significance of each of these categories, they are not individually measured, with only the categories previously outlined given special attention.

The selection of the outlined categories for explicit analysis over many larger categories relates to this study's objectives regarding the inclusion of aid. Specifically, the interest in aid here extends particularly to its environmental impact, both directly and via its impact on growth. It is also not the intention of this study to undertake a comprehensive comparison of the performance of the various aid sectors in the CRS. As such, only a representative selection of aid sectors considered to best capture conventional growth and development objectives, which were also expected to have a potential direct environmental impact, were selected. The one exceptional sector being Environmental Aid, which was included to examine the performance of aid directly intended to impact on the environment.

There were a variety of reasons why the various sectors included in Other Aid, were considered less suitable for explicit examination in this study's analysis. Unallocated/Unspecified aid is categorised in the Other Aid category by definition - as it is not possible to identify how this aid is used in recipient countries. Other Social Infrastructure and Services, Administrative Costs of Donors, Refugees in Donor Countries and Humanitarian Aid were identified as unsuitable for explicit consideration given that they do not relate directly to economic growth or development objectives. On the other hand, Population Programs/Policies and Reproductive Health and Water Supply and Sanitation sectors can both be considered growth and development focussed aid categories. They were excluded from specific analysis however, in favour of the Health aid category. This was due to the fact that Health Aid was considered to feature broadly similar objectives and underlying mechanics in terms of affecting population health and labour productivity. Furthermore, while Health aid is the smaller category, it covers a much broader range of health-related objectives making it a far more representative category. Additionally, the impact of population control is accounted for through the per capita measure of growth.

The Commodity Aid/General Program Assistance and Government and Civil Society aid categories were also omitted from specific analysis in spite of their relative size. These categories were considered to be “facilitating” forms of aid - impacting more so onto political and economic control factors rather than pursuing a direct growth and development objective.[20]

It should be noted that this study’s approach to examination of targeted aid sectors differs somewhat from previous studies using the CRS database. The approach used by Kretschmer et al. (2013) is the most similar to the present research. They directly examined the Production Sectors category and Energy sub-category of Economic Infrastructure and Services. However, Kretschmer et al. did not account for any other aid category in their analysis, outside of an aggregate aid variable, which again includes the Production Sectors and Energy sectors. The more common approach to the use of CRS aid data however, has been that employed by aid-growth studies. These studies typically examine the CRS aid sectors indirectly, grouping them in higher level categories based on various criteria. Table 4.2, provides a summary of a number of these studies.

The categorisation of aid sectors based on development objectives and timeframes as in Table 4.1, is appropriate in the context of aid-growth analysis. This approach would prove less insightful however, when also examining environmental impact. The direct examination of individual aid sectors as in Kretschmer et al., appears better suited to isolating specific channels of growth and environmental effect associated with different forms of aid. However, given Kretschmer et al. do not consider the growth effect of aid in their analysis, their selection of aid sectors is more limited. The approach adopted here of directly examining a broader range of individual aid sectors, is intended to be a suitable compromise between these two established alternatives. It is expected that this approach will better accommodate the dual growth and environmental impact relationships to be studies in regards to aid.

[20] It should be noted however, that a number of the political and economic control variables intended to be included in the model specification were ultimately omitted. Chapter 5 discusses this issue in more detail.

Table 4.2. Summary of select CRS-based aid-growth studies

Study	Aid Categorisation (constituent CRS categories in parentheses)	Dependent Variable	Results
Clemens et al. (2004)	Comprehensive classification of all CRS aid flows at a sub-category level based on the following groupings: - *"short-impact" aid* - *"long-impact" aid* - *humanitarian aid*	GDP per capita growth	Positive significant for "short impact" aid, insignificant for "long impact" aid and humanitarian aid
Dovern and Nunnenkamp (2007)	*"Short-impact" aid* (Economic Infrastructure and Services, Production Sectors, Commodity Aid/General Program Assistance and Debt Relief)	Conditional probability of growth acceleration	Positive significant
Kaya et al. (2012)	*Agricultural aid* (Agriculture subsector of Production Sectors), *"investment aid"* (Economic Infrastructure and Services, Production Sectors minus Agriculture), *social infrastructure aid* (Social Infrastructure and Services), *"non-investment aid"* (all remaining sectors)	GDP per capita	Positive significant for agricultural aid, insignificant for "investment aid" and "non-investment aid", variable for social infrastructure aid (negative significant or insignificant depending on specification)

Notes: Clemens et al. (2004) consider a "short-impact" timeframe in which aid is expected to impact on growth of four years.

Conclusion

The descriptive analysis of relevant statistics and trends in the sampled data reveals some important details that may inform subsequent analytical results. Most importantly, the relative significance of total aid disbursements to recipient economies and the measured sectoral aid categories relative to both recipient economies and total aid disbursements are determined to be quite small. As such they are expected to have only modest economic and environmental impacts on recipient countries.

Additionally, some interesting trends have been determined in relation to the dependent variables. In particular, per capital income appears to be correlated negatively to energy intensity and it is only marginally but positively correlated with the carbon emissions intensity. Such a scenario could present interesting implications for the EKC hypothesis, which is to be examined more thoroughly through the application of modern panel data analysis techniques in the following chapter.

Chapter 5

Results and Discussion

5.1 Estimation Method

Estimation Issues

In estimating the model outlined in Chapter 3, two key issues must be addressed. The first issue is the presence of endogenous variables. Specifically, in the system of three equations, the three dependent variables GDP, ENERGY, and EMISSIONS, variously also appear on the right-hand side of equations. Thus, their values are simultaneously determined within the system. This violates the assumption of non-zero correlation of the right-hand side variables and the error terms, which results in biased and inconsistent estimates of the coefficients in (3.10)-(3.12) if obtained via the method of OLS.

The endogeneity of aid variables is also well recognised within the aid-growth literature (see Rajan and Subramanian 2008 for instance). It results from the view that donors may be motivated to provide aid to higher performing recipients for whom aid appears to be particularly effective. Alternatively, donors may focus on countries whose growth performance is poor, based on more charitable motivations (Rajan and Subramanian 2008). It is also possible that poor growth performance may serve to discourage some donors under the belief that aid is not working. Effectively, these scenarios imply that aid may be simultaneously determined with the growth level of recipient countries, which causes the OLS estimators of the coefficients in equations (3.10)-(3.12) and (3.13) to be biased and inconsistent.

To verify endogeneity concerns, an augmented regression (Durbin-Wu-Hausman) test was performed for each of the suspected endogenous variables. The results confirm that each of these variables should be treated as endogenous. Appendix 5.1 contains further explanation of this test along with the results.

The second estimation issue is the potential for unobserved heterogeneity across the sample countries. Factors not explicitly controlled for in the model may influence the dependent variables substantially. This results in omitted variable bias, which again renders the results obtained from OLS to be biased and inconsistent.

Estimation Method

To address the issue of endogeneity in the model, the Two Stage Least Squares (2SLS) method is employed in estimating equations (3.10)-(3.12) and (3.13). 2SLS is the standard method to address endogeneity in econometric models. It has also been commonly employed in the aid-growth literature (for instance Burnside and Dollar 2000; Guillaumont and Chauvet 2001; Kaya et al. 2012) to deal with the endogeneity of aid, as well as by Omri (2013) for his simultaneous equations model for energy, emissions and growth and Ozturk and Al-Mulali (2015) in their study of the EKC in Cambodia.

2SLS allows for the endogenous explanatory variables to be instrumented by the variables that are exogenous, but also (preferably highly) correlated with the endogenous explanatory variables (Nagler 1999). With 2SLS, reduced-form regressions are run first with each of the endogenous variables separately being regressed on all of the relevant explanatory variables and specified instruments. The resulting predicted values for each endogenous variable are then substituted into the main structural equations of the model in place of the endogenous variables for the second stage regressions, which constitute the final results for the estimation (Nagler 1999).

In order for the structural equations 3.10-3.13 in Chapter 3 to be estimated, it is necessary to ensure that the model is identified. A model is identified if it is possible to obtain numerical estimates of the coefficients in the structural equations from estimates of the reduced form coefficients (Gujarati 2004). A necessary condition for identification is that each structural equation exclude at least m-1 endogenous or exogenous variables (where m is the number of equations in the model), that appear elsewhere in the model (Gujarati 2004). This is known as the Order Condition and specifically requires that each of the endogenous explanatory variables that appears in the model have at least one variable with which it is instrumented by. With a simultaneous equations model, each of the structurally endogenous variables (that is, GDP per capita, energy intensity and carbon emissions intensity) must therefore have at least one corresponding explanatory variable that is unique to its own identifying equation to use as an instrument (Nagler 1999). For the system of equations (3.10)-(3.12), the requirement can be satisfied with inflation rate for GDP per capita, energy price index for energy intensity and fossil fuel intensity for carbon emissions intensity. Additionally, the three equations also contain squared terms of each of these structurally endogenous variables, which due to being a direct function of the original variables, are also considered endogenous (Semykina and Wooldridge 2010). These squared endogenous variables can however be instrumented with squares of the excluded instruments, which is the approach adopted here (Semykina and Wooldridge 2010).[21]

While convention in the aid-growth literature dictates the use of the lag of aid or a set of variables intended to capture donor intent as instruments for aid, lagged GDP per capita is used as the instrument for aid here instead. The reason for this is that the explicit inclusion of lagged aid on the right hand side of each equation prevents it from being used as an instrument. Furthermore, the use of lagged GDP per capita eliminates the significant complexity associated with attempting to capture donor motivation for aid disbursement for use as an instrument.[22] As the endogeneity of aid is due to the reverse causality between aid and growth, past growth - as captured by one-year lagged GDP per capita - is expected to be correlated with aid. It should also be noted that total aid is instrumented in equations (3.11), (3.12) and (3.13), as per the example of Kretschmer et al. (2013).

Given the endogeneity of total aid, it is likely that the sectoral aid variables are also endogenous for similar reasons. However, these variables were not instrumented in the analysis. The specific reason for this decision was that lagged GDP per capita cannot be used to instrument for all five sectoral aid variables. Furthermore, the lags of the sectoral aid variables themselves - the typical choice of instrument (see for example Clemens et al. 2004; Kretschmer et al. 2013) - are unavailable due to their explicit inclusion in the regression equations. Clemens et al. (2004) have also determined that these lagged instruments performed poorly in their analysis. Given an apparent lack of suitable alternative instruments, the sectoral aid variables are left un-instrumented in the analysis. While this does adversely impact the reliability of results for these variables, instrumenting with weak or unsuitable instruments would not mitigate these reliability issues.

Finally, while aid is the primary non-dependent variable to present endogeneity concerns, it should be noted that Clemens et al. (2004) also considered the possibility of endogeneity problems presented by other control variables in their aid-growth analysis. They ultimately found however, that attempts to instrument for the various control variables used did not

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[21] Regarding performance for the variables that are instrumented; though first stage regression results are not reported here, the R squared statistics for these regressions ranged from approximately 0.3-0.97. This suggests that the strength of the instruments used here are, at a minimum, adequate for the purposes of the analysis.

[22] See Rajan and Subramanian (2008) for a thorough example of this instrumentation strategy.

meaningfully impact on their results. Further support for this outcome also comes from the earlier Burnside and Dollar (2000) study on aid, growth and macroeconomic policy - where the endogeneity of an index of macroeconomic policies was tested and rejected by the authors.

Unobserved Heterogeneity

While the 2SLS estimation method is able to address the issues arising from endogenous right-hand-side variables, it does not inherently account for issues relating to omitted variable bias. To address the issue of unobserved heterogeneity therefore, a fixed or random effects model is considered in conjunction with the 2SLS estimation method. Fixed effects may be used to account for unobserved, time-invariant heterogeneity between cross-sectional units while a random effects model assumes this variation to be random and uncorrelated with the independent variables (Torres-Reyna 2007). The two specifications differ from a usual regression specification (i.e., without fixed or random effects) that imposes a single intercept to all cross-sectional units. In contrast, the fixed and random effects models allow cross-sectional variation in the constant term and hence account for the impact of unobserved country specific-factors that do not change over the observed time period. Thus, they can reduce the bias associated with omitted variables (Klawitter 2012).

The aid-growth literature has primarily utilised the fixed effects specification (Hansen and Tarp 2000). Both Omri (2013)'s energy-emissions-growth study and Kretschmer et al. (2013)'s aid-environment study similarly utilised fixed effects. This specification is based on the view that unobserved time-invariant cross-sectional variation is the primary factor affecting panel-based aid impact analysis. Based on this existing precedent, and the similarities between the present research and these other studies in terms of data, included variables and relationships under examination, the fixed effects option is also chosen here.

Missing Variables

While unobserved heterogeneity in a general sense is a commonly addressed concern in the literature relating to the present research, this issue is specifically exacerbated here by the omission of certain relevant control variables. As mentioned previously, aside from the decision not to include energy and emissions intensity in each other's equation, a number of control variables are excluded from the GDP per capita equation, including: a measure of the recipient country's budget balance relative to GDP and a measure of the money supply (M2) relative to GDP. These non-aid variables were intended to capture the potential impact on aid effectiveness of differences in the economic and political environment in recipient countries, and may have also been relevant to the environment-growth relationships examined in equations 3.11-13. They were dropped from the estimated model however, due to a significant lack of observations. This leaves the inflation rate variable in equation 3.10, as well as the trade variable in all equations (which can also serve as a proxy for trade openness) solely to control for political and economic management factors. While this is hardly complete, the use of country specific fixed effects should reduce the adverse impact of resulting omitted variable bias. It should also be noted that Ekanayake and Chatrna (2010) included only the inflation rate as a means to control for economic and political factors in their aid-growth study, providing some support for the approach here.

In addition to the omitted non-aid variables, two aid-related variables were omitted from the GDP equation. First, the standard deviation of the total aid variable (to measure aid volatility) was not included due to its incompatibility with the country-specific fixed effects. While an alternative option exists by means of calculating the variance of the aid variable over a set number of years as a moving average, this approach has the significant disadvantage of reducing the sample period by a considerable margin. The inclusion of a measure of aid volatility by itself, was not considered sufficiently important to justify this disadvantage. Furthermore, aid volatility has not thus far been conventionally considered as a control variable in the aid-growth literature.

Second, a square term of the total aid variable was intended to capture potential absorptive capacity/diminishing returns to aid effects. This variable was omitted from the model due to the lack of appropriate instrument to deal with its potential endogeneity. Although it was instrumented initially by the square of the log of lagged GDP per capita, this instrument was suspected of performing poorly and adversely affected the remaining regression results to an extent that could not likely be accounted for solely by the inclusion of a squared aid term. Given the lack of a suitable alternative instrument, this explanatory variable was dropped from the final specification.[23]

The omission of the aid volatility and aid squared variables cannot be mitigated by the presence of other variables in the equation. As such, given the potentially significant nature

[23] The results with this variable included are presented in Appendix 5.2 for reference.

of each of these factors' influence on the aid-growth relationship, their lack of inclusion has the potential to impact on the reliability of subsequent regressions results. This issue should therefore be considered when interpreting these results.

Time Series Properties of the Sample

It should also be noted that, following the example of more recent studies by Kretschmer et al. (2013) and Ozturk and Al-Mulali (2015), this study did not attempt to examine the time series properties of the panel data used. When examining panel data, unit root tests are often employed to establish whether or not the data is stationary e.g. Ozturk and Acaravci (2010), Lau et al. (2014) and Jebli et al. (2016). The stationarity of the data is determined to ensure an appropriate estimation method is performed. If data is found to be non-stationary and conventional estimation methods such as OLS are used, the results may be subject to spurious regression (Wooldridge 2012). Spurious regression occurs when a statistically significant correlation is produced between two variables that actually possess no relation (Wooldridge 2012).

One other relevant study that does not attempt to establish the stationarity of the data used is that of Orubu and Omotor (2011) with their panel data EKC study using OLS. They instead performed an additional set of regressions incorporating time dummies to help mitigate concern regarding spurious regression.[24] This approach was originally suggested by Van Alstine and Neumayer (2010) as a means of helping to reduce issues with spurious regression, though it does not exactly resolve the issue. The statistical significance of the key variables of interest remains largely unchanged in the environmental equations, providing a degree of assurance against spurious regression issues with these results. However, there is a notable loss of significance to key variables in the GDP per capita equation, as well as a change in significance for the current period Total Aid variable in the carbon emissions intensity equation. This may suggest an issue with the reliability of these results which could impact on the subsequent analysis.

[24] The results for these regressions are presented in Appendix 5.3.

Multicollinearity

One final issue of relevance to the model estimation is collinearity between GDP per capita and its square. If two or more independent variables are highly correlated (as is often the case with a variable and its square term) this can result in large variances for the coefficient estimates of the affected variables, impacting their reliability (Wooldridge 2012). Narayan and Narayan (2010) identified multicollinearity as a significant issue affecting the existing EKC literature. They consequently proposed an alternative approach to analysing the income-environmental impact relationship by comparing the short and long run income elasticities of carbon emissions. If a country's long run elasticity is smaller (or negative) compared to its short run elasticity, this may confirm the existence of an EKC relationship in the country.

While Narayan and Narayan's approach is an effective means of avoiding issues with multicollinearity, it is not employed here. The justification for this decision is that Narayan and Narayan's approach does not directly measure the dynamics of an EKC relationship, but rather trends in the income-environmental impact relationship over time. Not including a quadratic (or higher order) income variable would lead to model misspecification in the context of an EKC analysis. It is argued that in this instance, model misspecification would be more problematic for the reliability of results than multicollinearity. In addition, there have been a number of EKC studies published since the Narayan and Narayan study which have also chosen to adopt the conventional analytical approach with standard and higher order income variables. These studies include Arouri et al. (2012), Ozturk and Al-Mulali (2015), Shabhaz et al. (2015), Apergis (2016) and Acaravci and Akalin (2017).

5.2 Results

In estimating Models 5.1-5.3, defined in equations (3.10)-(3.12) in Chapter 3, I considered two specifications, differentiated by the selection of aid variables included, as follows:

Model 1: $lnGDP_{r,t} = \alpha_{0,\mathrm{r}} + \alpha_1 AID_{r,t} + \alpha_2 AID_{r,t-1} + \alpha_3 lnENERGY_{rt} + \alpha_4 (lnENERGY_{rt})^2 + \alpha_5 lnEMISSIONS_{r,t} + \alpha_6 (lnEMISSIONS_{rt})^2 + \alpha_7 D_{r,t} + \alpha_8 D_{r,t-1} + \alpha_9 F_{r,t} + \alpha_{10} F_{r,t-1} + \alpha_{11} T_{r,t} + \alpha_{12} I_{r,t} + \varepsilon_{r,t}$

Model 2 $lnENERGY_{r,t} = \beta_{0,r} + \beta_1 AID_{r,t} + \beta_2 AID_{r,t-1} + \beta_3 lnGDP_{r,t} + \beta_4 (lnGDP_{rt})^2 + \beta_5 D_{r,t} + \beta_6 D_{r,t-1} + \beta_7 F_{r,t} + \beta_8 F_{r,t-1} + \beta_9 T_{r,t} + \beta_{10} SI_{r,t} + \beta_{11} EP_{r,t} + \nu_{r,t}$

Model 3 $lnEMISSIONS_{r,t} = \theta_{0,r} + \theta_1 AID_{r,t} + \theta_2 AID_{r,t-1} + \theta_3 lnGDP_{r,t} + \theta_4 (lnGDP_{rt})^2 + \theta_5 D_{r,t} + \theta_6 D_{r,t-1} + \theta_7 F_{r,t} + \theta_8 F_{r,t-1} + \theta_9 T_{r,t} + \theta_{10} SI_{r,t} + \theta_{11} FM_{r,t} + \omega_{r,t}$

with

(i) $\gamma_i AID_{r,t} = \gamma_i \, TAID_{r,t}$

(ii) $\gamma_i AID_{r,t} = \sum_{j=1}^{5} \gamma_{i,j} \, SAID_{j,r,t}$

where $\gamma = \alpha, \beta, \theta$, and i = 1, 2.

The first specification (i) includes, along with all relevant explanatory variables, a variable representing total aid relative to per capita GDP only (*TAID*) and does not include sectoral aid variables. The second specification replaces total aid with the five sectoral aid variables. Total aid is omitted from this specification to avoid exact collinearity.[25]

In addition to Models 1 through 3, the following model is also estimated:

Model 4: $lnEE_{r,t} = \phi_{0,r} + \phi_1 AID_{r,t} + \phi_2 AID_{r,t-1} + \phi_3 lnGDP_{r,t} + \phi_4 (lnGDP_{rt})^2 + \phi_5 D_{r,t} + \phi_6 D_{r,t-1} + \phi_7 F_{r,t} + \phi_8 F_{r,t-1} + \phi_9 T_{r,t} + \phi_{10} SI_{r,t} + \emptyset_{11} EP_{rt} + \phi_{12} FM_{r,t} + \varpi_{r,t}$

where the dependent variable, $EE = EMISSIONS \times ENERGY$, is the ratio of carbon emissions to GDP. Model (4) allows a direct test of the EKC hypothesis. It is also estimated in two different specifications using the aid variables defined in (i)-(ii).

The four models are estimated through the two-stage least squares (2SLS) method, with country-specific fixed effects as discussed. The estimation was implemented through Stata IC 14 software. Estimation results are reported in Tables 5.1 through 5.4, and the reported signs and significance of coefficients are discussed in more detail in subsequent sections.

[25] One additional model specification, including both Total Aid and the sectoral aid variables expressed as shares of Total Aid, was also examined for reference. The results from regressions run with this specification can be found in Appendix 5.4.

Table 5.1. GDP per capita equation 2SLS regression results[26][27]

Explanatory Variable	Equation 1.i	Equation 1.ii
Energy Intensity	-1.5090	1.5343*
	(-0.97)	(1.81)
Energy Intensity (squared)	-1.5487*	-2.1371***
	(-1.90)	(-3.87)
Carbon Emissions Intensity	2.5368*	1.6018**
	(1.95)	(2.25)
Carbon Emissions Intensity (squared)	-2.0884*	-0.8796
	(-1.82)	(-1.61)
Aid Variables		
Total Aid	-0.1682**	
	(-2.28)	
Total Aid (previous period)	0.0717	
	(1.64)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		0.0937
		(1.64)
Economic Inf. & Serv. Aid, previous period		0.0276
		(0.38)
Health Aid		-0.5281*
		(-1.77)
Health Aid, previous period		0.0902
		(0.26)
Production Sectors Aid		-0.1391
		(-0.74)
Production Sectors Aid, previous period		0.0158
		(0.10)
Environmental Aid		1.2766**
		(2.15)
Environmental Aid, previous period		1.0859*
		(1.91)
Other Aid		-0.0154*
		(-1.87)
Other Aid, previous period		-0.0105
		(-1.35)
Other Controls		
Domestic Investment	-0.0187**	-0.0095
	(-2.15)	(-1.53)
Domestic Investment (previous period)	-0.0029	-0.0017
	(-0.35)	(-0.35)
FDI	0.0075	-0.0093
	(0.30)	(-1.01)
FDI (previous period)	-0.0077	-0.0035
	(-0.37)	(-0.37)
Inflation Rate	-0.0000	-0.0000
	(-1.57)	(-0.99)
Trade	0.0109***	0.0057***
	(4.44)	(5.33)
Number of observations	1,298	1,298
Number of countries	45	45
Average number of years per country	28.8	28.8

t statistics in parentheses.
*, **, and *** represent that the coefficient is statistically significant at 1, 5, and 10% size.

[26] The *xtivreg2* Stata command was used to perform all regressions: Schaffer, Mark E. 2010. "xtivreg2: Stata Module to Perform Extended IV/2SLS, GMM and AC/HAC, LIML and K-Class Regression for Panel Data Models." http://ideas.repec.org/c/boc/bocode/s456501.html.
[27] The regressions were run using robust (White type) standard errors, which are robust to the presence of heteroskedasticity.

Table 5.2. Energy intensity equation 2SLS regression results

Explanatory Variable	Equation 2.i	Equation 2.ii
GDP per Capita	-1.6509***	-1.7147***
	(-7.76)	(-8.29)
GDP per Capita (squared)	0.0891***	0.0934***
	(5.63)	(5.87)
Aid Variables		
Total Aid	0.0027	
	(0.47)	
Total Aid (previous period)	0.0027	
	(0.87)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		-0.0051
		(-0.41)
Economic Inf. & Serv. Aid, previous period		-0.0165
		(-1.31)
Health Aid		0.0942*
		(1.69)
Health Aid, previous period		-0.0919
		(-1.38)
Production Sectors Aid		0.0088
		(0.27)
Production Sectors Aid, previous period		0.0280
		(0.78)
Environmental Aid		0.2123*
		(1.82)
Environmental Aid, previous period		0.2282**
		(2.02)
Other Aid		0.0021
		(1.55)
Other Aid, previous period		0.0012
		(0.91)
Other Controls		
Domestic Investment	-0.0049***	-0.0047***
	(-3.00)	(-2.87)
Domestic Investment (previous period)	-0.0021	-0.0019
	(-1.34)	(-1.26)
FDI	-0.0004	-0.0008
	(-0.24)	(-0.44)
FDI (previous period)	0.0033	0.0031
	(1.57)	(1.57)
Trade	0.0020***	0.0020***
	(6.64)	(6.12)
Share of Industry in GDP	-0.0038**	-0.0038**
	(-2.33)	(-2.42)
Energy Price Index	0.0000	-0.0001
	(0.19)	(-0.63)
Number of observations	1,298	1,298
Number of countries	45	45
Average number of years per country	28.8	28.8

t statistics in parentheses.

*, **, and *** represent that the coefficient is statistically significant at 1, 5, and 10% size.

Table 5.3. Carbon emissions intensity 2SLS regression results

Explanatory Variable	Equation 3.i	Equation 3.ii
GDP per Capita	2.3259***	2.1188***
	(9.34)	(10.38)
GDP per Capita (squared)	-0.1449***	-0.1346***
	(-8.93)	(-9.78)
Aid Variables		
Total Aid	0.0126	
	(1.60)	
Total Aid (previous period)	-0.0096**	
	(-2.11)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		-0.0346
		(-0.96)
Economic Inf. & Serv. Aid, previous period		0.0320
		(0.80)
Health Aid		0.0299
		(0.39)
Health Aid, previous period		-0.0977
		(-1.08)
Production Sectors Aid		-0.0004
		(-0.01)
Production Sectors Aid, previous period		-0.0420
		(-1.04)
Environmental Aid		-0.0617
		(-0.34)
Environmental Aid, previous period		0.1645
		(0.92)
Other Aid		-0.0016
		(-0.88)
Other Aid, previous period		-0.0009
		(-0.53)
Other Controls		
Domestic Investment	0.0038*	0.0040*
	(1.67)	(1.77)
Domestic Investment (previous period)	0.0041**	0.0045**
	(2.15)	(2.48)
FDI	-0.0060	-0.0047
	(-1.60)	(-1.26)
FDI (previous period)	-0.0017	-0.0024
	(-0.41)	(-0.61)
Trade	-0.0002	-0.0000
	(-0.53)	(-0.07)
Share of Industry in GDP	-0.0024	-0.0018
	(-1.51)	(-1.20)
Fossil Fuel Intensity	0.0109***	0.0133***
	(9.02)	(12.29)
Number of observations	1,298	1,298
Number of countries	45	45
Average number of years per country	28.8	28.8

t statistics in parentheses.
*, **, and *** represent that the coefficient is statistically significant at 1, 5, and 10% size.

Table 5.4. Carbon emissions over GDP 2SLS regression results

	Equation	
Explanatory Variable	4.i	4.ii
GDP per Capita	0.7627**	0.3228
	(2.20)	(1.64)
GDP per Capita (squared)	-0.0547**	-0.0369***
	(-2.57)	(-2.73)
Aid Variables		
Total Aid	0.0372**	
	(2.03)	
Total Aid (previous period)	-0.0157*	
	(-1.81)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		-0.0396
		(-1.04)
Economic Inf. & Serv. Aid, previous period		0.0152
		(0.34)
Health Aid		0.1231
		(1.34)
Health Aid, previous period		-0.1889*
		(-1.71)
Production Sectors Aid		0.0006
		(0.01)
Production Sectors Aid, previous period		-0.0209
		(-0.43)
Environmental Aid		0.1614
		(0.78)
Environmental Aid, previous period		0.4090**
		(2.10)
Other Aid		0.0004
		(0.19)
Other Aid, previous period		0.0002
		(0.11)
Other Controls		
Domestic Investment	-0.0008	-0.0006
	(-0.29)	(-0.27)
Domestic Investment (previous period)	0.0009	0.0026
	(0.38)	(1.32)
FDI	-0.0076	-0.0056
	(-1.59)	(-1.46)
FDI (previous period)	0.0040	0.0006
	(0.78)	(0.15)
Trade	0.0013**	0.0018***
	(2.51)	(4.75)
Share of Industry in GDP	-0.0070***	- -0.0055***
	(-3.77)	(-3.91)
Energy Price Index	-0.0010**	-0.0003
	(-2.06)	(-1.13)
Fossil Fuel Intensity	0.0099***	0.0147***
	(4.16)	(12.26)
Number of observations	1,298	1,298
Number of countries	45	45
Average number of years per country	28.8	28.8

t statistics in parentheses.

*, **, and *** represent that the coefficient is statistically significant at 1, 5, and 10% size.

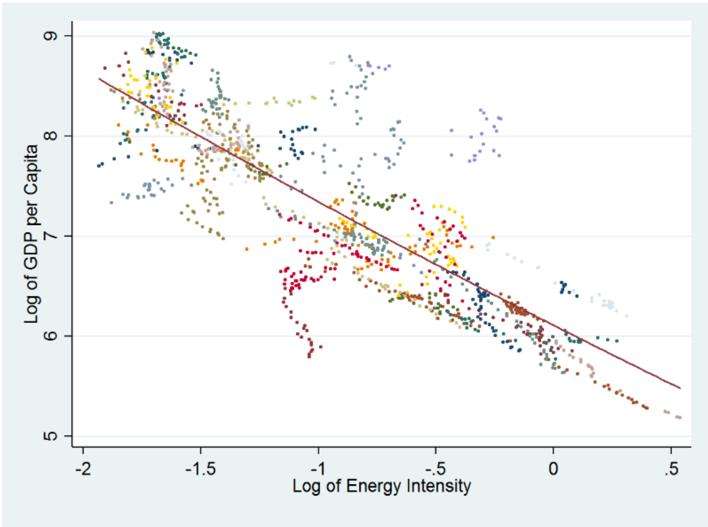
5.2.1 GDP per Capita, Energy and Emissions Intensity

GDP-Energy Intensity Relationship

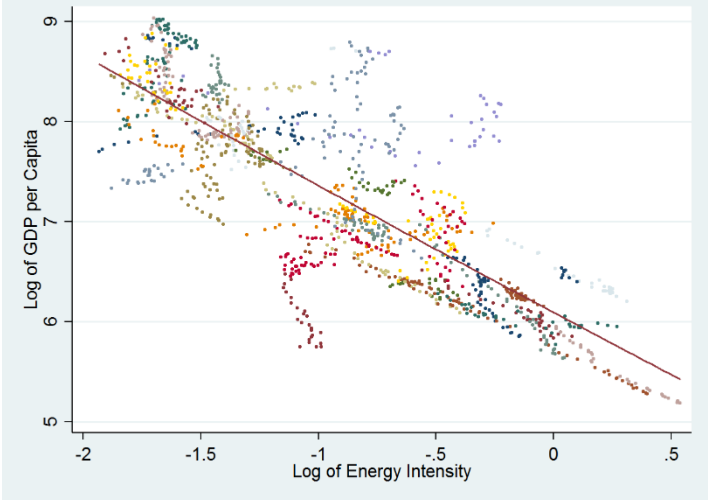
Firstly, for the link between per capita GDP and energy intensity, the estimated coefficients for the energy intensity variables in the GDP per capita equation (Model 1) are negatively significant for the squared term in both specifications while they differ qualitatively and quantitatively between each specification for the linear term; the coefficient is positive significant in specification (ii) (measuring the sectoral aid variables relative to per capita GDP) while negative and insignificant in the other specification (i).

The energy intensity coefficients from specification (i) implies no relationship between GDP per capita and energy intensity at lower levels of energy intensity, becoming a negative relationship at higher levels. By contrast, specification (ii) implies a positive GDP-energy intensity relationship at lower levels of energy intensity, becoming negative at higher levels. When plotting the predicted GDP-energy intensity relationship from each regression as in Figure 5.1 however, no discernible difference between the implied relationships is observed across the two specifications. Both of specifications (i) and (ii) illustrate an overall monotonic negative GDP-energy intensity relationship over the observed range.

Figure 5.1. GDP-energy intensity relationship as predicted by the estimated GDP equation (Model 1)



Specification (i)

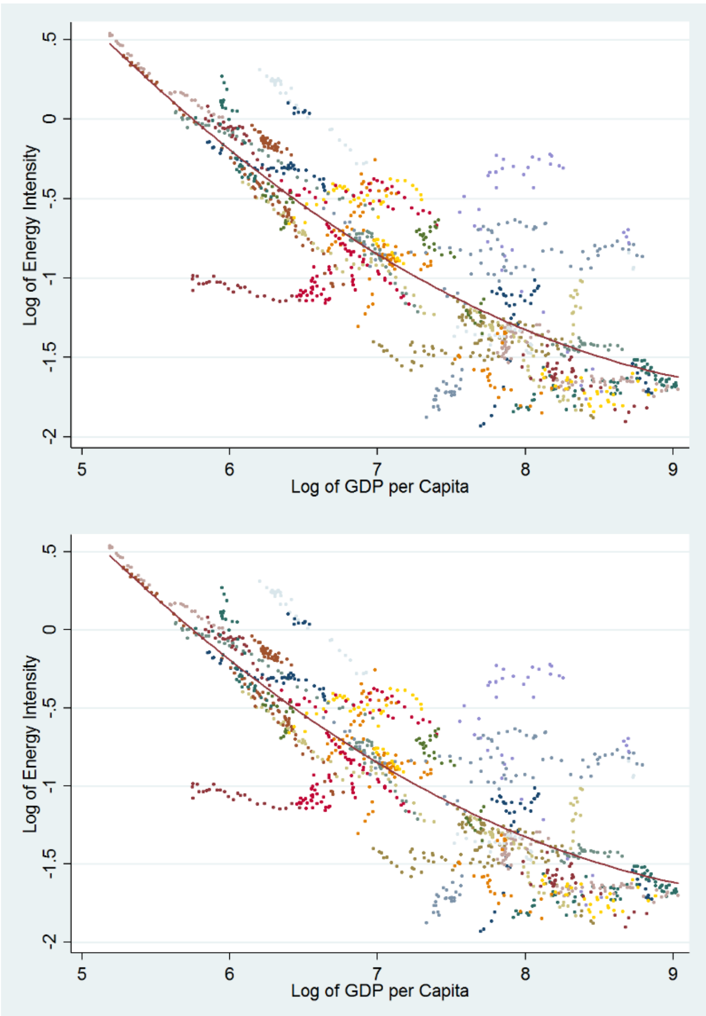


Specification (ii)

Moving to the energy intensity equation (Model 2), the estimated coefficients of per capita GDP are negatively and positively significant for the linear and squared terms respectively, in both specifications. These estimates imply that GDP per capita possesses a negative relationship with energy intensity at lower levels of income, becoming a positive relationship at higher levels. This relationship does not appear to align with the GDP-energy intensity relationship implied by the estimated GDP per capita equation (Models 1.i and 1.ii), which suggests that energy intensity has either a small positive or non-existent impact on GDP per capita at lower levels of energy intensity, changing to a negative impact at higher levels.

However, for the range of logged per capita GDP observed in the estimated regressions (ranging from 5.19 to 9.04), the estimated energy intensity equation for both specifications implies a monotonic negative relationship between per capita GDP and energy intensity, as shown in Figure 5.2. Specifically, for the estimated convex function, the turning point (the point where the marginal effect of GDP on energy intensity changes from negative to positive) occurs at 9.26, and 9.18, respectively for specifications (i) and (ii). These are both above the maximum logged per capita GDP value observed in our data, suggesting a relatively high level of income is required to experience a significant change in the dynamics of this relationship. This also means that the GDP-energy intensity relationship appears visually consistent between Models 1 and 2 over the observed range of data

Figure 5.2. GDP-energy intensity relationship as predicted by the estimated energy intensity equation (Model 2)



Specification (i)

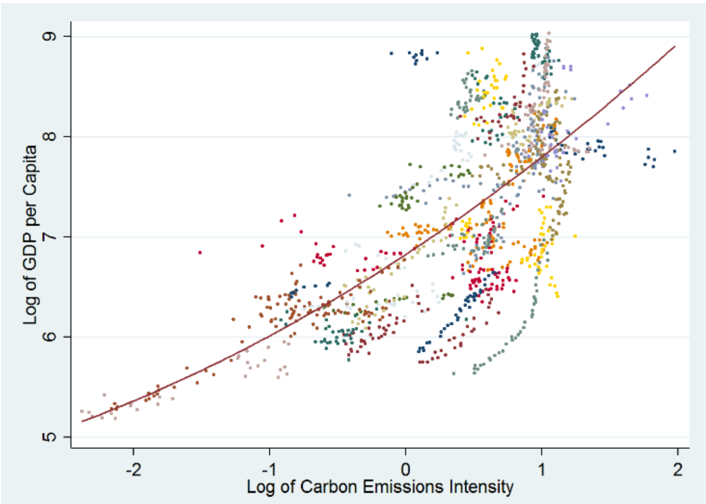
Specification (ii)

GDP-Emissions Intensity Relationship

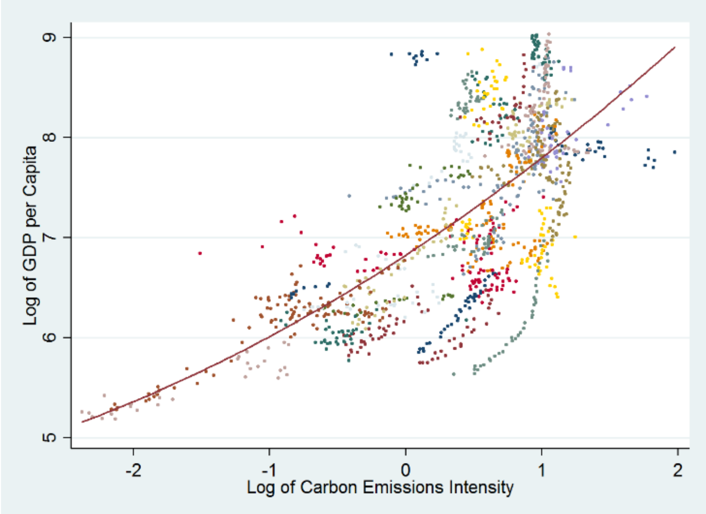
For the GDP-emissions intensity relationship in the GDP per capita equation (Model 1), the estimated coefficient for emissions intensity is positive significant for the linear term, and negative significant for the squared term in specification (i). The linear term remains positive significant in specification (ii) while the square term remains negative, but loses significance.

Plotting the predicted GDP-emissions intensity relationship from both specifications in Figure 5.3, the relationship appears similar across each. In each instance the overall relationship is positive, and mildly increasing at higher levels of emissions intensity.

Figure 5.3. GDP-emissions intensity relationship as predicted by the estimated GDP equation (Model 1)



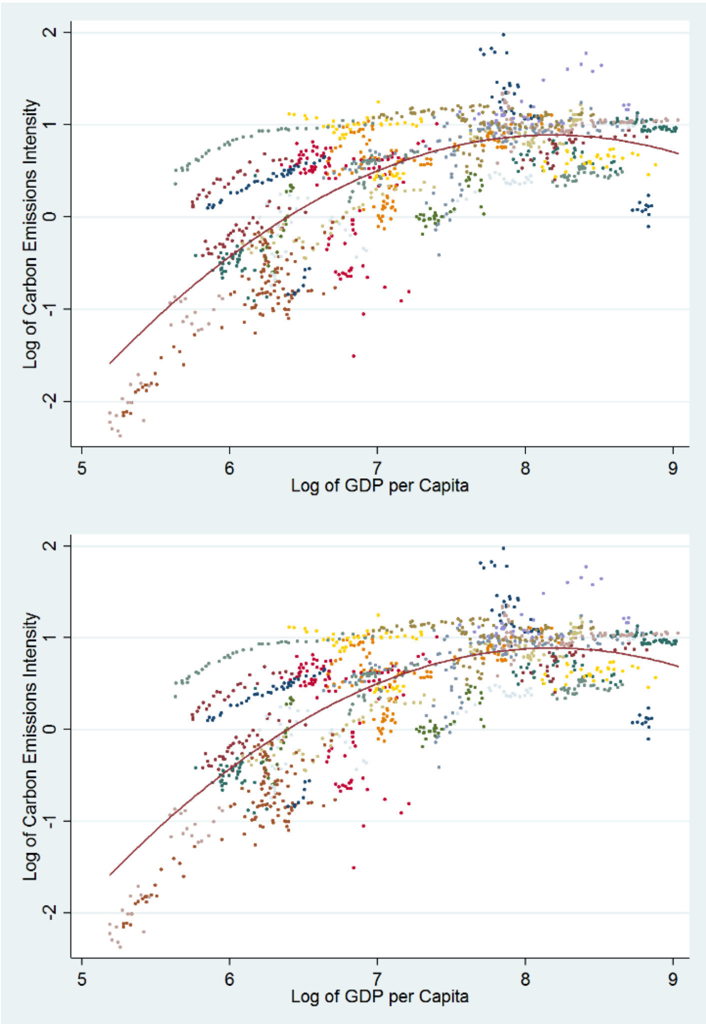
Specification (i)



Specification (ii)

Turning to the carbon emissions intensity equation (Model 3), the predicted coefficients for GDP per capita across both specifications are positive significant for the linear term and negative significant for the square term. When plotted in Figure 5.4, these predicted GDP-emissions intensity relationships across the two specifications appear consistent with each other. The illustrated relationship is positive at lower levels of GDP per capita, turning negative at higher levels, near the top of the observed range.

Figure 5.4. GDP-emissions intensity relationship as predicted by the estimated emissions intensity equation (Model 3)



Specification (i)

Specification (ii)

Comparing the predicted relationships between GDP per capita and emissions intensity in Models 1 and 3, it is apparent that these relationships aren't entirely consistent with each other. This can be explained however by the difference in variables included in each model. Specifically, the inclusion of energy intensity on the right hand side in Model 1, but not Model

3. Controlling (or not) for the effect of energy intensity in Models 1 and 3 is expected to have some impact on the regression results.

Lastly, the turning points for the GDP-emissions intensity relationship illustrated in Figure 5.4 (where the marginal effect of GDP on emissions intensity changes from positive to negative) are 8.03 and 7.87 respectively for logged GDP per capita in specifications (i)-(ii) of Model 3. The observed range for logged GDP per capita is 5.19-9.04 in the estimated model, encompassing both turning points. The lower turning point values for the GDP-emissions intensity relationship as compared to energy intensity also suggest a lower level of income is required to achieve a change in the dynamics of the former relationship.

Implications for the EKC Hypothesis

In order to link the estimated energy and emission intensity equations to the EKC hypothesis, Model 4 was also estimated with carbon emissions over GDP as the dependent variable. In the subsequent estimation results reported in Table 5.4, the coefficient estimates for GDP per capita are positive and negative significant respectively, for the linear and squared term in specification (i) and positive but not significant and negative significant for the linear and squares terms respectively in specification (ii). Figure 5.5 illustrates the relationship between GDP and carbon emissions over GDP as implied by the estimated Model 4 over the range of per capita GDP observed.

Figure 5.5. GDP-carbon emissions over GDP relationship as predicted by the estimated carbon emissions over GDP equation (Model 4)

Specification (i)

Specification (ii)

From Figure 5.5, an inverted U shape can be seen which is consistent with the EKC hypothesis. This inverted U shape is also similar to that for the GDP-emissions intensity relationship plotted in Figure 5.4, but contrasts with the monotonic negative GDP-energy intensity relationship observed in Figure 5.2. This suggests that the GDP-emissions intensity relationship outweighs the GDP-energy intensity relationship for the observed range of GDP per capita. Furthermore, the turning points for Model 4 (where the marginal effect of GDP on carbon emissions over GDP changes from positive to negative) are 6.97 and 4.38 for logged GDP per capita in specifications (i) and (ii) respectively. These turning points are significantly lower than those for the GDP-emissions intensity in Model 3, which is expected considering the energy intensity-GDP relationship is negative overall for the observed range. The influence of this negative relationship should work to reduce the level of income at which the GDP-carbon emissions over GDP relationship turns to negative as compared to emissions intensity, as is the case here.

Combining the findings from estimating Models 1-4 together leads to the following conclusion: When other relevant factors are controlled for, rising income initially lowers the energy intensiveness of GDP while increasing the emissions intensiveness of energy use. Effectively, while the significance of energy use in the economy falls with rising income while at lower income levels, this effect is outweighed by the impact of the increasing significance of more carbon intensive energy sources, resulting in a net effect of increasing environmental impact (carbon emissions over GDP) as income rises from low levels. This situation changes at higher levels of income; while energy intensity continues to decline with rising income, the emissions intensiveness of energy use begins to decline also, at least at the sub-High Income levels as observed here. Thus the net environmental impact of rising GDP per capita becomes negative at higher income levels. These results support the existence of an EKC for the sample, with countries potentially becoming more conscious of their environmental impact as they reach higher levels of income, and beginning to reduce their pollution levels by switching to cleaner energy sources. The determination that the GDP-energy intensity relationship turns positive just beyond the observed income range may have implications for this result however. Though given this turning point is not actually observed in the sample, its exact impact cannot be determined with confidence.

5.2.2 The Impact of Foreign Aid

<u>GDP</u>

To start with aid's impacts on GDP growth, the most notable finding from the estimation of the GDP equation, 1.i – 1.ii, is the significant negative coefficient for current period Total Aid in 1.i, which is the opposite of expectations. Specifically, an increase in overall aid received by an equivalent of 1% of the recipient country's GDP is expected to result in an approximate 0.17% decrease in real GDP per capita, all else being equal. However, considering that the amount of aid received by countries in the total sample averaged only approximately 1.44% of GDP annually, the average level of current period aid disbursed would need to increase relative to existing levels by approximately 69% to achieve this degree of effect. Furthermore, the negative aid-growth relationship applies only to current period aid in the specification; the coefficient for lagged total aid is positive, though not significant. This implies that the overall net effect of Total Aid on growth across both current and previous periods is negative.

The results for the sectoral aid categories in the estimated GDP per capita equation 1.ii are mixed.[28] Economic Infrastructure and Services aid is not significant in the current or previous period. In contrast, the estimated coefficient for Health aid is negative significant in the current period with a larger magnitude than infrastructure aid. It is not significant in the previous period but still larger in magnitude. This implies a relative negative impact on growth for Health aid against economic infrastructure and services aid in both current and lagged form.

Production Sectors aid is not significant in the current or previous periods. Though Environmental aid is found to be significantly positive in both current and lagged form, contrary to expectations of no associated economic impact for this type of aid. This result is particularly surprising considering the lack of significant positive impact for any of the economically targeted aid categories.

From the specification (ii) results, it appears that Health aid is the primary contributor to the negative significant coefficient for current period Total Aid in (i). This is due to this sectoral aid variable possessing the largest negative coefficient value by a significant degree of all current period aid variables in 1.ii. Though it is important to note again that aid flows, particularly in sectoral form, are of only a low level of significance in relation to recipient economies, as discussed in Chapter 4. The largest of the aid categories of interest only averaged less than 0.2% of recipient GDP in the sample.

Energy Intensity

Looking at the environmental impact of aid, in the energy intensity equation, 2.i, neither current nor lagged Total Aid has a significant impact on energy intensity. With the sectoral aid variables, current period Health aid and current and lagged Environmental aid are significant in specification (ii) - an identical pattern of significance to the GDP per capita equation. All three variables also feature positive signs, opposite to expectations.[29] Additionally, though not significant, both current and lagged Economic Infrastructure and

[28] For reasons outlined in Chapter 3, regression run including Education aid as a separate variable are not reported with the main results, but are included in Appendix 5.5.
[29] As discussed in Chapter 3, the primary means by which aid may impact on carbon emissions intensity in the model employed here is through technology and knowledge transfer - effectively the technique effect only - with GDP per capita controlling for scale and share of industry in GDP representing compositional effect. Subsequently, the prior expectation is for Total Aid to reduce carbon emissions intensity in both current and lagged form.

Services aid and lagged Health aid are negative, consistent with expectations. However, current and lagged Production Sectors aid are positive, against expectations. Given the lack of statistical significance for the Production Sectors aid estimates though, it is likely that they actually have no discernible effect. The results for the significant Health and Environmental aid variables however defy readily apparent explanation. Though the low level of significance of each individual aid category to recipient countries means that at least the implied impact is of a very modest nature.

Emission Intensity

Results for Model 3.i show that, unlike with energy intensity, Total Aid does have a significant impact on carbon emissions intensity. Specifically, though the estimated coefficient for current period Total Aid is not significant, one period lagged Total Aid is significantly negative. The significantly negative coefficient for lagged Total Aid conforms to prior expectation while the positive coefficient for current period Total Aid is opposite. However, given the insignificant nature of the current period coefficient estimate, it is likely that current period Total Aid actually has no significant impact on emissions intensity. Given the signs and significances of both variables, Total aid appears to have a net negative (albeit modest) impact on emissions intensity in recipient countries, in line with expectations.

Looking at the results for the sectoral aid variables in specifications (ii), none of the estimated coefficients for either current or lagged terms are significant, similar to Model 2.ii. The lack of significance for these variables is likely explainable by the modest significance of sectoral aid categories to recipient countries.

Carbon Emissions over GDP

The estimated coefficients for Total Aid in Model 4.i are positive significant for the current period term and negative weakly significant for the lagged term. This pattern follows the results for Model 3.i, suggesting that the aid-emissions intensity relationship outweighs the aid-energy intensity relationship.

Looking at the sectoral aid variables in 4.ii, only previous period Health and Environmental aid are significant. Of these, Health aid is negative, in line with expectations, while Environmental aid is positive, against expectations. The fact that the coefficient for lagged Environmental aid is the most strongly significant and largest in magnitude of the estimated sectoral aid coefficients in 4.ii is very surprising given that its sign is also counter to prior expectations. The implication of this result is that previous period Environmental aid has a significant positive impact on the overall environmental intensiveness of GDP. Given the lack of significance for many sectoral aid variables in Models 2 and 3 however, along with the previously discussed economic significance issues for aid in the sample, it is sensible to question the reliability of this result.

Implications of Aid Disbursement for the Environment

Effectively, the main conclusions that can be drawn from the insertion of aid into the environment-growth scenario relate to Total Aid only, with the effects of sectoral aid across all five categories frequently insignificant or exhibiting counter-intuitive, unreliable results. Based on the results from Models 1-3, Total Aid has a significant impact on carbon emissions intensity but not energy intensity. The net effect of aid on emissions intensity across the current and previous periods is mildly negative, given the negative significant nature of the previous period coefficient and lack of significance for the current period coefficient. The net impact of Total Aid on carbon emissions over GDP is also mildly positive across both periods as the current period coefficient estimate possesses a larger positive magnitude than the negative previous period coefficient.

Combining the net result for Total Aid's direct impact on the environmental impact variables, with its indirect impact via the Scale effect as captured in Model 1, allows the overall environmental impact of aid to be determined. An outline of each of these impacts for aid is presented in Table 5.5.

Table 5.5. Summary of Total Aid-environment outcomes

	Effect of Total Aid				
Environmental Impact Variable	Indirect Effect (low income levels)	Indirect Effect (higher income levels)	Direct Effect	Overall Effect (lower income levels	Overall Effect (higher income levels)
Energy Intensity	Positive	Negative	None	Positive	Negative
Carbon Emissions Intensity	Negative	Positive	Negative	Negative	Positive
Carbon Emissions over GDP	Negative	Positive	Positive	Negative	Positive

Notes: Outcomes for indirect effect calculated by taking the product of combined aid coefficient estimates from equation 1.i and coefficient estimates for standard and squared terms of GDP per capita in equations 2.i, 3.i and 4.i, respectively.
Outcomes for overall effect calculated by taking the sum of determined direct and indirect effects.

For energy intensity, aid features an indirect impact via the Scale effect only. This impact is positive at lower income levels, given Total Aid's tendency to reduce growth overall, and negative at higher income levels. With regards to carbon emissions intensity, the overall direct and indirect effect of aid is negative at low income levels and positive at higher income levels, based on the estimated coefficient values in Models 1.i and 3.i. When combining energy and emission intensity, the overall environmental impact of aid remains the same as with emissions intensity - negative at lower income levels and positive at higher levels of income.

It should also be noted that the effect of current period Total Aid on energy and carbon emissions intensity observed in this study differs substantially from Kretschmer et al. (2013), who reported a significant negative impact of aid on energy intensity and no significant effect on carbon emissions intensity. This difference may however, be at least partly explainable by the fact that they used aid commitments rather than disbursements in their sample. Furthermore, the significant difference in the range of countries analysed by Kretschmer et al., as well as the smaller range of control variables they use may also be contributing factors.

5.2.3 Effect of Control Variables

Looking at the control variables, results are mixed. Starting with the GDP per capita equation 1.i-1.ii, the estimated coefficients are significant and insignificant negative for current domestic investment in (i) and (ii) respectively, and insignificant for lagged domestic investment in both specifications. These are not as expected, yet align with existing empirical literature (e.g. Balasubramanyam et al. 1996 who found negative though insignificant results for the domestic investment-economic growth relationship, and Choe 2003 who found a lack of causality running from investment to growth). Weak and insignificant observed effects for current and lagged FDI on growth are also contrary to theoretical expectation, though consistent with findings in the FDI-growth empirical literature. This literature suggests a complex, varied relationship between FDI and growth, dependent on factors not specifically examined here, such as foreign and domestic capital substitution and trade policies (Balasubramanyam et al. 1996; de Mello Jr. 1999; Iamsiraroj 2016). Inflation rate remains insignificant in each of 1.i and 1.ii. However, this result needs to be interpreted with caution; the lack of significance could be caused by the omitted variables. In particular, as discussed in section 5.1, a number of additional control variables capturing the recipient country's policy environment are omitted from the final specification. The significant positive coefficients estimated for the trade variable however are more meaningful, potentially highlighting the significant role trade may play in the economies of the sample countries.

Looking at the Models 2.i-2.ii for energy intensity, current period domestic investment, trade and share of industry in GDP are all highly significant across both specifications. A significant negative coefficient for current period domestic investment conforms to expectations given that this variable, like aid, should primarily impact on energy intensity via the Technique effect in the specified model. The positive sign for the trade is against expectations however, given that this variable should also primarily work via the Technique effect. The significant negative coefficient for industry share in GDP is also against expectations, given that the industrial sector is typically regarded as amongst the most energy intensive of economic sectors (Kretschmer et al. 2013).

Energy Price Index and FDI are not significant in either of the specifications. The former result suggesting that energy price does not significantly impact on the energy intensiveness of GDP in aid-receiving countries, which can potentially result from an inelastic demand for energy inputs.

Amongst the control variables in the emissions intensity equation, 3.i-3.ii, both current and lagged domestic investment are positive significant, against prior expectations and in contrast to models 2.i-2.ii. FDI however, remains insignificant in 3.i-3.ii, as in the energy intensity equation. These results suggest that domestic investment is associated with improved energy efficiency, though dirtier energy use. While FDI on the other hand, has no impact on energy or emissions intensity in either timeframe.

Fossil fuel intensity is consistently positive and highly significant across 3.i-3.ii, as is expected given fossil fuel use is a major source of carbon emissions. Share of industry in GDP is not significant in specifications 3.i-3.ii, in contrast to 2.i-2.ii and against prior expectations. Though the relative ease of controlling fixed sources of emissions as compared to non-static sources may offer a partial explanation for this result. Finally, trade relative to GDP is not significant in either of 3.i-3.ii, in contrast to the energy intensity equation, implying that its environmental impact extends to energy efficiency, but not emissions.

5.2.4 Robustness Test

As illustrated in Chapter 4, the aid disbursement data for the sample shows a significant bias towards more recent decades of the sample period, with disbursement levels from 1990 onwards being considerably higher than in previous years.[30] To test the extent to which this coverage bias affected the results, regressions of Models 1-4 were also run with a sample including years 1990-2011 only. The results of these regressions are reported in Appendix 5.6, with a degree of variation being observed between these and the full sample results. The variation is particularly significant for Models 1 and 4 (GDP per capita and carbon emissions over GDP). However, differences are also observed between the coefficients for the aid and control variables in Models 2 and 3 (energy and carbon emissions intensity). This suggests that the results obtained here are sensitive to the time period used.

Results may also be skewed by over or under-representation of unobserved country-specific characteristics such as the size of the recipient economy. This would mean that the sample is not sufficiently representative, which may lead to biased results (Wooldridge 2012). However as discussed in section 5.1, the regressions were performed with fixed effects which controls for unobserved country heterogeneity. It was expected that the fixed

[30] Section 4.3, Figure 4.6b.

effects approach would also, to an extent, mitigate any bias resulting from such issues with sample selection.

5.3 Discussion

5.3.1 The Environment-Growth Relationship

In regards to the environment-growth relationship, the most prominent finding to emerge from the analysis was support for the existence of an EKC for the carbon intensiveness of GDP (carbon emissions over GDP). Furthermore, this finding appears to largely derive from the underlying GDP-emissions intensity relationship, which similarly describes an inverted U-shape. The GDP-energy intensity relationship by contrast, appears to be monotonic negative in nature over the observed income range. The obvious implication of these findings is that there is a tendency for countries to begin focussing on reducing their pollution impact as income rises - as per EKC theory - but that they do so in an inconsistent way. Specifically, there appears to be a significant bias towards emissions intensity reductions in regard to the EKC relationship, at least within the sub-High Income GDP per capita range of our sample. Advancing income brings about an increasing focus on the cleanliness of energy sources, though any such effect relating to energy efficiency is at best far milder.[31]

It is possible to speculate as to the reasons why developing countries may focus their efforts more so on reducing emissions intensiveness than improving energy efficiency. Perhaps it is less costly, or more politically palatable to implement clean energy projects. There may also be an influence from developed countries towards certain kinds of environmental projects such as renewable energy. Alternatively, it could be the case that clean energy investments produce more meaningful improvements relative to their energy efficiency counterparts. However, none of these possibilities can explain the energy intensity side of the environment-growth relationship or more particularly, why energy intensity falls in line with rising income even at low income levels.

In trying to explain the observed GDP-energy intensity relationship, examination of the characteristics of the energy intensity measure itself, as well as the income elasticity of energy demand, may prove insightful. As energy intensity is a measure of energy use relative to GDP, its level will fall against rising GDP per capita if real GDP growth is higher than both growth in the population and energy use. Such a scenario would imply that the negative

[31] While the GDP-energy intensity relationship is negative over the whole sample, suggesting that rising income does promote improved energy efficiency, this relationship appears to weaken as income rises. The evidence for this, noted in section 5.2.1, is that the relationship becomes positive just beyond the observed income range.

relationship observed here does not necessarily involve negative causation, but rather differences in the relative growth rates of the key variables. In such a scenario, it could be said that energy use is simply failing to "keep pace" with rising income. To test this, we can examine the average growth rates of real GDP, population and energy use in the sample, which are presented in Table 5.6.

Table 5.6. Average growth rates for real GDP, population and energy use in the sample

Variable	Average Growth Rate (%)
Real GDP	4.88
Population	1.77
Energy Use	4.41

From the table it can be seen that overall, real GDP growth does outpace both population and energy use growth over the sample period. While simplistic, these statistics do suggest the possibility that the observed relationship between energy intensity and GDP per capita results from the relative growth rates of the respective variables.

If it is the case therefore, that energy use is failing to "keep pace" with rising GDP per capita, consideration should be given to what may cause this difference in growth rates. Household energy use may provide an explanation; statistics from the UNDP and World Bank suggest that households contribute a relatively large amount towards total energy consumption in less developed countries as compared to developed countries (30-95% versus 25-30%) (UNDP and World Bank in Xiaohua and Zhenming 1996). Furthermore, as summarised by Nesbakken (1999), there have been numerous studies investigating the income elasticity of household electricity demand (as a proxy for energy demand) in developed countries, which have found elasticities above 0 but significantly less than 1. Similar studies examining developing countries (e.g. Shi et al. 2012 for China; Agostini et al. 2014 for Argentina) likewise determined income elasticities for energy demand between 0 and 1.[32] Such elasticities imply that household energy use increases at a relatively lower rate than income. This could explain our scenario of energy intensity falling relative to rising GDP per capita, providing household energy use contributed the majority extent towards gross energy use. Going by the previously quoted UNDP and World Bank figures, this appears to often be the case.

[32] It should be noted that these studies typically employ a measure of household rather than national income.

Developing the outlined theory further, it may also be possible to explain the potential turning point in the GDP-energy intensity relationship. As the significance of household energy use appears to fall relative to gross energy with rising income, this may in turn result in a change in the nature of the GDP-energy intensity relationship. If non-household energy use has an income elasticity equal to or greater than 1, its increasingly significant contribution to gross energy use as income rises would progressively reduce the negativity of the GDP-energy intensity relationship, all else being equal.

There is one issue that should be noted regarding this theory however. The results obtained from our analysis would seem to undermine the possibility of a non-household income elasticity for energy use that is equal or greater than 1. Specifically, the significant negative coefficient estimate for share of industry in equations 2.i and 2.ii implies a negative relationship between non-household energy use in GDP and energy intensity. Despite this implication however, the coefficient estimate alone is not a sufficient basis to rule out the previously outlined theory.

While this theory offers one possible explanation for the observed GDP-energy intensity relationship, it should be highlighted that we are only observing a subset of the relationship. Therefore, it is still possible that the dynamics may continue to change between GDP per capita and energy intensity at a level of income some way beyond the observed range. Attempts have also been made to accommodate this idea in the literature. A number of EKC studies for example, have attempted to capture the possibility of multiple turning points through the inclusion of an additional cubic income term (e.g. Grossman and Krueger 1995, who found multiple turning points for a number of pollution indicators) and the possibility of such cannot be ruled out here.

5.3.2 Total Aid and Growth

The most notable result to be derived from the analysis of aid is the negatively significant finding for Total Aid in the current period in equation 1.i, which contradicts the widely held view of aid as growth-promoting. As surprising as this result is, it is not without precedent in the literature; Mosley (1980), Mosley et al. (1987) and Rajan and Subramanian (2008) all have achieved similar outcomes for at least some of their aid-growth regressions. Additionally, as discussed, the aid results are affected by data coverage issues and omitted variable bias arising from the inability to include many conventional macroeconomic and policy controls in the regression model for the GDP per capita equation. However, it is worthwhile examining some of the theories from the aid-growth literature that may explain a negative aid-growth result.

The aid-growth literature has offered various explanations for the failure of aid to impact positively on growth (and potentially even undermine it). While Rajan and Subramanian (2008), suggested noise in the data as one possible explanation for their finding that aid did not promote growth, two more detailed explanations have also frequently been offered. These explanations are aid fungibility and Dutch Disease type effects.

The concept of fungibility refers to the possibility that aid received effectively replaces public funding intended for the aid-targeted area in the recipient country, with the displaced funds instead being spent on other, potentially less productive areas (Feyzioglu et al. 1998). A number of studies have attempted to specifically investigate this phenomenon in regards to various economic sectors, with results both in support of its existence (e.g. Feyzioglu et al. 1998; Dieleman et al. 2013), and against it (Van de Sijpe 2013).

One issue arising with the fungibility explanation in the context of the present research however, is the possibility of any effect it may have being inhibited by the model specification. Specifically, the primary channel through which fungibility would be expected to be observed is public investment. However, public investment is already accounted for in the model through the domestic investment variable.

Dutch Disease remains a plausible explanation for our results however. Dutch Disease type effects, in the context of foreign aid provision, typically refer to the potential for aid inflows to cause a deterioration in export performance in recipient countries due to real exchange rate appreciation (Rajan and Subramanian 2011). Support for this issue impacting on the effectiveness of foreign aid has been found by Younger (1992), Adenauer and Vagassky (1998) and Rajan and Subramanian (2011).

While the key variable through which Dutch Disease effects should work - trade - is already controlled for in the model specification, this variable captures the total value of trade only, and not specifically export performance. This allows for the possibility in our model, of an aid-induced deterioration in export performance harming growth. However, the positively significant coefficient estimate for trade in the GDP per capita equation would appear to reduce the likelihood of such a scenario. This therefore leaves omitted variable bias and data coverage issues as the most likely explanation for our counter-intuitive result.

5.3.3 Total Aid and the Environment

Looking at the direct impact of aid on the environment, the results from equations 2.i and 3.i suggest a significant relationship between Total Aid and emissions intensity, but not energy intensity. Furthermore, the aid-emissions intensity relationship is positive, though insignificant for current period aid, and negative in the previous period. These results suggest that there may be a Technique effect associated with aid. However, this effect appears to apply only to the cleanliness of energy sources and is subject to an impact lag.

The lack of a Technique effect for aid and energy intensity may be explained by a bias towards aid projects and programs that influence the nature, rather than efficiency of energy use, at least for the observed impact timeframe. Alternatively, it may be the case that the aid and energy intensity Technique effect has tended to produce less significant outcomes, or is subject to longer impact lags.

The impact of Total Aid on carbon over GDP however, cannot be so easily explained. The significant positive coefficient for current period Total Aid in equation 4.i is opposite to expectations and is particularly surprising given that current period Total Aid has no significant relationship with either energy or emissions intensity - the sole components of carbon over GDP. The only apparent explanation for this scenario is the difference in specification between 4.i and 2.i and 3.i. Specifically, unlike in equations 2.i and 3.i, equation 4.i includes energy price index *and* fossil fuel intensity, with both being significant.

Turning attention to the indirect effect of aid on the environment, interesting implications arise regarding the Scale effect for aid on both energy and emissions intensity. As discussed in Section 5.2.2, there is a positive Scale effect for energy intensity at low income levels, becoming negative at higher income levels.[33] In contrast, aid features a negative Scale effect for emissions intensity at low income levels, and a positive Scale effect at higher income levels. The Scale effect for aid on carbon emissions over GDP is also similar to that of emissions intensity, suggesting that aid's effect on emissions is the stronger of two. When

[33] The negative Scale effect refers to a fall in pollution resulting from a reduction in the level of economic activity.

taken together, it can be seen that aid's indirect effect on the environment is a contradictory one, influencing energy and emissions intensity in opposing directions dependent on income level. Overall however, Total Aid appears to indirectly worsen environmental impact as income rises; its growth-reducing effect offsetting the environmentally-improving effect of rising income determined in equation 4.i.

Combining the direct and indirect effect of Total Aid on the Environment, the full picture of aid's environmental impact becomes clear. As outlined in Table 5.5 in section 5.2.2, aid tends to worsen environmental impact overall for higher income countries, but improves it at low income levels. This is an interesting result, though should be treated with caution on account of the data coverage, economic significance and omitted variable issues.

5.3.4 Sectoral Aid

As covered in the discussion of results, the sectoral aid variables are affected by a general lack of significance throughout the regressions, most likely caused by the small size of each individual sector In relation to recipient GDP - an issue that may also impact on the reliability of any significant results obtained. Given this, there is unfortunately little confident insight that can be gained from the results for these variables.

Chapter 6

Conclusion

The overarching objective of the present research was to bridge three distinct, yet interrelated branches of literature exploring the environment-growth-aid relationship. As part of this, a number of specific aims were pursued. These included examining the environment-growth relationship with a specific view towards the Environmental Kuznets Curve hypothesis while also simultaneously analysing the effect of aid on the environment. Environmental impact itself was broken down into the two constituent components of energy and carbon emissions intensity as derived from the Kaya Identity. The disaggregation of environmental impact into two core components was intended to provide clearer insight into the nature of aid and growth's impact on the environment in the context of the EKC.

A simultaneous equations model was employed given its suitability to addressing the research question. It allowed for the identification of both direct and indirect channels of effect in terms of aid's impact on the environment. Furthermore, in addition to examining the impact of aid in general, an attempt was also made to disaggregate aid into certain major sectors targeted by donors to assess the relative performance of each in terms of growth and environmental impact. This additional consideration being drawn from a more recent trend in the aid-growth literature that attempts to capture the heterogeneous nature of aid.

It was specifically intended that this research would contribute to the existing literature through the simultaneous examination of environmental impact, economic growth and foreign aid. The study provided additional insight into the Environmental Kuznets Curve dynamics through the examination of constituent environmental impact components. This research added to the relatively small body of empirical literature on aid and the environment with the additional contributions of considering both direct and indirect channels of effect for aid, as well as the relative performance of sectoral aid categories. Greater reliability of results were obtained here as compared to a number of prior studies examining sectoral aid through the use of aid disbursements rather than commitments, as it took advantage of more recent improvements in data availability in the main aid data source used.

The most interesting finding from the subsequent analysis was the confirmation of an EKC for carbon emissions over GDP, resulting from the underlying GDP-emissions intensity relationship. The GDP energy-intensity relationship however, described a monotonic negative relationship over the observed income range. It was speculated that this latter relationship may result from a combination of the changing makeup of sectoral energy consumption in developing countries as income rises, combined with the relative income elasticities of energy consumption between different sectors. Specifically, as income rises household's contribution to total energy consumption falls, potentially making way for other sectors which may possess higher income elasticities for energy use. Ultimately however, these results suggest that rising income is associated with reduced environmental impact in developing countries, but there is still room for improvement. The potential turn towards positive for the GDP-energy intensity relationship at higher income levels highlights a need for a greater focus on energy efficiency in the context of environmental impact reductions in high Income nations.

The impact of foreign aid in relation to the environment and growth also produced some interesting results. Aid was found to reduce contemporaneous growth in the current period, but had no effect when lagged one year. The most likely explanation for this result was concluded to be data coverage issues and omitted variable bias. This was on account of the explanatory power of other theories offered by the aid-growth literature for the ability of aid to undermine growth being limited by the model specification. However, the primary concern here was the implication of the aid-growth relationship for aid's impact on the environment.

There were a number of notable findings in regards to the environmental impact of aid. A direct impact was found for aid on carbon emissions intensity, decreasing it in the lagged form. The lagged result supported the view of an aid-induced Technique effect on emissions subject to an impact lag. Amongst the other aid-environment findings, no significant relationship was determined between energy intensity and aid in either current or lagged form. The clear implication being that aid impacts directly on carbon emissions but not energy use. This scenario may indicate a bias amongst aid donors towards projects and programs that impact (either by active intention or as a by-product) on the cleanliness of energy use rather than energy efficiency. Finally, an unusual result was determined for the impact of aid on carbon over GDP, possibly explainable by differences in model specification.

Viewed together, the inconsistent direct impact of aid on both the environment and growth, and the variable nature of the growth and environmental impact relationship presented a complex picture of aid's overall impact on growth. Overall, aid was found to be environmentally improving at lower income levels, and environmentally damaging at higher income levels. More specifically, aid was found to have a detrimental effect on emissions intensity at high income levels, but an improving effect at low income levels. By contrast, aid was found to be detrimental to energy intensity at lower income levels and improving at higher levels.

Unfortunately, no strong conclusion could be drawn from the sectoral aid results, which tended towards insignificance for the most part. This outcome was most likely the result of the relatively modest significance of each individual category to the recipient country as noted in Chapter 5. This issue was also likely exacerbated by data coverage issues affecting the dataset, particularly in earlier years.

A number of practical implications arise from these results. As mentioned, while support was found for the EKC, the possibility that energy intensity may follow a positive relationship with income as the latter variable rises suggests a need for greater focus on the efficiency of energy use in developed countries. Additionally, the determination that aid is harmful to the environment overall in higher income countries is cause for concern. Though aid disbursements would be expected to be smaller in such countries, thus mitigating this effect. Nonetheless, the results do suggest room for improvement in the environmental impact of aid disbursement. In particular, there is potential for aid-related technology and knowledge transfer to focus more effectively on improving energy efficiency in recipient countries.

In light of the conclusions drawn, it is important to address the fact that this research is not without its issues and limitations. While these have all been discussed in preceding chapters, it is worth reiterating them. Perhaps the most significant issue facing the research was the relatively poor coverage rates for aid data from the OECD CRS database - an issue particularly affecting earlier years of the sample. As was illustrated in Figure 4.6b, this effectively limits the majority of the observations used in the regressions to years from 1990-onwards. A situation which in turn reduces the potential for this research to fully capture the extent of time trends possible with the sample period used.

Omitted variables were another significant issue affecting the analysis. As discussed in Chapter 5, these variables primarily related to the economic and policy environment in aid receiving countries and intended to control for the impact of the effectiveness of government and economic management on aid performance, in line with the established precedent in the aid-growth literature. Due to insufficient observations, many of these variables were dropped from the actual regressions, leaving only the inflation rate variable as the sole means to control for these factors.

Omitted variable issues also affected the environmental impact equations. As with the aid-growth relationship, convention in the EKC literature has been to control for a variety of political factors that may affect the environment-growth relationship, which was not done here for similar reasons as with aid. Furthermore, due to a lack of suitable instruments, energy and emissions intensity were not included in each other's equations. This was in spite of the possibility for bi-directional causality running between them.

One final limitation of note was the decision to include only a single year lag for relevant variables, most notably aid. As previously discussed, a single year is unlikely to be sufficient to fully capture the economic and environmental effect of aid on a recipient economy over time, particularly for certain sectoral categories such as Education and Health. However, the single year lag used does at least provide some indication of the possible longer term impact of aid, without sacrificing the time dimension of the data any further.

The limitations and conclusions presented here also offer further opportunities for analysis. Aside from the possible opportunity for future research to utilise likely more complete datasets for aid, thus improving the reliability of results from studies such as these, the findings produced here also suggest additional lines of inquiry. An extension of this research in terms of capturing the growth and environmental impact relationship at higher income levels could provide insight into the behaviour of energy intensity in relation to a country's development. Additionally, more specific analysis of the role of various economic sectors in contributing to overall energy intensity may also provide a clearer picture of the dynamics of the income-energy use relationship over the course of a country's development.

Ultimately, it does appear that the advancing development of a country brings about greater concern for pollution impact amongst countries, with aid being able to play an additional role in promoting this phenomenon while also helping to mitigate pollution impact in the interim.

However, in practice this is a complex scenario, with variable effects for growth and aid on different environmental factors and in different timeframes. We can conclude that the outcomes of this research for the view of the environment, growth and aid are neither entirely positive nor entirely negative. While there is, and has been environmental improvement bought about by advancing growth and the provision of aid, there is also potential for both to exacerbate environment harm. It is therefore beholden of the governments and institutions of both developing and developed countries to review the possibility for improvement in these areas, in light of the threat of climate change facing all nations.

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Appendix 3.1 - Variable Data Sources

Variable	Remarks	Source
GDP per Capita	World Bank Series Name: GDP per capita (constant 2005 US$)	World Bank (2016)
Energy Intensity	Manually calculated from World Bank data series: Population, total, GDP (constant 2005 US$) and Energy use (kg of oil equivalent per capita)	International Energy Agency (2014) in World Bank (2016), World Bank (2016)
Carbon Emissions Intensity	World Bank Series Name: CO2 intensity (kg per kg of oil equivalent energy use)	Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, in World Bank (2016)
Aid (Total, Economic Infrastructure and Services, Education, Health, Production Sectors, Environmental)	From the OECD Creditor Reporting System (Official Development Assistance, Gross Disbursements, All Channels, All Types, All Donors): (1000: Total All Sectors, 200: II. Economic Infrastructure and Services, Total, 110: I.1. Education, Total, 120: I.2. Health, Total, 300: III. Production Sectors, Total, 410: IV.1. General Environmental Protection, Total), converted to percentage of recipient GDP using World Bank GDP figures	OECD (2016), World Bank (2016)
Domestic Investment	World Bank Series Name: Gross capital formation (% of GDP)	World Bank (2016)
Foreign Direct Investment	World Bank Series Name: Foreign direct investment, net inflows (% of GDP)	World Bank (2016)
Trade Relative to GDP	World Bank Series Name: Trade (% of GDP)	World Bank (2016)
Inflation Rate	World Bank Series Name: Inflation, consumer prices (annual %)	World Bank (2016)
Share of Industry in GDP	World Bank Series Name: Industry, value added (% of GDP)	World Bank (2016)
Energy Price Index	World Bank Series Name: Energy, 2000=100, constant 2000$	Global Economic Monitor (GEM) Commodities (2015) in World Bank (2016)
Fossil Fuel Mix	World Bank Series Name: Fossil fuel energy consumption (% of total)	International Energy Agency (2014) in World Bank (2016)

Notes: Environmental aid variable is exclusive of 41050: Flood Prevention/Control which is considered an adaptation oriented rather than impact-oriented form of environmental aid. It is instead included in Other Aid.

Appendix 4.1 - OECD Creditor Reporting System Sectors

100: I. Social Infrastructure & Services, Total
110: I.1. Education, Total
111: I.1.a. Education, Level Unspecified, Total
11110: Education policy & administrative management
11120: Education facilities and training
11130: Teacher training
11182: Educational research
112: I.1.b. Basic Education, Total
11220: Primary education
11230: Basic life skills for youth & adults
11240: Early childhood education
113: I.1.c. Secondary Education, Total
11320: Secondary education
11330: Vocational training
114: I.1.d. Post-Secondary Education, Total
11420: Higher education
11430: Advanced technical & managerial training
120: I.2. Health, Total
121: I.2.a. Health, General, Total
12110: Health policy & administrative management
12181: Medical education/training
12182: Medical research
12191: Medical services
122: I.2.b. Basic Health, Total
12220: Basic health care
12230: Basic health infrastructure
12240: Basic nutrition
12250: Infectious disease control
12261: Health education
12262: Malaria control
12263: Tuberculosis control
12281: Health personnel development
. 130: I.3. Population Policies/Programmes & Reproductive Health, Total
13010: Population policy and administrative management
13020: Reproductive health care
13030: Family planning
13040: Std control including hiv/aids
13081: Personnel development for population & reproductive health
140: I.4. Water Supply & Sanitation, Total
14010: Water resources policy/administrative management
14015: Water resources protection
14020: Water supply and sanitation - large systems
14021: Water supply - large systems
14022: Sanitation - large systems
14030: Basic drinking water supply and basic sanitation
14031: Basic drinking water supply
14032: Basic sanitation
14040: River basins development
14050: Waste management/disposal
150: I.5. Government & Civil Society, Total
151: I.5.a. Government & Civil Society-general, Total
15110: Public sector policy and administrative management
15111: Public finance management
15112: Decentralisation and support to subnational government
15113: Anti-corruption organisations and institutions
15114: Tax policy and tax administration support
15130: Legal and judicial development
15150: Democratic participation and civil society
15151: Elections
15152: Legislatures and political parties
15153: Media and free flow of information
15160: Human rights
15170: Women's equality organisations and institutions
152: I.5.b. Conflict, Peace & Security, Total
15210: Security system management and reform
15220: Civilian peace-building, conflict prevention and resolution
15230: Participation in international peacekeeping operations
15240: Reintegration and SALW control
15250: Removal of land mines and explosive remnants of war
15261: Child soldiers (prevention and demobilisation)
160: I.6. Other Social Infrastructure & Services, Total
16010: Social/welfare services
16020: Employment policy and administrative management
16030: Housing policy and administrative management
16040: Low-cost housing
16050: Multisector aid for basic social services
16061: Culture and recreation
16062: Statistical capacity building
16063: Narcotics control
16064: Social mitigation of HIV/AIDS
200: II. Economic Infrastructure & Services, Total
210: II.1. Transport & Storage, Total
21010: Transport policy & administrative management
21020: Road transport
21030: Rail transport
21040: Water transport
21050: Air transport
21061: Storage
21081: Education and training in transport & storage

14081: Education and training in water supply and sanitation
220: II.2. Communications, Total
22010: Communications policy & administrative management
22020: Telecommunications
22030: Radio/television/print media
22040: Information and communication technology (ICT)
230: II.3. Energy, Total
231: Energy Policy, Total
23110: Energy policy and administrative management
23181: Energy education/training
23182: Energy research
23183: Energy conservation and demand-side efficiency
232: Energy generation, renewable sources, Total
23210: Energy generation, renewable sources - multiple technologies
23220: Hydro-electric power plants
23230: Solar energy
23240: Wind energy
23250: Marine energy
23260: Geothermal energy
23270: Biofuel-fired power plants
233: Energy generation, non-renewable sources, Total
23310: Energy generation, non-renewable sources, unspecified
23320: Coal-fired electric power plants
23330: Oil-fired electric power plants
23340: Natural gas-fired electric power plants
23350: Fossil fuel electric power plants with carbon capture and storage (CCS)
23360: Non-renewable waste-fired electric power plants
234: Hybrid energy plants, Total
23410: Hybrid energy electric power plants
235: Nuclear energy plants, Total
23510: Nuclear energy electric power plants
236: Energy distribution, Total
23610: Heat plants
23620: District heating and cooling
23630: Electric power transmission and distribution
23640: Gas distribution
240: II.4. Banking & Financial Services, Total
24010: Financial policy & administrative management
24020: Monetary institutions
24030: Formal sector financial intermediaries
24040: Informal/semi-formal financial intermediaries
24081: Education/training in banking & financial services
250: II.5. Business & Other Services, Total
25010: Business support services & institutions
25020: Privatisation
300: III. Production Sectors, Total
310: III.1. Agriculture, Forestry, Fishing, Total
311: III.1.a. Agriculture, Total
31110: Agricultural policy & administrative management
31120: Agricultural development
31130: Agricultural land resources
31140: Agricultural water resources
31150: Agricultural inputs
31161: Food crop production
31162: Industrial crops/export crops
31163: Livestock
31164: Agrarian reform
31165: Agricultural alternative development
31166: Agricultural extension
31181: Agricultural education/training
31182: Agricultural research
31191: Agricultural services
31192: Plant and post-harvest protection and pest control
31193: Agricultural financial services
31194: Agricultural co-operatives
31195: Livestock/veterinary services
312: III.1.b. Forestry, Total
31210: Forestry policy & administrative management
31220: Forestry development
31261: Fuelwood/charcoal
31281: Forestry education/training
31282: Forestry research
31291: Forestry services
313: III.1.c. Fishing, Total
31310: Fishing policy and admin. management
31320: Fishery development
31381: Fishery education/training
31382: Fishery research
31391: Fishery services
320: III.2. Industry, Mining, Construction, Total
321: III.2.a. Industry, Total
32110: Industrial policy & admin. mgmt
32120: Industrial development
32130: Small and medium-sized enterprises (SME) development
32140: Cottage industries & handicraft
32161: Agro-industries
32162: Forest industries
32163: Textiles - leather & substitutes
32164: Chemicals
32165: Fertilizer plants
32166: Cement/lime/plaster
32167: Energy manufacturing
32168: Pharmaceutical production
32169: Basic metal industries
32170: Non-ferrous metal industries
32171: Engineering
32172: Transport equipment industry
32182: Technological research & development

322: III.2.b. Mineral Resources & Mining, Total
32210: Mineral/mining policy & admin. mgmt
32220: Mineral prospection and exploration
32261: Coal
32262: Oil and gas
32263: Ferrous metals
32264: Non-ferrous metals
32265: Precious metals/materials
32266: Industrial minerals
32267: Fertilizer minerals
32268: Off-shore minerals
323: III.2.c. Construction, Total
32310: Construction policy and admin. mgmt
331: III.3.a. Trade Policies & Regulations, Total
33110: Trade policy and admin. management
33120: Trade facilitation
33130: Regional trade agreements (RTAs)
33140: Multilateral trade negotiations
33150: Trade-related adjustment
33181: Trade education/training
332: III.3.b. Tourism, Total
33210: Tourism policy and admin. management
400: IV. Multi-Sector / Cross-Cutting, Total
410: IV.1. General Environment Protection, Total
41010: Environmental policy and admin. mgmt
41020: Biosphere protection
41030: Bio-diversity
41040: Site preservation
41050: Flood prevention/control
41081: Environmental education/training
41082: Environmental research
430: IV.2. Other Multisector, Total
43010: Multisector aid
43030: Urban development and management
43040: Rural development
43050: Non-agricultural alternative dvpt
43081: Multisector education/training
43082: Research/scientific institutions
500: VI. Commodity Aid / General Programme Assistance, Total
510: VI.1. General Budget Support, Total
51010: General budget support-related aid
520: VI.2. Developmental Food Aid/Food Security Assistance, Total
52010: Food aid/Food security programmes
530: VI.3. Other Commodity Assistance, Total
53030: Import support (capital goods)
53040: Import support (commodities)
600: VII. Action Relating to Debt, Total
60010: Action relating to debt
60020: Debt forgiveness
60030: Relief of multilateral debt
60040: Rescheduling and refinancing
60061: Debt for development swap
60062: Other debt swap
60063: Debt buy-back
700: VIII. Humanitarian Aid, Total
720: VIII.1. Emergency Response, Total
72010: Material relief assistance and services
72040: Emergency food aid
72050: Relief co-ordination; protection and support services
730: VIII.2. Reconstruction Relief & Rehabilitation, Total
73010: Reconstruction relief and rehabilitation

Appendix 4.2 - List of Countries Used in the Sample

Algeria
Bangladesh
Benin
Bolivia
Brazil
Cameroon
China (People's Republic of)
Colombia
Congo, Dem. Rep.
Congo, Rep.
Costa Rica
Dominican Republic
Ecuador
Egypt
El Salvador
Gabon
Ghana
Guatemala
Honduras
India
Indonesia
Iran
Jamaica
Kenya
Malaysia
Mexico
Morocco
Nepal
Nicaragua
Nigeria
Pakistan
Panama
Paraguay
Peru
Philippines
Senegal
South Africa
Sri Lanka
Sudan
Thailand
Togo
Tunisia
Turkey
Uruguay
Venezuela
Zambia

Appendix 5.1 - Durbin-Wu-Hausman Augmented Regression Test

Variable	1.i	2.i	3.i
GDP per capita		0.5702*** (2.97)	0.1219*** (-2.93)
Energy Intensity	1.8947*** (6.13)		
Carbon Intensity	-0.9570*** (-6.99)		
Total Aid	1.2305*** (133.87)	-0.1151*** (-3.09)	0.0098 (0.22)

t-statistics in parentheses.
*, **, and *** represent that the coefficient is statistically significant at 1, 5, and 10% size.

The Durbin-Wu-Hausman Augmented regression test involves running a reduced form regression for each of the suspected endogenous regressors, whereby the endogenous variable is regressed onto all of the right-hand-side variables in the system of equations. The residuals from this regression are then added into the original structural equation in which the endogenous regressor appears. If the coefficient for the residuals is statistically significant, the null hypothesis of exogeneity for the regressor is rejected (Davidson and MacKinnon 1993; Cong 2018).

The table above shows the results for the residual coefficients for each of the suspected endogenous variables. As can be seen, in all except one instance the coefficients are highly significant, leading to a rejection of the null of exogeneity for these variables.

The one exception is the Total Aid variable in the carbon emissions intensity equation, where the results suggest the variable is exogenous. However, Total Aid was still instrumented in this equation to ensure consistency and comparability of results between equations.

Appendix 5.2 - Regressions Results with Total Aid Squared

Table 1. GDP per capita equation 2SLS regression results

Explanatory Variable	
Energy Intensity	0.7270
	(0.16)
Energy Intensity (squared)	-1.7799
	(-0.85)
Carbon Emissions Intensity	2.3169
	(1.02)
Carbon Emissions Intensity (squared)	-2.2535
	(-1.01)
Aid Variables	
Total Aid	0.3184
	(0.74)
Total Aid (previous period)	0.1169
	(0.80)
Total Aid (squared)	-0.0240
	(-0.92)
Other Controls	
Domestic Investment	-0.0289*
	(-1.83)
Domestic Investment (previous period)	0.0320
	(0.94)
FDI	0.0906
	(0.88)
FDI (previous period)	-0.1377
	(-0.96)
Inflation Rate	-0.0001
	(-0.60)
Trade	0.0087*
	(1.87)
Number of observations	1,298
Number of countries	45
Average number of years per country	28.8

t statistics in parentheses.
*, **, and *** represent that the coefficient is statistically significant at 1, 5, and 10% size.

Appendix 5.3 - Regression Results with Added Yearly Time Dummies

Table 1. GDP per capita equation 2SLS regression results

	Equation	
Explanatory Variable	1.i	1.ii
Energy Intensity	1.6241	-6.8554
	(0.20)	(-0.15)
Energy Intensity (squared)	-1.5823	-0.4227
	(-1.06)	(-0.05)
Carbon Emissions Intensity	-0.3658	4.2846
	(-0.12)	(0.19)
Carbon Emissions Intensity (squared)	0.8064	-5.4671
	(0.18)	(-0.17)
Aid Variables		
Total Aid	-0.0571	
	(-1.10)	
Total Aid (previous period)	0.0225**	
	(2.18)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		-0.1036
		(-0.10)
Economic Inf. & Serv. Aid, previous period		-0.0232
		(-0.05)
Health Aid		-0.0326
		(-0.01)
Health Aid, previous period		-1.4184
		(-0.16)
Production Sectors Aid		0.0736
		(0.07)
Production Sectors Aid, previous period		0.7424
		(0.15)
Environmental Aid		5.4754
		(0.18)
Environmental Aid, previous period		3.7872
		(0.19)
Other Aid		-0.0582
		(-0.20)
Other Aid, previous period		-0.0405
		(-0.20)
Other Controls		
Domestic Investment	-0.0072	-0.0180
	(-0.54)	(-0.34)
Domestic Investment (previous period)	0.0043	-0.0042
	(0.64)	(-0.11)
FDI	-0.0028	-0.0306
	(-0.11)	(-0.22)
FDI (previous period)	-0.0110	0.0077
	(-0.83)	(0.08)
Inflation Rate	-0.0000	-0.0000
	(-0.67)	(-0.23)
Trade	0.0022	0.0142
	(0.26)	(0.23)
Number of observations	1,241	1,241
Number of countries	45	45
Average number of years per country	27.6	27.6

t statistics in parentheses.
*, **, and *** represent that the coefficient is statistically significant at 1, 5, and 10% size.

Table 2. Energy intensity equation 2SLS regression results

	Equation	
Explanatory Variable	2.i	2.ii
GDP per Capita	-1.6615***	-1.6567***
	(-8.58)	(-8.26)
GDP per Capita (squared)	0.0805***	0.0825***
	(5.25)	(4.98)
Aid Variables		
Total Aid	-0.0064	
	(-1.05)	
Total Aid (previous period)	0.0021	
	(0.84)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		-0.0130
		(-0.99)
Economic Inf. & Serv. Aid, previous period		-0.0132
		(-0.93)
Health Aid		0.0210
		(0.36)
Health Aid, previous period		-0.0412
		(-0.61)
Production Sectors Aid		0.0037
		(0.13)
Production Sectors Aid, previous period		0.0131
		(0.38)
Environmental Aid		0.1494
		(1.25)
Environmental Aid, previous period		0.0968
		(0.74)
Other Aid		0.0005
		(0.38)
Other Aid, previous period		-0.0002
		(-0.14)
Other Controls		
Domestic Investment	-0.0037***	-0.0036***
	(-2.77)	(-2.59)
Domestic Investment (previous period)	-0.0000	-0.0005
	(-0.02)	(-0.35)
FDI	-0.0025	-0.0021
	(-1.30)	(-1.08)
FDI (previous period)	-0.0016	-0.0008
	(-0.67)	(-0.40)
Trade	0.0012***	0.0013***
	(4.23)	(4.29)
Share of Industry in GDP	-0.0015	-0.0020*
	(-1.17)	(-1.79)
Energy Price Index	0.0001	-0.0004
	(0.07)	(-0.18)
Number of observations	1,241	1,241
Number of countries	45	45
Average number of years per country	27.6	27.6

Table 3. Carbon emissions intensity 2SLS regression results

	Equation	
Explanatory Variable	3.i	3.ii
GDP per Capita	2.3495***	1.9911***
	(6.62)	(9.13)
GDP per Capita (squared)	-0.1274***	-0.1199***
	(-5.71)	(-7.62)
Aid Variables		
Total Aid	0.0391**	
	(2.41)	
Total Aid (previous period)	-0.0130**	
	(-2.07)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		-0.0349
		(-0.89)
Economic Inf. & Serv. Aid, previous period		0.0378
		(0.92)
Health Aid		0.0754
		(0.93)
Health Aid, previous period		-0.1098
		(-1.18)
Production Sectors Aid		0.0163
		(0.36)
Production Sectors Aid, previous period		-0.0401
		(-0.98)
Environmental Aid		0.1482
		(0.69)
Environmental Aid, previous period		0.0662
		(0.33)
Other Aid		-0.0011
		(-0.58)
Other Aid, previous period		-0.0002
		(-0.11)
Other Controls		
Domestic Investment	0.0019	0.0030
	(0.75)	(1.37)
Domestic Investment (previous period)	0.0007	0.0031*
	(0.28)	(1.69)
FDI	-0.0037	-0.0051
	(-0.75)	(-1.28)
FDI (previous period)	0.0056	0.0013
	(1.05)	(0.31)
Trade	0.0003	0.0004
	(0.73)	(1.09)
Share of Industry in GDP	-0.0062***	-0.0034**
	(-3.49)	(-2.51)
Fossil Fuel Intensity	0.0105***	0.0146***
	(6.14)	(12.62)
Number of observations	1,241	1,241
Number of countries	45	45
Average number of years per country	27.6	27.6

Table 4. Carbon over GDP 2SLS regression results

Explanatory Variable	Equation 4.i	Equation 4.ii
GDP per Capita	0.5764**	0.3337
	(2.07)	(1.53)
GDP per Capita (squared)	-0.0440**	-0.0374**
	(-2.39)	(-2.40)
Aid Variables		
Total Aid	0.0233*	
	(1.77)	
Total Aid (previous period)	-0.0082*	
	(-1.74)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		-0.0479
		(-1.32)
Economic Inf. & Serv. Aid, previous period		0.0246
		(0.52)
Health Aid		0.0964
		(1.10)
Health Aid, previous period		-0.1510
		(-1.44)
Production Sectors Aid		0.0200
		(0.40)
Production Sectors Aid, previous period		-0.0270
		(-0.57)
Environmental Aid		0.2976
		(1.32)
Environmental Aid, previous period		0.1631
		(0.78)
Other Aid		-0.0006
		(-0.28)
Other Aid, previous period		-0.0004
		(-0.22)
Other Controls		
Domestic Investment	-0.0016	-0.0006
	(-0.62)	(-0.28)
Domestic Investment (previous period)	0.0012	0.0026
	(0.51)	(1.33)
FDI	-0.0066	-0.0072*
	(-1.46)	(-1.78)
FDI (previous period)	0.0030	0.0004
	(0.67)	(0.11)
Trade	0.0016***	0.0017***
	(3.67)	(4.33)
Share of Industry in GDP	-0.0070***	-0.0055***
	(-4.21)	(-3.92)
Energy Price Index	-0.0007	-0.0004
	(-0.28)	(-0.20)
Fossil Fuel Intensity	0.0122***	0.0146***
	(7.83)	(11.43)
Number of observations	1,241	1,241
Number of countries	45	45
Average number of years per country	27.6	27.6

Appendix 5.4 - Regression Results with Sectoral Aid Shares

Table 1. GDP per capita equation 2SLS regression results

Explanatory Variable	
Energy Intensity	-0.4504
	(-0.24)
Energy Intensity (squared)	-2.2436**
	(-1.98)
Carbon Emissions Intensity	2.9191*
	(1.70)
Carbon Emissions Intensity (squared)	-2.3495
	(-1.52)
Aid Variables	
Total Aid	-0.1964**
	(-2.09)
Total Aid (previous period)	0.0754
	(1.57)
By sector (% total aid)	
Health Aid	-0.0063
	(-0.79)
Health Aid, previous period	0.0166**
	(2.33)
Production Sectors Aid	-0.0062*
	(-1.95)
Production Sectors Aid, previous period	-0.0003
	(-0.10)
Environmental Aid	-0.0063
	(-0.70)
Environmental Aid, previous period	0.0102
	(1.19)
Other Aid	0.0017
	(0.81)
Other Aid, previous period	-0.0031*
	(-1.88)
Other Controls	
Domestic Investment	-0.0230*
	(-1.96)
Domestic Investment (previous period)	-0.0001
	(-0.01)
FDI	0.0175
	(0.56)
FDI (previous period)	-0.0214
	(-0.84)
Inflation Rate	-0.0000
	(-1.03)
Trade	0.0112***
	(3.62)
Number of observations	1,217
Number of countries	45
Average number of years per country	27

t statistics in parentheses.
*, **, and *** represent that the coefficient is statistically significant at 1, 5, and 10% size.
The Economic Infrastructure and Services aid sector, as the largest of the categories of interest, is omitted to avoid exact collinearity. All sectoral aid coefficients are interpreted relative to this category.

Table 2. Energy intensity equation 2SLS regression results

Explanatory Variable	
GDP per Capita	-1.8097***
	(-8.18)
GDP per Capita (squared)	0.1004***
	(6.12)
Aid Variables	
Total Aid	0.0035
	(0.56)
Total Aid (previous period)	0.0022
	(0.71)
By sector (% total aid)	
Health Aid	0.0016**
	(2.30)
Health Aid, previous period	0.0015*
	(1.91)
Production Sectors Aid	-0.0007*
	(-1.69)
Production Sectors Aid, previous period	-0.0005
	(-1.36)
Environmental Aid	0.0007
	(0.66)
Environmental Aid, previous period	0.0000
	(0.00)
Other Aid	-0.0000
	(-0.15)
Other Aid, previous period	-0.0002
	(-1.20)
Other Controls	
Domestic Investment	-0.0055***
	(-3.55)
Domestic Investment (previous period)	-0.0018
	(-1.26)
FDI	0.0005
	(0.27)
FDI (previous period)	0.0022
	(0.99)
Trade	0.0019***
	(6.69)
Share of Industry in GDP	-0.0050***
	(-3.06)
Energy Price Index	-0.0001
	(-0.65)
Number of observations	1,217
Number of countries	45
Average number of years per country	27

Table 3. Carbon emissions intensity 2SLS regression results

Explanatory Variable	
GDP per Capita	2.4140***
	(8.23)
GDP per Capita (squared)	-0.1488***
	(-7.84)
Aid Variables	
Total Aid	0.0199**
	(2.30)
Total Aid (previous period)	-0.0125**
	(-2.38)
By sector (% total aid)	
Health Aid	0.0006
	(0.44)
Health Aid, previous period	-0.0024*
	(-1.67)
Production Sectors Aid	0.0006
	(1.22)
Production Sectors Aid, previous period	0.0011**
	(2.51)
Environmental Aid	-0.0002
	(-0.13)
Environmental Aid, previous period	-0.0005
	(-0.30)
Other Aid	-0.0006
	(-1.29)
Other Aid, previous period	0.0004
	(0.93)
Other Controls	
Domestic Investment	0.0033
	(1.27)
Domestic Investment (previous period)	0.0036
	(1.64)
FDI	-0.0074*
	(-1.72)
FDI (previous period)	-0.0001
	(-0.02)
Trade	-0.0005
	(-1.07)
Share of Industry in GDP	-0.0023
	(-1.33)
Fossil Fuel Intensity	0.0104***
	(7.67)
Number of observations	1,217
Number of countries	45
Average number of years per country	27

Table 4. Carbon over GDP 2SLS regression results

Explanatory Variable	
GDP per Capita	0.5979
	(1.56)
GDP per Capita (squared)	-0.0437*
	(-1.86)
Aid Variables	
Total Aid	0.0372**
	(2.08)
Total Aid (previous period)	-0.0156*
	(-1.85)
By sector (% total aid)	
Health Aid	0.0030*
	(1.74)
Health Aid, previous period	-0.0020
	(-1.05)
Production Sectors Aid	-0.0001
	(-0.16)
Production Sectors Aid, previous period	0.0006
	(1.29)
Environmental Aid	0.0014
	(0.88)
Environmental Aid, previous period	-0.0003
	(-0.15)
Other Aid	-0.0010
	(-1.63)
Other Aid, previous period	0.0003
	(0.64)
Other Controls	
Domestic Investment	-0.0019
	(-0.65)
Domestic Investment (previous period)	0.0010
	(0.36)
FDI	-0.0077
	(-1.49)
FDI (previous period)	0.0039
	(0.71)
Trade	0.0011*
	(1.87)
Share of Industry in GDP	-0.0075***
	(-3.79)
Energy Price Index	-0.0010**
	(-2.09)
Fossil Fuel Intensity	0.0108***
	(4.73)
Number of observations	1,217
Number of countries	45
Average number of years per country	27

Appendix 5.5 - Regression Results with Education Aid Variable

Table 1. GDP per capita equation 2SLS regression results

Explanatory Variable	
Energy Intensity	2.0138**
	(2.54)
Energy Intensity (squared)	-2.2527***
	(-4.18)
Carbon Emissions Intensity	1.4386**
	(2.24)
Carbon Emissions Intensity (squared)	-0.6679
	(-1.47)
Aid Variables	
By sector (% GDP)	
Economic Inf. & Serv. Aid	0.0952*
	(1.65)
Economic Inf. & Serv. Aid, previous period	0.0317
	(0.50)
Health Aid	-0.7390**
	(-2.50)
Health Aid, previous period	0.0447
	(0.14)
Education Aid	36.3897*
	(1.81)
Education Aid, previous period	31.7708*
	(1.73)
Production Sectors Aid	-0.2013
	(-1.20)
Production Sectors Aid, previous period	-0.0394
	(-0.30)
Environmental Aid	0.7680*
	(1.79)
Environmental Aid, previous period	0.4096
	(0.92)
Other Aid	-0.0159**
	(-2.01)
Other Aid, previous period	-0.0120
	(-1.53)
Other Controls	
Domestic Investment	-0.0091
	(-1.47)
Domestic Investment (previous period)	-0.0007
	(-0.15)
FDI	-0.0091
	(-1.04)
FDI (previous period)	-0.0068
	(-0.75)
Inflation Rate	-0.0000
	(-1.21)
Trade	0.0053***
	(5.14)
Number of observations	1,298
Number of countries	45
Average number of years per country	28.8

t statistics in parentheses.
*, **, and *** represent that the coefficient is statistically significant at 1, 5, and 10% size.

Table 2. Energy intensity equation 2SLS regression results

Explanatory Variable	
GDP per Capita	-1.7861***
	(-8.50)
GDP per Capita (squared)	0.0979***
	(6.08)
Aid Variables	
By sector (% GDP)	
Economic Inf. & Serv. Aid	-0.0065
	(-0.53)
Economic Inf. & Serv. Aid, previous period	-0.0172
	(-1.36)
Health Aid	0.0584
	(1.08)
Health Aid, previous period	-0.1157*
	(-1.77)
Education Aid	8.6908***
	(3.29)
Education Aid, previous period	4.7174
	(1.50)
Production Sectors Aid	-0.0034
	(-0.10)
Production Sectors Aid, previous period	0.0241
	(0.67)
Environmental Aid	0.1483
	(1.30)
Environmental Aid, previous period	0.1312
	(1.16)
Other Aid	0.0018
	(1.36)
Other Aid, previous period	0.0007
	(0.53)
Other Controls	
Domestic Investment	-0.0048***
	(-2.89)
Domestic Investment (previous period)	-0.0018
	(-1.20)
FDI	-0.0008
	(-0.47)
FDI (previous period)	0.0025
	(1.29)
Trade	0.0020***
	(6.19)
Share of Industry in GDP	-0.0038**
	(-2.40)
Energy Price Index	-0.0002
	(-0.84)
Number of observations	1,298
Number of countries	45
Average number of years per country	28.8

Table 3. Carbon emissions intensity 2SLS regression results

Explanatory Variable	
GDP per Capita	2.1340***
	(10.38)
GDP per Capita (squared)	-0.1355***
	(-9.82)
Aid Variables	
By sector (% GDP)	
Economic Inf. & Serv. Aid	-0.0342
	(-0.94)
Economic Inf. & Serv. Aid, previous period	0.0320
	(0.81)
Health Aid	0.0385
	(0.50)
Health Aid, previous period	-0.0918
	(-1.00)
Education Aid	-2.4796
	(-0.40)
Education Aid, previous period	-0.6400
	(-0.09)
Production Sectors Aid	0.0024
	(0.05)
Production Sectors Aid, previous period	-0.0413
	(-1.01)
Environmental Aid	-0.0469
	(-0.26)
Environmental Aid, previous period	0.1883
	(1.04)
Other Aid	-0.0016
	(-0.84)
Other Aid, previous period	-0.0008
	(-0.46)
Other Controls	
Domestic Investment	0.0040*
	(1.78)
Domestic Investment (previous period)	0.0045**
	(2.46)
FDI	-0.0047
	(-1.25)
FDI (previous period)	-0.0022
	(-0.57)
Trade	-0.0000
	(-0.09)
Share of Industry in GDP	-0.0018
	(-1.20)
Fossil Fuel Intensity	0.0133***
	(12.28)
Number of observations	1,298
Number of countries	45
Average number of years per country	28.8

Table 4. Carbon over GDP 2SLS regression results.

Explanatory Variable	
GDP per Capita	0.2693
	(1.38)
GDP per Capita (squared)	-0.0334**
	(-2.49)
Aid Variables	
By sector (% GDP)	
Economic Inf. & Serv. Aid	-0.0404
	(-1.08)
Economic Inf. & Serv. Aid, previous period	0.0144
	(0.31)
Health Aid	0.0953
	(1.09)
Health Aid, previous period	-0.2072*
	(-1.91)
Education Aid	6.0379
	(0.95)
Education Aid, previous period	4.4513
	(0.61)
Production Sectors Aid	-0.0085
	(-0.18)
Production Sectors Aid, previous period	-0.0239
	(-0.50)
Environmental Aid	0.1102
	(0.53)
Environmental Aid, previous period	0.3334*
	(1.67)
Other Aid	0.0002
	(0.08)
Other Aid, previous period	-0.0002
	(-0.13)
Other Controls	
Domestic Investment	-0.0006
	(-0.27)
Domestic Investment (previous period)	0.0027
	(1.36)
FDI	-0.0056
	(-1.42)
FDI (previous period)	0.0002
	(0.04)
Trade	0.0019***
	(4.76)
Share of Industry in GDP	-0.0055***
	(-3.87)
Energy Price Index	-0.0003
	(-1.32)
Fossil Fuel Intensity	0.0147***
	(12.28)
Number of observations	1,298
Number of countries	45
Average number of years per country	28.8

Appendix 5.6 - Regression Results with 1990-2011 Sample

Table 1. GDP per capita equation 2SLS regression results

	Equation	
Explanatory Variable	1.i	1.ii
Energy Intensity	7.5283	3.0271
	(1.50)	(1.35)
Energy Intensity (squared)	-4.7591**	-2.8037**
	(-2.01)	(-2.28)
Carbon Emissions Intensity	-2.9713	-1.6686
	(-1.49)	(-1.27)
Carbon Emissions Intensity (squared)	3.9238	1.8786
	(1.60)	(1.37)
Aid Variables		
Total Aid	0.0721	
	(1.01)	
Total Aid (previous period)	0.0012	
	(0.06)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		0.0563
		(0.45)
Economic Inf. & Serv. Aid, previous period		-0.0900
		(-0.63)
Health Aid		-0.0884
		(-0.42)
Health Aid, previous period		0.3922
		(1.12)
Production Sectors Aid		0.3077
		(1.24)
Production Sectors Aid, previous period		0.1264
		(0.66)
Environmental Aid		-0.5173
		(-0.64)
Environmental Aid, previous period		-0.2356
		(-0.33)
Other Aid		0.0026
		(0.30)
Other Aid, previous period		0.0055
		(0.66)
Other Controls		
Domestic Investment	-0.0008	-0.0048
	(-0.05)	(-0.68)
Domestic Investment (previous period)	-0.0039	0.0002
	(-0.29)	(0.03)
FDI	-0.0117	-0.0009
	(-0.53)	(-0.10)
FDI (previous period)	0.0079	0.0013
	(0.48)	(0.14)
Inflation Rate	-0.0000	-0.0000
	(-0.41)	(-0.48)
Trade	-0.0024	0.0020
	(-0.39)	(0.99)
Number of observations	872	872
Number of countries	45	45
Average number of years per country	19.4	19.4

t statistics in parentheses.
*, **, and *** represent that the coefficient is statistically significant at 1, 5, and 10% size.

Table 2. Energy intensity equation 2SLS regression results

	Equation	
Explanatory Variable	2.i	2.ii
GDP per Capita	-2.0031***	-2.1703***
	(-11.86)	(-13.39)
GDP per Capita (squared)	0.1135***	0.1247***
	(9.81)	(10.86)
Aid Variables		
Total Aid	0.0028	
	(0.91)	
Total Aid (previous period)	0.0002	
	(0.20)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		-0.0203
		(-1.19)
Economic Inf. & Serv. Aid, previous period		-0.0138
		(-0.82)
Health Aid		0.0380
		(0.86)
Health Aid, previous period		-0.0514
		(-1.04)
Production Sectors Aid		0.0274
		(1.25)
Production Sectors Aid, previous period		0.0333
		(1.17)
Environmental Aid		0.2403**
		(2.47)
Environmental Aid, previous period		0.2953***
		(3.04)
Other Aid		0.0001
		(0.15)
Other Aid, previous period		-0.0002
		(-0.28)
Other Controls		
Domestic Investment	-0.0018*	-0.0018**
	(-1.85)	(-2.03)
Domestic Investment (previous period)	-0.0007	-0.0006
	(-0.64)	(-0.63)
FDI	0.0004	0.0004
	(0.25)	(0.22)
FDI (previous period)	0.0015	0.0017
	(0.78)	(0.89)
Trade	0.0019***	0.0019***
	(7.65)	(7.83)
Share of Industry in GDP	-0.0010	-0.0007
	(-1.08)	(-0.89)
Energy Price Index	-0.0004*	-0.0006***
	(-1.70)	(-3.22)
Number of observations	872	872
Number of countries	45	45
Average number of years per country	19.4	19.4

Table 3. Carbon emissions intensity 2SLS regression results

	Equation	
Explanatory Variable	3.i	3.ii
GDP per Capita	1.8026***	1.9218***
	(4.89)	(5.37)
GDP per Capita (squared)	-0.1131***	-0.1209***
	(-4.92)	(-5.42)
Aid Variables		
Total Aid	-0.0070	
	(-1.52)	
Total Aid (previous period)	0.0004	
	(0.20)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		0.0464*
		(1.78)
Economic Inf. & Serv. Aid, previous period		0.0121
		(0.35)
Health Aid		0.0363
		(0.61)
Health Aid, previous period		-0.1009
		(-1.48)
Production Sectors Aid		-0.1186***
		(-3.40)
Production Sectors Aid, previous period		-0.0989***
		(-2.99)
Environmental Aid		-0.0688
		(-0.50)
Environmental Aid, previous period		0.0778
		(0.57)
Other Aid		0.0006
		(0.40)
Other Aid, previous period		0.0009
		(0.58)
Other Controls		
Domestic Investment	0.0029	0.0033
	(0.89)	(1.02)
Domestic Investment (previous period)	0.0013	0.0006
	(0.59)	(0.25)
FDI	-0.0029	-0.0041
	(-0.65)	(-0.95)
FDI (previous period)	-0.0050	-0.0046
	(-1.31)	(-1.12)
Trade	-0.0007	-0.0008*
	(-1.49)	(-1.68)
Share of Industry in GDP	-0.0024	-0.0033*
	(-1.33)	(-1.73)
Fossil Fuel Intensity	0.0158***	0.0167***
	(10.62)	(10.74)
Number of observations	872	872
Number of countries	45	45
Average number of years per country	19.4	19.4

Table 4. Carbon over GDP 2SLS regression results

	Equation	
Explanatory Variable	4.i	4.ii
GDP per Capita	-0.4206	-0.3134
	(-1.00)	(-0.90)
GDP per Capita (squared)	0.0109	0.0074
	(0.44)	(0.33)
Aid Variables		
Total Aid	-0.0099	
	(-1.31)	
Total Aid (previous period)	0.0021	
	(0.70)	
By sector (% GDP)		
Economic Inf. & Serv. Aid		0.0257
		(0.89)
Economic Inf. & Serv. Aid, previous period		-0.0028
		(-0.08)
Health Aid		0.0719
		(1.06)
Health Aid, previous period		-0.1530*
		(-1.94)
Production Sectors Aid		-0.0951**
		(-2.32)
Production Sectors Aid, previous period		-0.0689*
		(-1.70)
Environmental Aid		0.1748
		(1.03)
Environmental Aid, previous period		0.3758**
		(2.30)
Other Aid		0.0008
		(0.41)
Other Aid, previous period		0.0006
		(0.38)
Other Controls		
Domestic Investment	0.0012	0.0016
	(0.38)	(0.50)
Domestic Investment (previous period)	0.0013	0.0000
	(0.53)	(0.01)
FDI	-0.0024	-0.0039
	(-0.50)	(-0.93)
FDI (previous period)	-0.0046	-0.0030
	(-1.17)	(-0.76)
Trade	0.0012**	0.0011**
	(2.19)	(2.19)
Share of Industry in GDP	-0.0034*	-0.0041**
	(-1.74)	(-2.15)
Energy Price Index	-0.0001	-0.0006*
	(-0.33)	(-1.90)
Fossil Fuel Intensity	0.0181***	0.0176***
	(8.20)	(10.61)
Number of observations	872	872
Number of countries	45	45
Average number of years per country	19.4	19.4