



# ENVIRONMENTAL REGULATION AS A DETERMINANT OF TRADE

An empirical investigation of the “Pollution Haven Hypothesis” in  
the context of international trade

## Abstract

This paper applies an augmented version of the Heckscher-Ohlin-Vanek model to a broad cross section of countries for the period 2001 to 2011, providing evidence that a country’s environmental regulatory regime has an influence on the energy content of trade. These results conform to predictions made under the “Pollution Haven Hypothesis” and the notion of “Carbon Leakage”, reiterating the importance of incorporating these issues to some extent in the formulation of future trade and climate policy.

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## Contents

I - Introduction .....	2
II - Literature Review.....	3
Production and Consumption Based Approaches to Carbon Accounting.....	3
Chart Set 1 – Net Transfers of CO <sub>2</sub> Emissions Embodied in Trade .....	4
The “Pollution Haven” and “Factor Endowments” Hypotheses.....	5
Figure 1 – The Pollution Haven Hypothesis.....	6
Figure 2 – The Factor Endowments Hypothesis.....	7
Environmental Policy as an “Endowment”.....	8
III - Theoretical Framework and Methodology .....	9
The Simple HOV Model.....	9
A Model for the Energy Content of Trade.....	10
Model Formulation .....	11
Data and Empirical Model.....	13
Energy Content of Trade.....	13
Conventional Factor Endowments and Other Control Variables.....	13
Environmental Indices .....	14
Model Specification.....	15
IV – Results .....	16
Descriptive Analysis.....	16
Chart 2 – Energy Content of Trade by Region .....	16
Chart Set 3 – EPI scores by Country and Region .....	17
Regression Results.....	18
Table 1 – Pooled OLS (only EPI) for the period 2002 to 2011 .....	18
Table 2 – Pooled OLS (with Conventional Factor Endowments) for the Period 2002 to 2011....	19
Table 3 – Pooled OLS (Full Model) for the Period 2002 to 2011 .....	20
Table 4 – Fixed Effects (Full Model) for the Period 2002 to 2011.....	21
Robustness to Alternative Indices.....	22
V - Discussion and Conclusion.....	24
Appendix.....	26
Data and Environmental Indices.....	26
ISIC Rev.3 to GTAP Concordance .....	28
Country List by Index Coverage.....	29
Charts 4 to 6 – Energy Content of Trade by Country .....	30
Table 5 – ERRI, CLIMI, CCPI and ESI Regression Results .....	31
Table 6 – Index Correlation Matrix .....	32
References.....	33

## I - Introduction

As the spectre of global warming looms and the long term consequences of unmitigated Greenhouse Gas (GHG) emissions become gradually more apparent, increasing attention has been given to the social and economic factors that underlie the structure and pattern of energy use. One such area of concern is the effect that globalisation has had on country level efforts to reduce their carbon dioxide emissions. Does increasing trade, with its associated consequences for industrialisation and technology transfer, contribute to rising emission levels? Does a stricter framework of regulation in developed countries lead to the outsourcing of relatively pollution intensive industries to countries with lower environmental standards? The nature of the threat that increasing GHG emissions pose makes these issues a collective action problem that is difficult to solve at anything but the level of multilateral institutions.

These concerns have led to the development of theories such as the “Pollution Haven Hypothesis” and the notion of “Carbon Leakage”, as well as much empirical work aimed at quantifying the flow of carbon dioxide embodied in trade and the most appropriate means of accounting for its production and consumption. As the first step to forming any coherent global policy to curb emissions, some degree of consensus on how to apportion and quantify responsibility will likely be necessary before any meaningful action is taken.

All of these questions suggest the importance of understanding the drivers behind the flow of embodied energy and GHG emissions within international trade. Not only would this facilitate a better understanding of the problem, but would give some insight into how proposed policies would interact with these underlying dynamics. In this spirit, this paper will utilise an analytical framework inspired by the insights of the Heckscher-Ohlin-Vanek model and extended to include the notion of “environmental permits” as an endowment capable of influencing the direction of trade. In particular, it will attempt to assess the relationship between the stringency of a country’s environmental policy regime and the energy content of its trade.

The next section of this paper will continue with a literature review outlining a number of issues relevant to the embodied energy/carbon content of trade, as well as providing preliminary justification for elements of the model to be used. Section III continues with an account of the Heckscher-Ohlin-Vanek theory underlying the model, as well as a full description of the methodology and data utilised in later analysis. Section IV presents the results of this regression analysis applied to a broad cross section of countries for the period 2001 to 2011. Section V will conclude and provide some discussion of potential weakness in the analysis presented.

## II - Literature Review

### Production and Consumption Based Approaches to Carbon Accounting

The recent past has seen a number of empirical studies concerned with the measurement of carbon dioxide (CO<sub>2</sub>) emissions embodied in international trade<sup>1</sup>. Much of this research is motivated by the difficult question of how best to assess a country's contribution to global greenhouse gas emissions and the complex role played by trade in this process. Should a country be accountable merely for the emissions produced within its own territorial boundaries, the so called *production* based approach? Or is the more appropriate measure of responsibility an account based upon the actual carbon content of goods and services *consumed* within a society?

As the dominant paradigm employed by most national governments and international institutions (including The United Nations Framework Convention on Climate Change (UNFCCC)), the production based approach has the advantage of being relatively easy to calculate and understand. It also conforms to the tendency of market economies to gravitate towards methods of regulatory accounting which assess the harmful byproducts of industrial production as the responsibility of producers, rather than the result of consumer preferences (Lenzen, Murray, Sack, & Wiedmann, 2007). The consumption based approach on the other hand is more difficult to compute, necessarily involving an assessment of the effects (and fairness) of allocating responsibility for mitigation based on the carbon embodied in a country's exports and imports of goods and services.

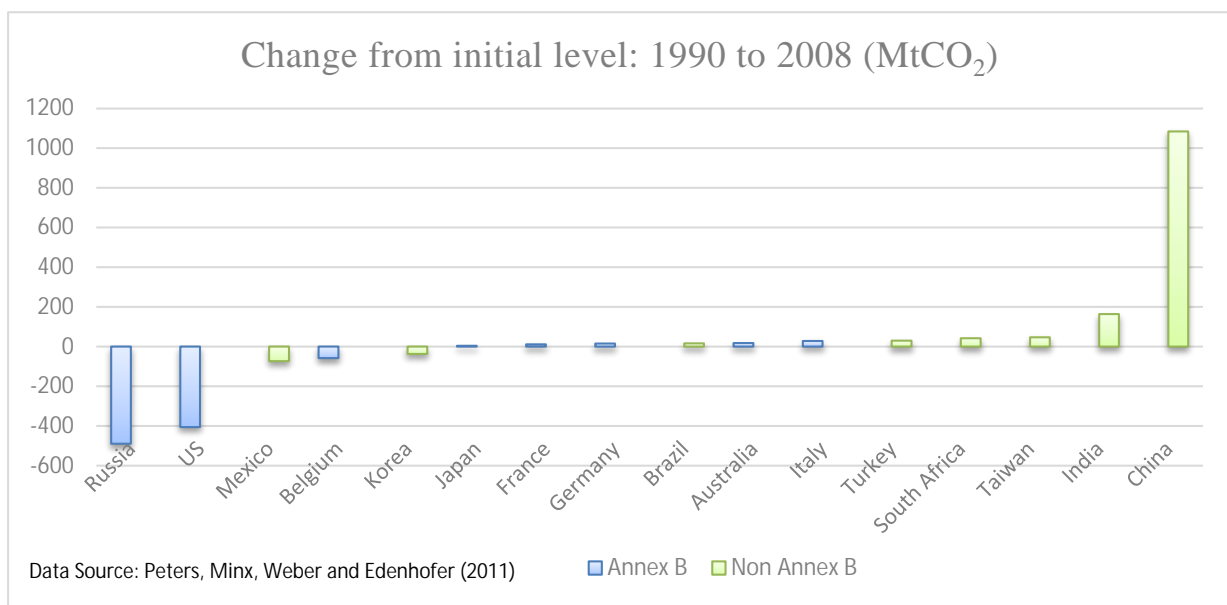
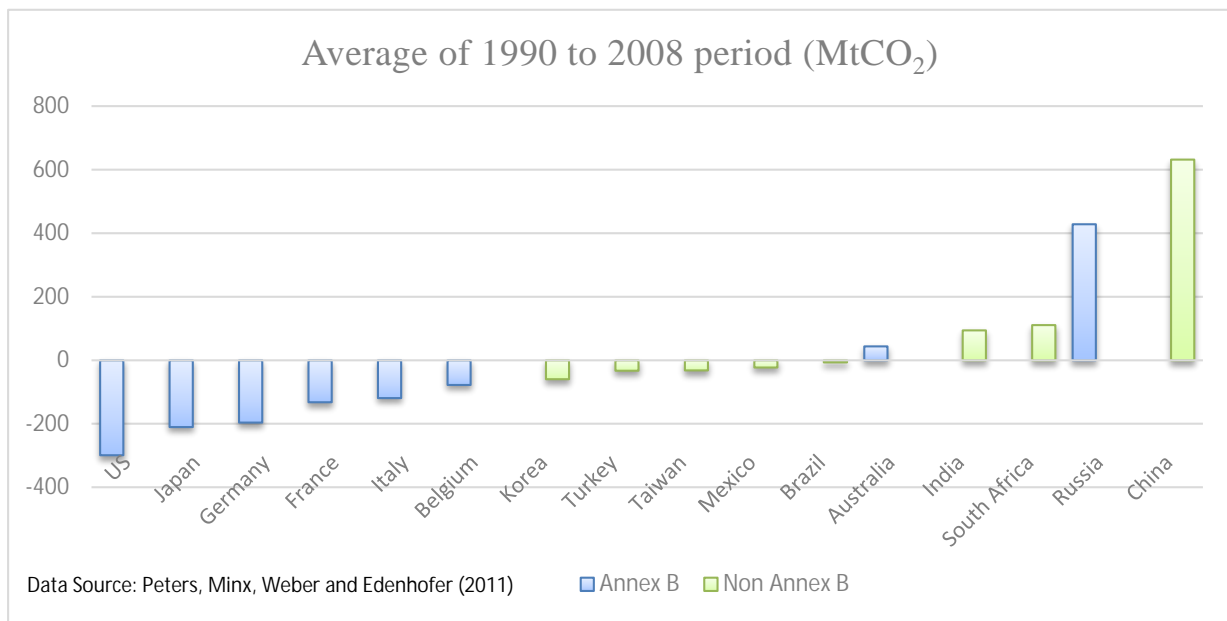
The differences in outcomes between these two approaches have led to concerns over the idea of *Carbon Leakage* or *Carbon Outsourcing* – the notion that developed countries in particular may be abrogating their responsibilities for reducing CO<sub>2</sub> emissions by moving towards a trade structure in which they increasingly tend to import goods from countries with lower regulatory standards (embodying a relatively higher CO<sub>2</sub> content) as a substitute for carbon intensive domestic production (Intergovernmental Panel on Climate Change, 2007). As a result, these countries are able to reduce their domestic production of CO<sub>2</sub> in line with mitigation commitments, while consuming similar (or potentially greater) amounts of embodied carbon in goods and services. The converse of this idea is the tendency of developing countries to export a higher proportion of goods with a relatively greater embodied carbon content, thereby increasing the overall carbon content of their domestic production. Critics of the production based approach note that, under the above framework, the burden for mitigation may be transferred from developed to developing countries, despite the stark differences in historical culpability for these emissions (Munksgaard & Pedersen, 2001).

In their 2011 paper, Peters, Minx, Weber and Edenhofer developed a trade linked global database for CO<sub>2</sub> emissions covering 113 countries and 57 economic sectors for the time period 1990 to 2008. Using the concept of “net emission transfers”, the authors find large regional shifts in the location of the production and consumption of embodied carbon as a result of differing emission intensities of production and the changing structure of international trade. Categorising countries broadly into developed (Kyoto Protocol “Annex B”) and developing (“non-Annex B”), the study finds that net emissions transfers from developing to developed countries have grown at an average annual rate of 17%, from 0.4 Gt CO<sub>2</sub> in 1990 to 1.6 Gt CO<sub>2</sub> in 2008. The authors note that, not only was the average annual net emission transfer over this period 18% larger than the average notional reductions these countries were expected to make under Kyoto Protocol commitments, but that the net effect was to turn the estimated 2% average reduction that was actually achieved over this period into an approximately 7% *increase* in emissions under the consumption based framework.

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<sup>1</sup> See (Sato, 2013) for a broader review of empirical literature

Chart Set 1 – Net Transfers of CO<sub>2</sub> Emissions Embodied in Trade



Country level analysis shows that a shift to a consumption based accounting approach often alters the relative ranking of countries in terms of their carbon emission “performance” (with developed countries generally rising in rankings compared to the conventional baseline). In particular, while China is considered the foremost polluter under a production based carbon inventory, with the U.S in second position, this situation is reversed under a consumption based framework. Additionally, the data shows the importance that China’s export led growth has had on net emissions transfers: The rise in Chinese emissions over the period accounted for over half of the growth in world CO<sub>2</sub> emissions (with exports alone accounting for 18%). Most remarkably, the imports of Chinese goods to developed countries account for 75% of the growth in their consumption based emissions.

In conclusion, the paper notes that a large and continually increasing share of global carbon emissions arise from the production of tradable goods and services. This in turn has led to an increasing

territorial divergence between the place of production and consumption, with all of that fact's attendant implications for mitigation responsibility. Additionally, the scale of these transfers was often found to exceed the apparent production based reductions in emissions reported by developed countries, casting further doubt on the degree of progress made towards international mitigation goals.

Similar studies have been performed for a number of countries and regions with a range of different results. However, they are generally supportive of the idea that the standard, production based approach to evaluating a country's carbon emission performance is likely to misrepresent the true situation by omitting the role played by the consumption of goods and services actually produced outside the territorial bounds of the country (European Bank for Reconstruction and Development, 2011). In his survey of the empirical literature, Sato (2013) outlines the difficulties inherent in studies of this nature and the problems surrounding cross study comparisons. These include issues with primary data (particularly the collection and aggregation of carbon emissions and intensity information), as well as various methodological issues, such as whether it is appropriate to apply domestic emission intensity factors (i.e. the import substitution / domestic technology assumption) to calculate the carbon embodied in imports, concerns over multidirectional feedback in trade and the difficulty of allocating imports to intermediate and final demand.

Despite these caveats, the above studies provide compelling evidence for increasingly large imbalances in the carbon content of trade. However, in isolation, they do not explain the extent to which these imbalances are driven by the incentives created by differences in regulatory policy (i.e. "Carbon Leakage"), or whether they simply reflect the consequences of growth in the productive capacity of emerging market economies and the increasingly important role they play in global trade. While suggestive of the former, any attempt to isolate the effect of environmental stringency on the carbon content of trade would require these other factors to be accounted for.

On the face of it, consumption based accounting of carbon emissions is merely another method of tracing the flow of the carbon embodied in goods and services through the global economy (Jakob & Marschinski, 2012). As noted by Caldeira and Davis (2011), its utility derives from whether or not we believe it represents "an accounting system that conforms with our intuitions about how responsibility should be shared among participants in a complex system". In any case, the formulation of effective and equitable policies aimed at reducing greenhouse gas emissions requires not only an agreed upon accounting methodology, but an understanding of the underlying determinants of these trade based emissions transfers (Jakob & Marschinski, 2012).

## The "Pollution Haven" and "Factor Endowments" Hypotheses

In their 2003 paper, Copeland and Taylor provide a survey of theoretical arguments regarding the consequences of economic growth and international trade liberalisation on the environment, covering a number of theories that may shed insight on the underlying drivers of the carbon emissions embodied in trade. They identify a country's comparative advantage as playing a central role in the sector/industry composition effects that are so important to the environmental impacts of trade. The two primary theories driving differing conceptions of comparative advantage in this regard may be described as "The Pollution Haven Hypothesis" and "The Factor Endowments Hypothesis".

The authors illustrate the difference in predicted outcomes between these two theories via the use of a simple relative supply and demand analysis: The model involves two goods, X and Y, as well as two regions, "North" and "South", which may differ in factor endowments or pollution policy but are

assumed to be identical in other regards. Given a number of assumptions<sup>2</sup>, the intersection of relative supply and demand can be used to infer autarky prices and thus the resulting pattern of trade under liberalisation.

The “Pollution Haven Hypothesis” can be represented by assuming that North and South are identical except for differences in pollution policy( $\tau$ ). The less stringent regulatory environment in South ( $\tau^* < \tau$ ) stimulates the industry producing X (assumed to be the pollution intensive industry), while contracting the industry producing Y.  $RS^N$  and  $RS^S$  refer to the supply of X relative to Y for North and South respectively under conditions of autarky, while  $RS^W$  indicates the relative supply faced by both countries post liberalisation and trade. RD indicates the demand for X relative to Y, which is assumed to be identical for both countries (see footnote). The RS and RD schedules below thus represent a country’s relative supply and demand for X and Y for a given set of relative prices, P (i.e.  $P^X/P^Y$ ).

As South enjoys a laxer regulatory environment, its supply of X relative to Y will be greater than that of North for a given relative price, illustrated by the starting position of its relative supply curve ( $RS^S$ ) to the right of North’s ( $RS^N$ ) – see figure 1.

Figure 1 – The Pollution Haven Hypothesis

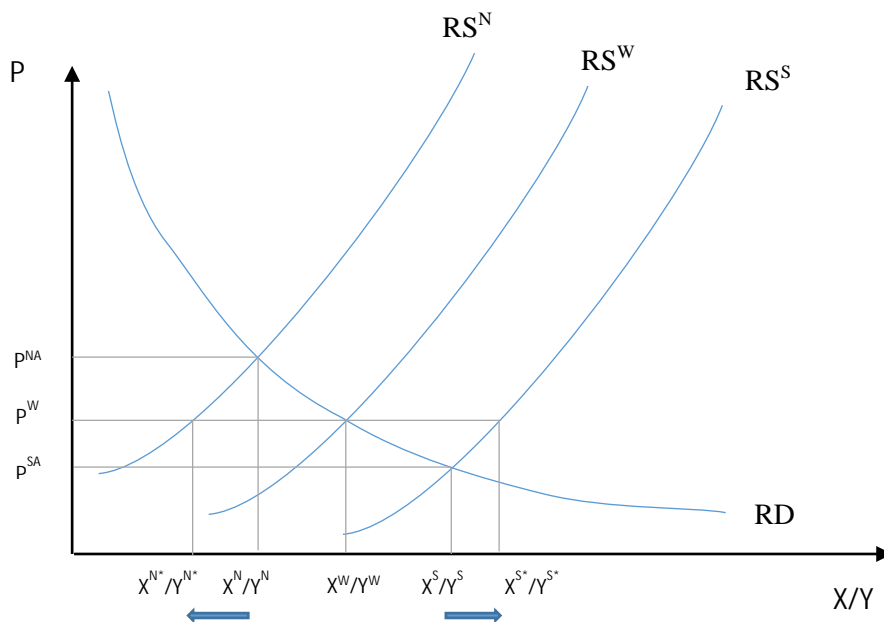


Figure adapted from Copeland and Taylor (2003)

Clearly, North and South will face different relative prices under autarky: Since North taxes pollution more heavily, relatively less of the pollution intensive good (X) will be produced there, implying that North’s relative prices,  $P^{NA}$ , will be greater than those of South,  $P^{SA}$ . This difference in relative prices

<sup>2</sup> From Copeland and Taylor (2003): Preferences over goods are homothetic and independent of environmental policy. The demand for X relative to Y is independent of income. Relative Demand is thus simply a function of prices:  $RD(p)$  where  $RD'(p) < 0$ . Identical preferences and income independence result in the same RD curve for both countries.

The conditions of non-positive profits and full employment allow output in each industry to be represented as a function of endowments, prices and policy( $\tau$ ):  $x = x(p, \tau, K, L)$  and  $y = y(p, \tau, K, L)$

With the assumption of constant returns to scale, RS can thus be represented as a function of prices,  $K/L$  and policy:  $(p, \tau, K/L) = \frac{x(p, \tau, K/L, 1)}{y(p, \tau, K/L, 1)}$ . This results in a standard upward sloping RS curve, with an increase in p raising the supply of X relative to Y.

suggests a comparative advantage for South in the production of the polluting good (and vice versa), resulting in an incentive for trade under liberalisation.

Under this scenario, North will import X from South and South will import Y from North, thereby stimulating the production of the pollution intensive good in the South and contracting it in the North. This results in an increase in South's production ratio from  $X^S/Y^S$  to  $X^{S^*}/Y^{S^*}$ , with a decrease in North from  $X^N/Y^N$  to  $X^{N^*}/Y^{N^*}$ . Trade liberalisation has thus resulted in an increase in the pollution generated by the country with less stringent environmental policies (South), with a corresponding reduction in pollution realised by North, thereby creating a "Pollution Haven" dynamic driven by the differences in comparative advantage these divergent environmental policies bring.

On the other hand, the "Factor Endowments Hypothesis" assumes that it is not differences in environmental policy that drive trade, but rather differing relative factor endowments of the type conventionally seen in this type of analysis (i.e. capital, labour etc.).

If North is relatively capital abundant (i.e.  $K^N/L^N > K^S/L^S$ ) and the production of X is considered relatively capital intensive (as well as generating a relatively greater level of pollution), the position of North's relative supply curve will start out to the right of South's relative supply curve – i.e. at a given relative price, North's supply of X relative to Y will be greater than that of South (see figure 2). North enjoys a comparative advantage in the production of the capital intensive, dirty good X (and vice versa), reflected in the different autarky prices faced by both countries prior to trade.

Figure 2 – The Factor Endowments Hypothesis

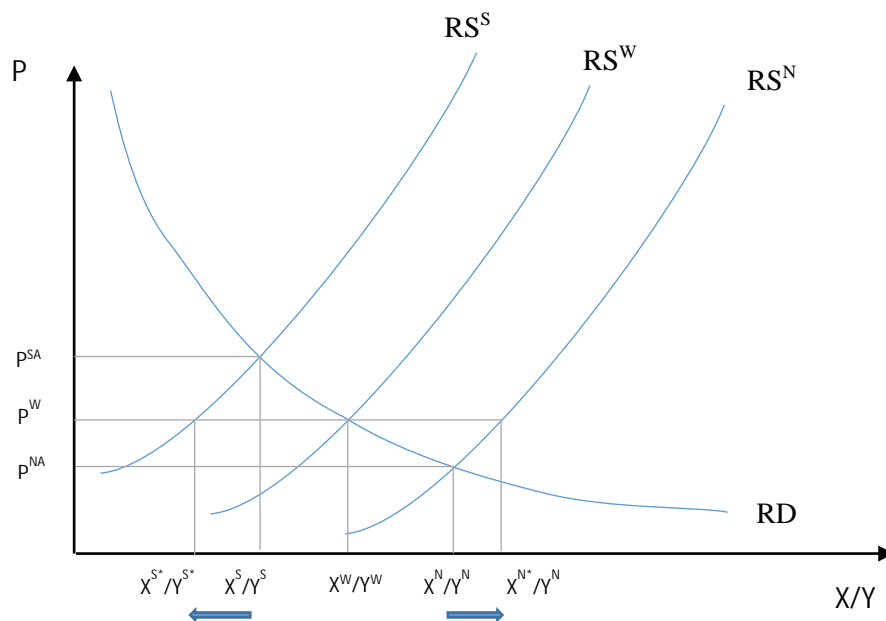


Figure adapted from Copeland and Taylor (2003)

After liberalisation, the lower autarky relative price faced by North ( $P^{NA}$ ) incentivises it to export X and import Y (vice versa for South). This results in a decrease in South's production ratio from  $X^S/Y^S$  to  $X^{S^*}/Y^{S^*}$ , with an increase in North from  $X^N/Y^N$  to  $X^{N^*}/Y^{N^*}$ . Trade thus increases the environmentally harmful, capital intensive industry in the capital abundant country, while reducing the size of the polluting industry in the capital scarce South. Under the "Factor Endowments Hypothesis", the environmental impacts of trade liberalisation occur as a by-product of the incentives

created by a country's underlying relative factor endowments, not as a result of explicit environmental policy.

Copeland and Taylor note that these two effects may in fact work in ways that are diametrically opposed to one another, with the overall result dependent on which of these two drivers is more dominant for a given country. Indeed, the Factor Endowments Hypothesis may still be used to explain the concentration of relatively polluting industries in developing countries if the particular mix of factor endowments these countries possess supports such a conclusion. This suggests the distinction between the notions of "Strong Carbon Leakage", whereby differences in environmental regulation directly incentivise the expansion of carbon intensive industries in developing countries; and "Weak Carbon Leakage", whereby structural factors such as differences in endowments, technology, societal preferences etc. are the key drivers of net emission transfers (Davis & Caldeira, 2010).

### Environmental Policy as an "Endowment"

In their 2007 paper examining evidence for the Pollution Haven Hypothesis in India, Dietzenbacher and Mukhopadhyay expand upon the idea of regulatory based comparative advantage by interpreting it in terms of the Heckscher-Ohlin (HO) Theory. In particular, they suggest that in circumstances where pollution is restricted by environmental policy, the overall extent to which a country is allowed to pollute may be thought of as an "endowment" with the potential to influence the direction of trade. In this framework, developing countries perceived to be relatively well endowed with hypothetical "emission permits" may be seen to have a comparative advantage in the production and export of emission intensive goods in relation to developed countries governed by more stringent environmental regulation. It is this conception of environmental policy as a driver of trade which this paper aims to test.

However, carbon dioxide emissions and other pollutants are essentially just the undesirable by-products of the generation of energy necessary for the production of other goods and services. As such, the embodied factor under consideration here will not be the carbon/pollution content of trade, but rather its energy content. Additionally, the review above illustrates the importance of including other country specific factors capable of influencing the energy content of trade, such as conventional HO endowments of labour and capital. In this way, this study aims to distinguish the role of environmental policy as a driver of the energy content of trade from other complementary or competing factors. The next section will continue with a more comprehensive discussion of the HO model motivating this hypothesis, as well as an explanation of the specific model to be utilised in this investigation.

### III - Theoretical Framework and Methodology

Under the standard Heckscher-Ohlin (HO) model of international trade, a country exports those goods that use intensively the factors of production for which the country is relatively well endowed and imports those goods whose production uses intensively the factors which are relatively scarce. This approach provides a powerful theoretical framework from which to assess and explain the gross patterns of trade between countries of varying factor endowments.

Vanek (1968) extended this model to investigate the relationship between the *factor content* of trade and the relative scarcity of production factors. In this conception, the cross border flow of goods may be seen as an indirect method of exchanging the factors (or factor services) contained within this trade. This leads to the following hypothesis, known as the Heckscher-Ohlin-Vanek (HOV) theorem: A country will export the services of the factors of production in which it is relatively well endowed and import the services of the factors that are relatively scarce. Thus, instead of making predictions regarding the gross direction of trade between countries, the HOV framework explains the factor contents of exports and imports based on the scarcity of the production factors.

#### The Simple HOV Model

Given the following assumptions -

- Perfect competition in goods and factor markets
- Constant returns to scale
- Production technology and quality of factors common between countries
- At least as many goods as factors of production
- No barriers to trade
- Goods and factor price equalisation
- Identical and homothetic tastes

- a simple representation of the HOV model may be formally described as follows:

Let  $A$  be the  $m \times n$  matrix of technology coefficients, where an element of the matrix,  $a_{kj}$ , represents the total quantity of the  $k^{th}$  factor used per unit of production of good  $j$ .

A country's net exports ( $T$ ) is given by its output ( $Y$ ) minus its consumption ( $C$ ). The factors embodied in this trade can thus be represented as:

$$AT = A(Y - C) \quad \text{where } T, Y \text{ and } C \text{ indicate vectors of goods within these respective categories.}$$

Factor market equilibrium requires  $AY = E$ , where  $E$  is the vector of the country's endowments (i.e. demand for factors equals their supply).

The identical and homothetic tastes assumption implies that each country consumes a constant share ( $s$ ) of world output:  $C = sC_w = sY_w$ .

$$\begin{aligned} \text{Thus, } AC &= sAC_w = sAY_w \\ &= sE_w \quad \text{where } E_w \text{ is the factor content of world production/world factor endowment.} \end{aligned}$$

In this way, the factor content of a country's consumption can be represented as a fraction of world endowments.

Since  $AT = A(Y - C) = AY - AC$ , the above results imply that  $AT = E - sE_w$ . Thus, the factor content of trade is characterised by the difference between a country's domestic factor content of production ( $AY$ ) and its "share" of the factor content of world production ( $AC$ ). Or alternatively, the difference between its endowments ( $E$ ) and its share of world endowments ( $sE_w$ ).

If the specific factor content of a country's net exports is positive (e.g.  $\sum_{j=1}^n a_{kj} \times t_j$ ), this implies that  $e_k - se_{kw}$  must be positive too for the above identity to hold.

In this way, a country will be revealed to be relatively abundant in a factor  $e_k$  by the factor content of its trade when  $e_k > se_{kw}$ , as well as exhibiting relative scarcity in a factor when  $e_k < se_{kw}$  (e.g. country is relatively abundant in capital if  $K > sK_w$  and vice versa).

Thus, the model is determined through the conditions of factor and consumption market equilibrium, as well as balanced trade.

## A Model for the Energy Content of Trade

In order to act as meaningful determinants of trade, the factors described in the HOV model are presumed to exhibit at least a fairly high degree of immobility: A country or region's endowments of labour, capital, land etc. may not easily be transferred to another country or region in the short term. As this paper aims to investigate the determinants of the *energy* content of trade in particular, this poses the following questions: How might one measure a country's endowment in the factor responsible for its trade in the embodied "energy" of its goods and would such a consideration be meaningful in the first place?

Since the energy embodied in the production of goods and services ultimately derives from the exploitation of natural resources such as coal, oil, gas, nuclear fissile material (and to a lesser extent, renewable sources such as wind, solar radiation, tides and currents etc.), it might seem reasonable to assess a country's "energy endowment" based on its relative abundance in these factors. However, the high degree of mobility that characterises these resources on international energy markets makes them a highly imperfect measure of a country's endowment in a factor: Not only are these resources (in particular fossil fuels such as coal, oil, natural gas etc.) some of the most liquid and highly traded commodities available, but in many regions there is substantial trade in the electricity generated from their exploitation.

However, the "Pollution Haven Hypothesis", as described by Dietzenbacher and Mukhopadhyay (2007), provides an alternate explanation for the flow of energy embodied in trade: Rather than attempt to use natural resources as an endowment, differences in countries' "environmental stringency" may be seen as the source of the comparative advantage driving the factor content of trade. In this framework, regions with restrictive environmental regulation are seen to face higher costs in the production of energy intensive goods and services than those with laxer or less ambitious regulatory environments in place, all else equal. In this way, the economy of a country may be described as possessing a stock of environmental "permits" regulating the extent to which it may pollute — at this point a restriction largely imposed by the preferences of its political constituents. As concern over the implications of climate change grows, these notional limitations are increasingly coming to equate to carbon emission "permits".

Countries with larger stocks of these hypothetical “permits” are thus more likely to engage in production characterised by and/or necessitating the use of energy intensive techniques. In this way, the tolerance of a society for the environmental harm created as a byproduct of its production may be viewed as a country specific, idiosyncratic “resource” or endowment that has the potential for driving the flow of international trade. Unlike an attempt to explain the factor content of trade utilising a country’s stock of energy based natural resources, a society’s preferences for environmental policy may be viewed as relatively fixed and thus better conform to the notion of an endowment necessary for inclusion in the HOV model.

Under the standard HOV framework, countries endowed with a relative abundance of environmental “permits” would be expected to export goods and services embodying a relatively high proportion of the environmental harm these permits represent, and vice versa. Since the primary source of these harms largely originates from the generation of energy (necessary for production, consumption, transport etc.), energy may be viewed as the factor embodied in trade that is driven by a country’s relative endowment of environmental “permits”.

The standard approach to testing the HOV model with the inclusion of energy as a factor of production would require the collection/construction of data on gross factor input requirements, appropriate input-output tables and some objective, quantitative measure of countries’ endowments of environmental “permits”. However, the difficulty of obtaining these factor intensities (especially with regard to energy use) for a broad cross section of countries over time, as well as the non-existence of quantitative measures of hypothetical environmental “permits” necessitates a different approach.

## Model Formulation

In line with the “commodity composition” approach proposed by Baldwin (1971) and Leamer (1984), this paper will attempt an empirical route to testing the HOV theorem via the regression analysis of the energy factor content of a country’s trade. The regression equation necessary for this analysis may be represented as follows:

$$ET_i = \beta_1\theta_{1i} + \beta_2\theta_{2i} + \dots + \beta_m\theta_{mi} + \beta_e\varphi_i + \varepsilon_i$$

Where  $ET_i$  represents energy factor content of trade for country  $i$ , the  $\theta$ s are gross factor input requirements (factor intensities) of factors other than energy,  $\varphi$  is a measure of the stringency of a country’s environmental policy regime (as a proxy for environmental “permits”) and the  $\beta$ s are their associated coefficients. Needless to say, this approach is an imperfect test of the relationship between factor abundance, factor intensity and net trade described by the HOV theorem: Its purpose is to utilise the above mentioned data to investigate the relationship between the energy content of trade ( $ET$ ) and a country’s environmental policy “permits” or endowments ( $\varphi$ ), while controlling for the production intensities of other factors. As discussed above, the importance of conventional endowments (i.e. “The Factor Endowments Hypothesis”) and other structural issues in determining the energy content of trade necessitate the inclusion of these factors in any meaningful attempt to identify and isolate the role played by environmental policy in this regard.

Although not strictly a representation of the theorem described above, the existence of an association suggesting that a country’s regulatory environment may be a driver of the energy content of its trade is nevertheless an indication of the type of relationship between factor content of trade and endowments that underlies the formal HOV theory. Furthermore, such a relationship would be relevant to discussions of “Carbon Leakage” and “The Pollution Haven Hypothesis” that focus specifically on the carbon or energy content of trade.

According to this formulation, one would expect to find a negative coefficient on the environmental policy regime variable ( $\varphi$ ), indicating that an increase in environmental stringency (i.e. a decrease in the relative endowment of environmental “permits”) is associated with a decrease in the embodied energy content of (net) trade. The predicted signs of the control variables will depend on the expected association between the production intensity of a given factor and the energy content of trade. As the above mentioned formulation is agnostic about the quantitative magnitude of these parameters, only their sign can be interpreted in any truly meaningful way (Alleyne & Subramanian, 2001). One can thus make claims regarding the manner in which relative endowments and factor intensities of production influence the direction of trade, but not necessarily about the magnitude of this effect.

## Data and Empirical Model

Data were gathered for a large sample of countries representing a broad cross section of conventional factor endowments, development levels and environmental policy regimes. This included information on energy intensity of production, trade flows, employment, capital stock, GDP per capita, total factor productivity and various indices used to measure aspects of country level environmental performance. Where available, this data was collected for the years 2001 to 2011, resulting in a sample of approximately 85 countries for the full period under consideration<sup>3</sup>.

Given the breadth of the data available, this paper will attempt to implement panel estimation techniques in order to take into account both time series and cross sectional relationships, as well as take advantage of the benefits to efficiency, identification and the potential alleviation of multicollinearity such an approach brings.

In line with the broad aim of estimating the effect of differing relative endowments of environmental “permits” on the energy content of trade, the general regression equation may be represented as follows:

$$ET_{it} = \alpha_i + \beta_1\theta_{1it} + \beta_2\theta_{2it} + \dots + \beta_m\theta_{mit} + \beta_e\varphi_{it} + \varepsilon_{it}$$

Where  $t$  represents time,  $i$  represents the country index and  $\alpha_i$  is the regression constant.

### Energy Content of Trade

The energy content of trade variable was constructed by multiplying energy intensity of production by industry (calculated from energy and output data in the Global Trade Analysis Project (GTAP) database) with trade data by industry (obtained from the OECD Structural Analysis database) to create a series for the energy content of trade by industry. These values were then summed across all industries to obtain a single energy content of trade variable for each year:

$$ET_{it} = \sum_{j=1}^n e_{jit} \times t_{jit}$$

Where  $e_{jit}$  is the energy intensity of production for industry  $j$  and  $t_{jit}$  is the trade flow associated with industry  $j$ . Again,  $i$  and  $t$  refer to country and time indices respectively.  $e_{jit}$  was calculated as the amount of energy utilised by an industry (in Millions of Tonnes of Oil Equivalent) per unit of output in that industry.

This process was performed for exports, imports and net exports. As the calculated energy intensity of production variable refers only to the available GTAP base year of 2007, the calculation of energy content of trade thus presumes that the basic energy intensity of production does not change significantly over time. Nevertheless, this approach does allow for the industry composition of trade to alter over time, which would then be reflected in the energy content of the final variable (i.e. if high energy intensity industries become more prominent in trade over time this would have a greater effect on the energy content of trade variable than the Dollar value of that increase in trade may suggest, and vice versa).

### Conventional Factor Endowments and Other Control Variables

In practice, the “control” factor intensities ( $\theta$ 's) utilised in the regression will consist of the conventional HOV measures of labour and capital intensity of production, as well as indicators of country income/development level and technological state:

A measure for labour intensity was created by categorising employment by skilled and unskilled status. Skilled employees were considered to be those corresponding to occupation categories 1-3 in

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<sup>3</sup> See appendix for full description of data and sources

The International Standard Classification of Occupations (ISCO) framework (Weingarden & Tsigas, 2010). Other employees were considered unskilled. Employment data was obtained predominantly from The International Labour Organization's (ILO) ILOSTAT database, with certain countries requiring alternative sources. Labour intensity was then calculated as skilled and unskilled labour per unit of output. The lack of data on employment by occupation for India necessitated the use of education to determine skill level: Employees with a technical diploma or above were considered skilled for this purpose. A number of countries did not have the required labour data available for the full period under consideration (2001-2011). As such, the closest available year was used where necessary.

The measure for capital intensity utilised was capital stock per unit of output, while GDP per capita was used to control broadly for a country's overall state of development. A measure of Total Factor Productivity (TFP) was used as an indicator of a country's general technological state (i.e. the efficiency with which it converts factors into output). Data on capital stock, GDP per capita, output, and TFP was obtained from the Penn World Table 8.1 database.

### Environmental Indices

In order to assess the stringency of countries' regulatory environments, data from a number of prominent organisations engaged in the compilation of indices of "environmental performance" were collected. These indices served as a proxy for a country's environmental policy "permits" or endowments ( $\varphi$ ). These include:

- The Environmental Performance Index (EPI)<sup>4</sup>
- The Environmental Sustainability Index (ESI)<sup>5</sup>
- The Climate Change Performance Index (CCPI)<sup>6</sup>
- The Climate, Laws, Institutions and Measures Index (CLIMI)<sup>7</sup>
- The Environmental Regulatory Regime Index (ERRI)<sup>8</sup>

The EPI, ESI and CCPI are fairly broad indices, taking into account a range of policy areas and outcomes related to environmental sustainability, climate and energy issues. In particular, the CCPI places a large emphasis on the issue of climate change and thus country level efforts to mitigate CO<sub>2</sub> and other greenhouse gas emissions. The final two indices, CLIMI and ERRI, focus to a greater degree on the policy and regulatory framework employed by countries in their efforts to mitigate the effects of climate change and other environmental issues, with less emphasis placed on realised outcomes.

While at least some data on the ESI and CCPI were available for multiple years in the sample period, concerns over the methodological consistency and comparability of these calculated index values over time excluded their use in time series/ panel analysis. As such, the ESI, CCPI, CLIMI and ERRI were only available for single year regressions. In contrast, the EPI index values obtained reflected a consistent methodology "backcast" from the most recent version of the index to prior releases. Additionally, it afforded the largest range of observations with regard to both time (2002 to 2011) and countries covered (85 after subsequent matching to energy, trade and other data). Given these advantages, EPI will constitute the primary index used in further analysis, with the alternative indices

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<sup>4</sup> Yale Center for Environmental Law & Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN)

<sup>5</sup> YCELP and CIESIN

<sup>6</sup> Germanwatch

<sup>7</sup> European Bank for Reconstruction and Development (EBRD)

<sup>8</sup> Esty and Porter (2002)

providing an opportunity to test the robustness of these results to differing conceptions of environmental regulatory stringency<sup>9</sup>.

### Model Specification

In line with the suggestions for regression equations such as the above made by Deardorff (1984), this analysis scaled the trade variable by output to account for an economy's relative size in the scheme of world production/trade. Additionally, robust regression techniques were utilised to attempt to correct for the issue of heteroskedasticity that is likely to arise in these situations. However, in contrast to Deardorff's suggestions, data on total factor shares was not available for the wide range of countries over the time period necessary, so relative physical ratios were used for capital and labour intensity.

The specific functional form chosen for later regression analysis was predominantly that of a log model. The nature of many of the variables in question suggested the use of log transformations to achieve distributions more conformable to OLS regression and alleviate concerns over the non-normality of residual distributions etc. The variables transformed in this way include: Energy Content of Exports and Imports, Capital Stock, Skilled and Unskilled Labour (all scaled by output). Although not a perfect substitute, the log of the ratio of the Energy Content of Exports and Imports was used as a replacement for Net Exports.

Please see the Data Appendix for a more comprehensive description of the data and their sources discussed in this section.

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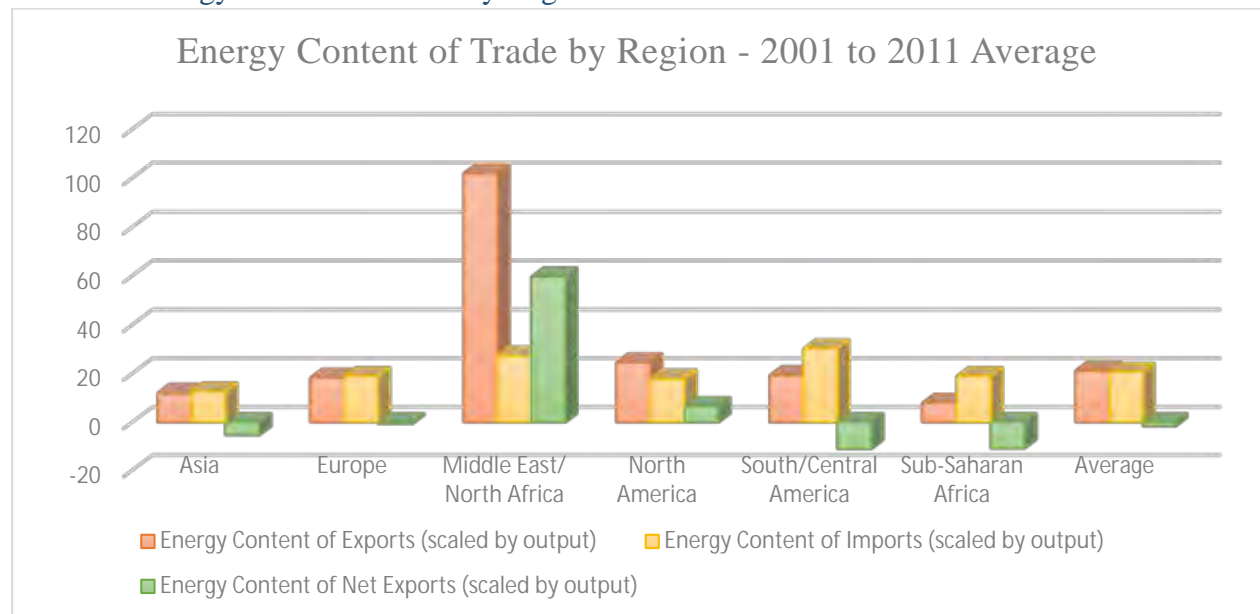
<sup>9</sup> See appendix for country list by index coverage

## IV – Results

### Descriptive Analysis

A number of separate regressions were performed in order to analyse the association between the energy content of trade and a country's hypothetical endowment of environmental "permits". However, the following charts give some preliminary insight into the nature of the relationship in question and the variables used to assess it:

Chart 2 – Energy Content of Trade by Region



This chart gives an indication of the wide discrepancy in the energy content of various trade measures depending on the geographical region of the country concerned. Most evident is the high energy content of exports exhibited by countries from the Middle East and North Africa region, arising both as a result of high overall energy intensities of production, as well as the fact that in many of these countries a small subset of high energy exports constitutes a large proportion of their output. North America is the only other region where the energy content of exports exceeds that of imports, again suggesting the energy intensive nature of the export oriented sectors within the U.S. and Canadian economies.

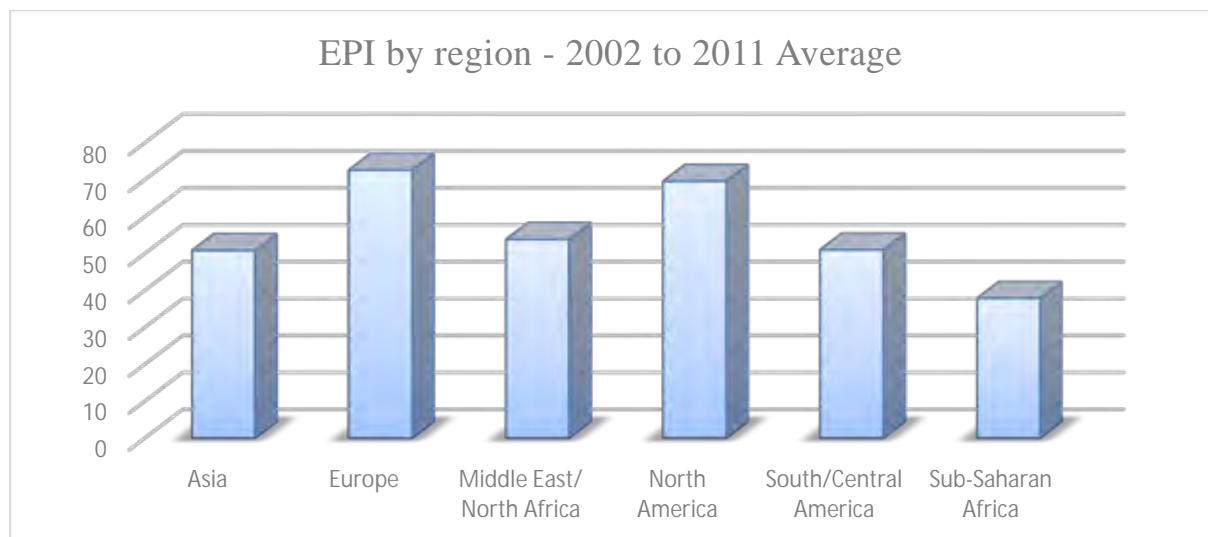
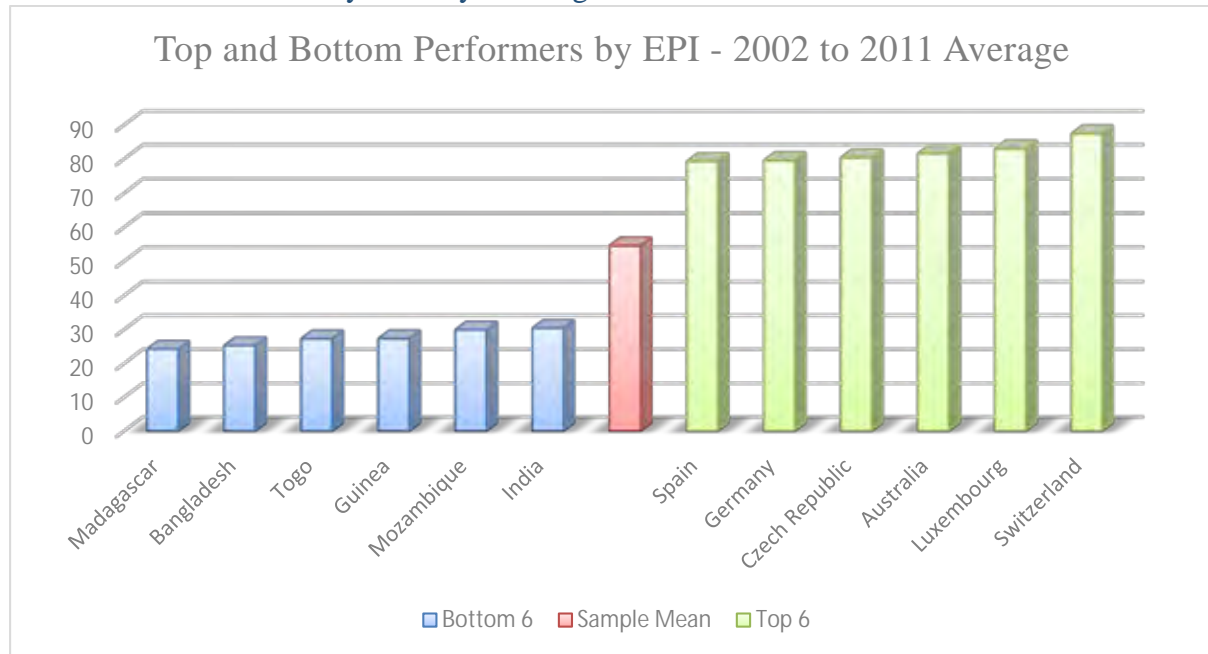
Both South and Central America, as well as Sub-Saharan Africa, exhibit relatively large deficits in the energy content of their net exports, suggesting that they tend to import goods characterised by relatively high energy intensities (as measured by their own, domestic energy intensities of production) and export goods with relatively low energy intensities. However, when the energy content variable is scaled by measures of trade, rather than output, this deficit is moderated somewhat, suggesting that trade deficits associated with energy intensive goods may partially explain the observed discrepancy.

On average, Asian countries exhibit relatively low energy content for both imports and exports (with in a slight net deficit apparent). Europe is the region closest to achieving a balance of energy content in its trade behaviour, with a relatively insignificant net deficit. Europe's results closely match that of

the average across regions, reflecting the relatively high representation of European countries in the sample.

Charts 4 to 6 (see appendix) illustrate the wide divergence in the energy content of exports, imports and net exports between the top and bottom countries in each category. As would be expected, developing countries tend to exhibit the lowest energy content of both exports and imports, while resource rich countries dominate the high end of the energy content of exports.

Chart Set 3 – EPI scores by Country and Region



The above charts give an indication of the degree and nature of the divergence in EPI performance between countries and regions as a whole. As would be expected, developed countries (particularly relatively affluent European nations) dominate the higher end of EPI scores. On the other end of the spectrum, the lowest performing countries are almost exclusively developing African states, with the notable exception of India as an atypically poorly performing Asian country (China is the next lowest non-African state in the sample, with an average index value approximately 12 points higher than that of India).

In general, European and North American countries perform significantly better in the metrics tracked by the EPI than all other regions. In contrast, Sub-Saharan Africa performs worst, while the other three regions exhibit average scores of a similar magnitude, in between these two extremes.

The relatively good performance of the Middle East/ North Africa region gives an indication of the broad nature of the measures tracked by the index (i.e. it accounts for policy, regulatory issues and outcomes distinct from those narrowly focused only on emission intensities of production etc.), as well as reflecting a degree of selection bias in both the countries tracked by the EPI and those eventually included in this investigation. In particular, the only Middle Eastern countries with EPI data in the sample are Turkey and Iran, thus excluding a number of potentially poorly performing Gulf states etc.

As discussed in the preceding section, although data on five environmental indices were collected, the Environmental Performance Index was the only variable truly suitable for time series/panel analysis (owing to the methodological consistency afforded by the “backcast” nature of its calculation and the large sample of observations covered). As such, the following regression analysis will proceed by focusing on the relationship between the EPI and the energy content of trade.

## Regression Results

Table 1 simply presents the results of the separate pooled OLS regressions of the energy content of exports, imports and the export-import ratio (scaled by output) on a country’s EPI score<sup>10</sup>.

Table 1 – Pooled OLS (only EPI) for the period 2002 to 2011

	~Exports/Output	~Imports/Output	~Exports/Imports
EPI	0.024*** (0.003)	-0.006** (0.003)	0.031*** (0.002)
Constant	0.554*** (0.198)	2.882*** (0.175)	-2.477*** (0.164)
R-squared	0.074	0.008	0.183
N	702	685	683

\* p<0.10    \*\* p<0.05    \*\*\* p<0.01    Standard Errors in parentheses

The coefficients on the EPI variable are significant for all three models (at least at the 5% level), suggesting a relationship between a measure of a county’s environmental regulatory stringency and the energy content of its trade does indeed exist. However, the signs of these coefficients are precisely the opposite of what one might expect under the Pollution Haven Hypothesis: Instead of a relative abundance of “environmental permits” (as proxied for by increasing values of EPI) being associated with a decrease in the energy content of exports and an increase in the energy content of imports (with a corresponding decrease for net exports/ export-import ratio), the above results suggest the reverse to be true.

<sup>10</sup> ~ Indicates that a variable has been logged





decrease in the energy content of exports (scaled by output), with a 1 unit increase in EPI associated with a decrease in this variable of approximately 4.6%, *ceteris paribus*. In contrast, a 1% increase in Skilled Labour and Capital Stock per unit of Output are associated with a 0.57% and 0.29% increase in the energy content of the export-import ratio respectively, *ceteris paribus*. Of the traditional factor endowments, Unskilled Labour appears to have the biggest impact, with a 1% increase in Unskilled Labour per unit of Output associated with a 1.14% decrease in the energy content of the export-import ratio, *ceteris paribus*. These findings suggest that environmental regulatory stringency is at least as important a factor in determining the energy content of trade as are conventional factor endowments such as labour and capital.

Despite attempts to control for omitted variable bias in the above model, there is a strong likelihood of the existence of a number of unobserved factors correlated with both the explanatory and dependant variables. As such, a fixed effects (FE) regression was utilised in order to control for time invariant, country specific factors which may have influenced the pooled OLS results above. Table 4 presents the results for the FE model below, thereby exploiting the within-group (country) variation in the energy content of trade across time (time dummies omitted from table):

**Table 4 – Fixed Effects (Full Model) for the Period 2002 to 2011**

	~Exports/Output	~Imports/Output	~Exports/Imports
~Skilled Labour/Output	-0.079 (0.104)	-0.176** (0.082)	0.096 (0.110)
~Unskilled Labour/Output	-0.234 (0.153)	0.144 (0.230)	-0.318 (0.217)
~Capital/Output	0.511*** (0.189)	0.510** (0.202)	0.040 (0.268)
TFP	0.080 (0.259)	0.013 (0.374)	0.126 (0.628)
~GDP/Capita	1.684*** (0.524)	1.666*** (0.356)	-0.031 (0.507)
EPI	0.042 (0.026)	0.077*** (0.027)	-0.037* (0.022)
Constant	-16.353*** (4.137)	-18.841*** (2.865)	2.507 (3.920)
R-squared	0.405	0.567	0.011
N	600	582	581

\* p<0.10    \*\* p<0.05    \*\*\* p<0.01                      Standard Errors in parentheses

Under the FE specification, the coefficient on the EPI variable is positive for the import model and negative for the export-import ratio model (although only at the 10% significance level). Although this broadly corresponds to predictions under the Pollution Haven Hypothesis, the conclusion appears to be less robust with regards to the energy content of net exports than that of the preceding pooled

OLS model. Nevertheless, the high correlation between the country specific error term ( $u_i$ ) and the predicted values ( $X\beta$ ) in all three versions of the model suggests that country level unobserved factors were indeed present and that the pooled OLS results should be viewed with caution.

Interestingly, the FE specification dramatically reduces the importance of labour abundance in the model, with only the coefficient on Skilled Labour displaying significance in any version of the model. This may be due to the relatively high degree of time invariance exhibited by these labour proportions in the data. Additionally, Skilled Labour reverses its sign from the previous regressions, indicating that, for a given country, an increase in Skilled Labour as a proportion of output across time is associated with a decrease in the energy content of imports (scaled by output), *ceteris paribus*. However, this effect does not carry through to a significant, positive coefficient in the export-import ratio model.

Both Capital Stock per unit of Output and GDP per Capita have significant, positive coefficients in the exports and imports versions of the model. However, these effects appear to be of similar magnitudes, thus cancelling each other out and becoming insignificant in the export-import ratio model.

The EPI variable in the imports model appears to be the largest driver overall, suggesting that, for a given country, a 1 unit increase in EPI across time is associated with an approximately 7.7% increase in the energy content of imports, *ceteris paribus*. However, as mentioned above, these magnitudes should probably be interpreted with caution and best used simply as an indication of direction. This is also the only effect which appears to carry over into the exports-imports ratio with any significance (if only at the 10% level).

The particular importance of EPI in the imports model may be a reflection of the fact that a country's imports are likely to be more responsive to changes in regulatory policy in the short run than its exports would be. While the energy content of exports is dependent on a number of structural factors related to domestic production that may respond slowly to tightening environmental regulation, firm and consumer level import decisions in response to these same constraints may respond relatively quickly. In this way, it could be argued that the FE regression (capturing the within-country variation over time) is better able to reflect these short run, country level dynamics. In contrast, the prior, pooled OLS estimates reflect the long run relationship, which may be more responsive to the changing patterns of production and other structural issues that would have a stronger influence on exports. Additionally, the seemingly strong relationship between EPI and the energy content of imports within the FE model appears to correspond to the notion of "Carbon Leakage" as a driver of trade, at least as far as developed countries are concerned.

## Robustness to Alternative Indices

Table 5 (see appendix) shows the simple pooled OLS regression results for the remaining four indices, utilising the full range of control variables mentioned above. The small sample size available for these regressions (effectively a single year of observations with a reduced number of countries<sup>11</sup>), as well as the inability to control for time invariant, country specific unobservable factors via a fixed effects model suggests these results should be viewed with some caution. Nevertheless, a number of results appear to support the findings of the above analysis:

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<sup>11</sup> See appendix for country list by index coverage, as well as the specific years for which analysis using a particular index was performed.

For the models involving CLIMI and ESI, a negative, at least somewhat significant coefficient was found for the index variable in the exports version of the model, corresponding with the predictions of the Pollution Haven Hypothesis. However, neither of these results carried through to a significant, negative coefficient on the export-import ratio model. The ESI and ERRI models displayed significant, negative coefficients for the Unskilled Labour variable in their export-import ratio versions, again conforming to the results of the above analysis.

However, other than these ad hoc similarities, the results of the regressions involving the other four indices do not appear to provide much explanatory power with regard to the drivers of the energy content of trade, neither in support of the Pollution Haven Hypothesis nor the Factor Endowments Hypothesis. This is perhaps not surprising given the limitations mentioned above. However, the relatively high degree of correlation<sup>12</sup> exhibited between these indices and the EPI suggests that, had a broader range of comparable data been available, both across countries and time, the results may have been more similar.

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<sup>12</sup> See appendix table 6 for index correlation matrix

## V - Discussion and Conclusion

In an effort to evaluate the underlying factors driving the energy content of international trade, this paper aims to investigate the validity of two theories in particular: The Pollution Haven Hypothesis and the Factor Endowments Hypothesis. Following Dietzenbacher and Mukhopadhyay's (2007) hypothetical extension of the HOV model, a country's willingness to pollute was conceived of as a stock of "environmental permits" serving as a means with which to assess relative endowments in this regard. In pursuit of this aim, a number of regression analyses were performed to ascertain the relationship between the energy content of trade, the stringency of a country's environmental policy regime and measures of conventional factor endowments typically found in studies of this nature.

The preceding regression results provide evidence that both of these drivers are likely to play an important role in this dynamic: Using pooled OLS techniques, models suggest that an increase in regulatory stringency (as measured by increasing EPI values) is associated with a decrease in the energy content of net exports, conforming to the predictions of the Pollution Haven Hypothesis. At the same time, changes in measures of more traditional factor intensities are also found to have significant effects on the energy content of trade, often in tension with the effects of increasing environmental policy concern. As per the predictions of Copeland and Taylor (2003), the overall effects of these conflicting tendencies will depend on the relative dominance of each for the country in question.

Results from the fixed effects analysis appear to confirm the importance of the association between increasing environmental stringency and the energy content of trade, particularly with regard to its impact on imports. This effect speaks to the motivation afforded by the phenomenon of "Carbon Leakage", whereby the incentives created by increasing costs for high energy intensity production (at least as far as energy usage is associated with carbon dioxide emissions) in developed countries leads to the outsourcing of energy/carbon intensive production to developing countries with less demanding environmental regimes.

Although many of these results appear fairly robust, a number of concerns over the above analysis remain: Firstly, the only index variable truly suitable for panel analysis for a large range of countries over an extended period of time was the Environmental Performance Index. Although this index had the advantage of methodological consistency over time and a large sample of countries, the broad range of indicators used to calculate its index values means that it may not perfectly target the measurement of environmental regulatory stringency as required by the model. However, the high correlation between the EPI and other indices such as the CLIMI and ERRI, which explicitly focus on measures of regulatory policy, suggests that EPI remains an acceptable proxy. Nevertheless a richer coverage of these other indices would have been desirable.

Secondly, the data on energy intensity by industry used to calculate the energy content of trade were obtained for GTAP base year 2007. This analysis thus assumes that these energy intensities remain constant over time, with variation coming through the sectoral/industry composition of exports and imports, as well as the overall level of trade. In addition, the energy intensity of imports was calculated using the energy intensity of domestic production (i.e. the import substitution/ domestic technology assumption), rather than the energy intensities of the source countries. Although both of these assumptions are understandable given the difficulty of obtaining and calculating these measures for a broad range of countries over time, they nevertheless may represent a distortion to the "true" energy content of trade.

Lastly, even with the relatively large sample of countries matched with the EPI, there is likely to be some degree of selection bias involved in which countries appeared within the final analysis. The simple availability of data with regard to a number variables used in the investigation may have the

effect of over representing the type of industrialised, developed countries that tend to more reliably produce such data.

Even with these caveats in mind, the above analysis appears to provide some evidence that a country's environmental regulatory regime has an influence on the energy content of trade, and thus, the direction of trade in general. This conforms to predictions made under the Pollution Haven Hypothesis and the notion of "Carbon Leakage", suggesting that countries and international institutions tasked with the formulation of future trade policy may have to take these factors into consideration when balancing the dual aims of global growth and trade liberalisation on the one hand, and sustainable progress towards the mitigation of environmental harm on the other.

# Appendix

## Data and Environmental Indices

### *Energy*

Data on energy usage was obtained from the Global Trade Analysis Project (GTAP). The GTAP database is a large repository of information covering trade, structural analysis, macroeconomic, energy and emission data (amongst much else). Although data in the GTAP repository is derived from a wide variety of sources and time periods, it has been constructed in such a way as to make its contents as comparable as possible for analysis and simulation. This allows for a consistent representation of the global economy for a given base year and version of the database (Centre for Global Trade Analysis, 2015).

The data utilised in this paper derives from the GTAP 8.1 database (base year 2007), covering 129 regions and 57 economic sectors. Data were collected on country energy usage by sector (Millions of Tonnes of Oil Equivalent), as well as output by sector (Millions of Dollars – 2007 prices). The primary source of this information in the GTAP database is the International Energy Agency's (IEA) "Extended Energy Balances" dataset.

### *Trade*

Data on trade flows were collected from the OECD STAN (Structural Analysis) database, part of the wider OECD.stat repository. In particular, the Bilateral Trade by Industry and End-use dataset was used to obtain data on exports and imports by ISIC Rev.3 industry classification (Thousands of current Dollars).

### *Concordance*

A concordance between GTAP sectors and ISIC Rev.3 industries was created using documentation available on the GTAP website (Hutcheson, 2007). The particular aggregation schemes in both the GTAP and STAN databases necessitated the grouping of certain industries and sectors in order to maintain consistency. Only industries producing tradable goods were considered (ISIC industries 1-36 and GTAP sectors 1-42). See appendix for details of concordance.

### *Capital Stock, GDP per Capita and Total Factor Productivity*

Data on country level capital stock, output and GDP per capita was obtained from the Penn World Table 8.1 database (Millions of Dollars, constant 2005 prices). This database was also used to obtain a measure of total factor productivity (TFP) comparable across time and countries (with United States TFP considered the reference case)<sup>13</sup>.

### *Labour*

Labour data were collected primarily from The International Labour Organization's (ILO) ILOSTAT database. In particular, country level information was obtained on employment by occupation, categorised according to The International Standard Classification of Occupations (ISCO-88). Additionally, Nigerian labour data by occupation were constructed from The Nigeria Demographic and Health Survey (2008), while data on Indian employment by education level were obtained from India's 2011 census information.

All currency values mentioned above were rebased to constant 2007 Dollar values for further analysis. Where available, data were collected for the years 2001 to 2011.

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<sup>13</sup> See Inklaar and Timmer (2013) for calculation methodology of capital stock and TFP

### *EPI*

The Environmental Performance Index is a joint project between the Yale Center for Environmental Law & Policy (YCELP) and the Center for International Earth Science Information Network (CIESIN) at Columbia University. It is constructed through the calculation and aggregation of a number of different indicators reflecting country level environmental data. It is a broad measure, covering a wide range of policy areas from health impacts to climate and energy issues. Indicators are weighted according to which issues are deemed more pertinent to a particular country's stage of development and international obligations (Yale Center for Environmental Law & Policy; Center for International Earth Science Information Network, 2015). Data were collected from the 2014 EPI release, using "backcasted" data (i.e. methodology and criteria from the 2014 version used to recalculate earlier indices) to arrive at values for the years 2002 to 2011.

### *ESI*

The Environmental Sustainability Index is an earlier collaboration between YCELP and CIESIN aimed at measuring overall progress towards environmental sustainability. It too is based on a wide range of country level indicators, collected into the broad categories of: "Environmental Systems", "Reducing Environmental Stresses", "Reducing Human Vulnerability to Environmental Stresses", "Societal and Institutional Capacity to Respond to Environmental Challenges" and "Global Stewardship" (Yale Center for Environmental Law & Policy; Center for International Earth Science Information Network, 2015). Data was collected for the year 2001.

### *CCPI*

The Climate Change Performance Index is a project developed by the civil group Germanwatch to measure country level progress in efforts to reduce carbon dioxide emissions. Its indicators focus on the issue of climate change to a greater degree than the previous two indices and may be broken down into the following broad categories: "Emissions Level", "Development of Emissions", "Efficiency", "Renewable Energies" and "Climate Policy" (Germanwatch, 2015). Data were collected for the years 2008 to 2011. Due to concerns over methodological consistency in the calculation of this variable over time, as well as the strong trend component included within it, an average value over this period was created for use in a single year regression analysis.

### *CLIMI*

The Climate, Laws, Institutions and Measures Index was developed by the European Bank for Reconstruction and Development (EBRD) in order to directly assess country level policies and measures directed towards the mitigation of climate change, rather than merely track environmental outcomes such as carbon emissions etc. Data are based on "National Communications" to the United Nations Framework Convention on Climate Change (UNFCCC), detailing these countries' progress and plans with regard to climate change adaptation and mitigation policies over time (European Bank for Reconstruction and Development, 2011). Data were collected for the year 2011.

### *ERRI*

The Environmental Regulatory Regime Index is an index constructed by Esty and Porter in a chapter provided to the World Economic Forum's Global Competitiveness Report 2001-2002. The index is intended to provide a measure of the performance of the environmental regulatory system in a country by assessing measures of regulatory stringency, structure, subsidies and enforcement (Esty & Porter, 2002). Data were collected for the year 2002.

## ISIC Rev.3 to GTAP Concordance

ISIC Rev.3 Industry Classification	GTAP Sector
01: Agriculture, Hunting	1 to 12
02: Forestry, Logging	13
05: Fishing	14
10: Mining of coal and lignite; extraction of peat	15
11: Extraction of crude petroleum and natural gas	16 to 17
12: Mining of uranium and thorium ores	18
13: Mining of metal ores	18
14: Other mining and quarrying	18
15T16: Food products, Beverages and Tobacco	19 to 26
17: Textile	27 to 28
18: Leather	29
19: Footwear	29
20: Wood and Products of Wood and Cork	30
21T22: Pulp, Paper, Paper Products, Printing and Publishing	31
23: Coke, Refined Petroleum Products and Nuclear Fuel	32
24: Chemicals and Chemical Products	33
25: Rubber and Plastics Products	33
26: Other Non-Metallic Mineral Products	34
271T31: Iron and Steel	35
272T32: Non-Ferrous Metals	36
28: Fabricated Metal Products	37
29: Machinery and Equipment, not elsewhere classified	41
30: Office, Accounting and Computing Machinery	40
31: Electrical Machinery and Apparatus, not elsewhere classified	41
32: Radio, Television and Communication Equipment	40
33: Medical, Precision and Optical Instruments	41
34: Motor Vehicles, Trailers and Semi-Trailers	38
35: Other Transport Equipment	39
36T37: Manufacturing not elsewhere classified: Recycling	42

GTAP Description	GTAP Sector
Paddy rice	1
Wheat	2
Cereal grains	3
Vegetables, fruit, nuts	4
Oil seeds	5
Sugar cane, sugar beet	6
Plant-based fibers	7
Crops	8
Bovine cattle, sheep and goats, horses	9
Animal products	10
Raw Milk	11
Wool, silk-worm cocoons	12
Forestry	13
Fishing	14
Coal	15
Petroleum Production	16
Natural Gas Production	17
Minerals	18
Bovine meat products	19
Meat products	20
Vegetable oils and fats	21
Dairy products	22
Processed rice	23
Sugar	24
Food products	25
Beverages and tobacco products	26
Textiles	27
Wearing apparel	28
Leather products	29
Wood products	30
Paper products, publishing	31
Petroleum, coal products	32
Chemical, rubber, plastic products	33
Mineral products	34
Ferrous metals	35
Metals	36
Metal products	37
Motor vehicles and parts	38
Transport equipment	39
Electronic equipment	40
Machinery and equipment	41
Manufactures	42

## Country List by Index Coverage

Country	2002-2017					Country	2002-2017				
	EPI	ESI	CLIMI	CCPI	ERRI		EPI	ESI	CLIMI	CCPI	ERRI
Argentina						Kazakhstan					
Australia						Kenya					
Austria						Kuwait					
Bangladesh						Luxembourg					
Belgium						Madagascar					
Benin						Malawi					
Bolivia						Mauritius					
Botswana						Mexico					
Brazil						Morocco					
Burkina Faso						Mozambique					
Cambodia						Namibia					
Cameroon						Netherlands					
Canada						New Zealand					
Central African Republic						Nicaragua					
Chile						Nigeria					
China						Norway					
Colombia						Panama					
Costa Rica						Paraguay					
Cyprus						Peru					
Czech Republic						Poland					
Denmark						Portugal					
Ecuador						Russia					
Egypt						Rwanda					
El Salvador						Senegal					
Ethiopia						Slovakia					
Finland						Slovenia					
France						South Africa					
Georgia						South Korea					
Germany						Spain					
Ghana						Sweden					
Greece						Switzerland					
Guatemala						Tanzania					
Guinea						Togo					
Honduras						Tunisia					
Hungary						Turkey					
India						Uganda					
Indonesia						United Kingdom					
Iran						United States					
Ireland						Uruguay					
Israel						Venezuela					
Italy						Zambia					
Ivory Coast						Zimbabwe					
Japan						Total	85	83	52	41	54

The presence of a coloured block indicates that a particular index covers the corresponding country. The numbers appearing above the index names indicate the period/year for which analysis was performed using the respective indices.

Charts 4 to 6 – Energy Content of Trade by Country

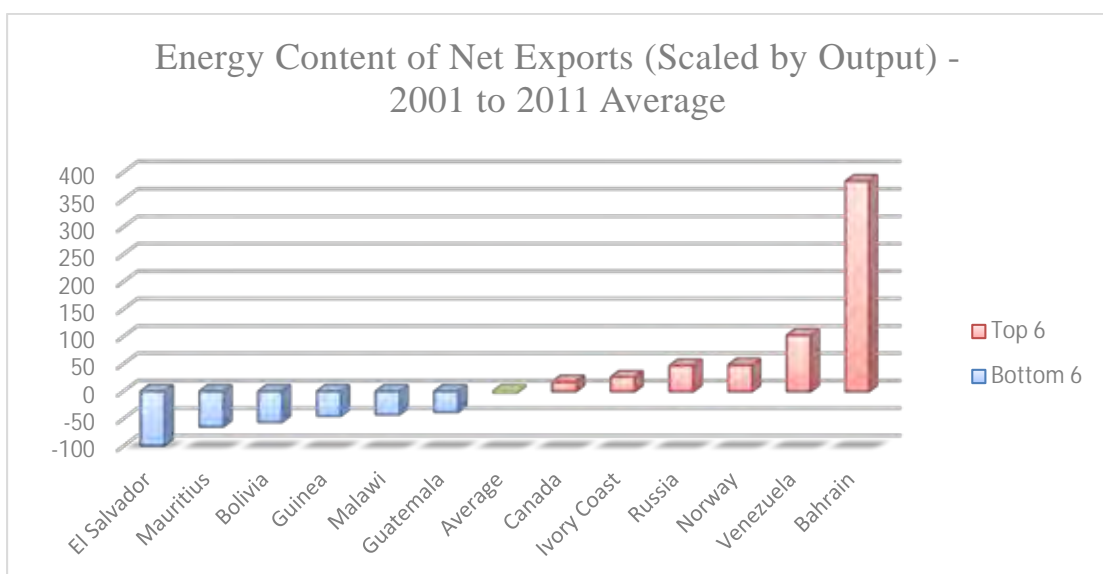
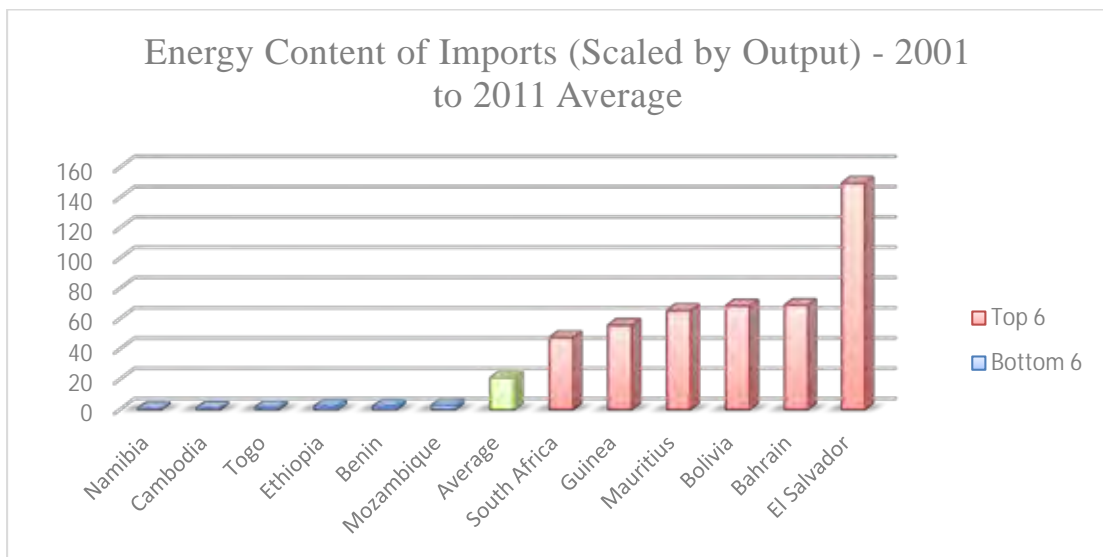
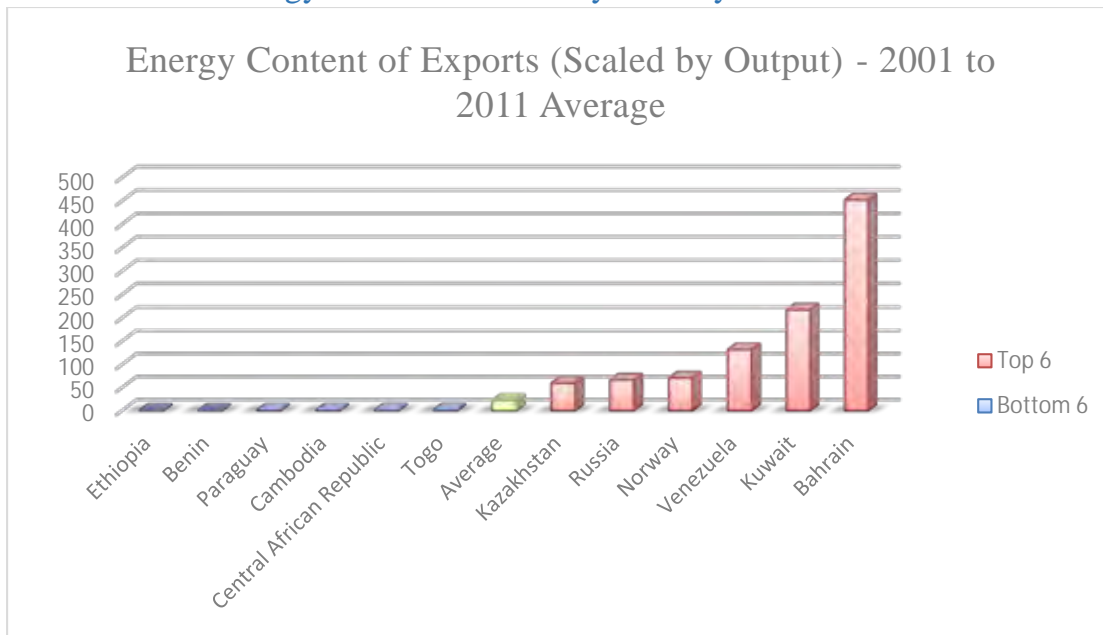


Table 5 – ERRI, CLIMI, CCPI and ESI Regression Results

	ERRI			CLIMI			CCPI			ESI		
	~X/Y	~M/Y	~X/M	~X/Y	~M/Y	~X/M	~X/Y	~M/Y	~X/M	~X/Y	~M/Y	~X/M
~Skilled Labour/Y	0.512 (0.676)	0.031 (0.455)	0.481 (0.425)	0.299* (0.167)	0.034 (0.212)	0.209 (0.141)	1.478* (0.761)	0.564 (0.642)	0.447 (0.629)	0.365 (0.455)	0.350 (0.253)	0.321 (0.276)
~Unskilled Labour/Y	-1.526** (0.711)	-0.140 (0.372)	-1.386** (0.552)	-0.544* (0.295)	-0.669* (0.378)	0.105 (0.298)	-0.368 (0.844)	-0.286 (0.585)	-0.242 (0.556)	-0.887 (0.579)	0.093 (0.520)	-1.269** (0.477)
~Capital/Y	-0.356 (0.651)	-0.440 (0.424)	0.084 (0.448)	-0.392 (0.877)	-0.837 (0.721)	0.423 (0.338)	-1.376 (0.962)	-1.317* (0.714)	-0.322 (0.856)	-0.227 (0.526)	-0.673** (0.333)	0.259 (0.309)
TFP	-2.960* (1.743)	-0.997 (1.532)	-1.963 (1.384)	-1.322 (1.795)	-1.932 (1.488)	0.664 (0.877)	-0.530 (2.542)	-1.332 (1.874)	-0.050 (1.631)	-2.262* (1.183)	-1.314 (0.891)	-1.137 (0.905)
~GDP/Capita	-0.987 (0.924)	-0.613 (0.529)	-0.374 (0.574)	0.472 (0.489)	-0.180 (0.458)	0.574* (0.306)	0.204 (0.763)	-0.005 (0.523)	0.235 (0.499)	0.365 (0.603)	0.510 (0.593)	-0.403 (0.510)
Index	0.141 (0.299)	-0.104 (0.171)	0.245 (0.219)	-2.593** (0.981)	-1.282* (0.639)	-0.967 (0.706)	-0.009 (0.019)	-0.008 (0.013)	0.010 (0.016)	-0.038* (0.022)	-0.019 (0.013)	0.004 (0.012)
Constant	18.455* (9.431)	10.789** (4.916)	7.666 (6.198)	1.723 (3.969)	9.496* (4.832)	-7.081* (3.639)	1.471 (10.625)	5.681 (7.641)	-2.890 (6.578)	4.170 (6.819)	-1.168 (6.942)	7.030 (5.833)
R-squared	0.102	0.464	0.313	0.133	0.122	0.445	0.124	0.106	0.092	0.160	-0.008	0.347
N	49	49	49	46	45	45	40	39	39	59	57	57

Standard Errors in parentheses

\*\*\* p<0.01 \*\* p<0.05 \* p<0.10

Table 6 – Index Correlation Matrix

	<i>EPI</i>	<i>ESI</i>	<i>CCPI</i>	<i>CLIMI</i>	<i>ERRI</i>
<i>EPI</i>	1				
<i>ESI</i>	0.70394	1			
<i>CCPI</i>	0.770118	0.527995	1		
<i>CLIMI</i>	0.723698	0.697412	0.415632	1	
<i>ERRI</i>	0.806798	0.70194	0.643976	0.654421	1

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