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# Trade Patterns and the Ecological Footprint – a theory-based Empirical Approach

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## **Abstract**

With global specialization and trade, countries make directly but also indirectly use of the environment via traded goods. Based on the theory of comparative advantages, the Heckscher-Ohlin-Vanek approach, we are using the Ecological Footprint as a broad measure of environmental use because its methodology explicitly accounts for the environmental use embodied in the traded goods. The comparative advantages depend on the endowment of environment as well as on the stringency of environmental policy which regulate the access to these factors. We empirically analyse the determinants of the ecological side of the trade pattern, i.e. whether the net export of the Ecological Footprint, embodied in the traded goods, depends on the comparative advantages as predicted by the theory, but also on a couple of control variables. A special focus is put on the role of environmental policy stringency which links our analysis to the “Pollution Haven” hypothesis. We also briefly analyse the role of FDI flows for the emergence of the ecological specialization pattern of production and trade.

**Keywords:** Trade; comparative advantage; Ecological Footprint; environmental policy; Pollution Haven; FDI

**JEL Classification:** F18, F14, F11, Q57, Q56

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## 1 Introduction

Nearly each form of production and consumption makes use of the natural environment in different forms. With the focus on the production of goods we interpret the “environmental services” (delivering resources, occupying land, absorption of various sorts of pollution etc.) as an input factor such like capital or labor. However, labor and capital are private goods which have to be purchased on factor markets while the natural environment is typically an Allmende good. The costs of these environmental services are therefore the costs associated with the appropriation of the environment, but also the costs associated with environmental policy regulations (see Rauscher (2005)). The latter comprise different sorts of environmental taxes, costs of purchasing pollution rights, and legal obligations to adopt more expensive but ecologically more efficient technologies. The further sort of costs are related to the amount and availability of environmental services which will be called “biocapacity”.

When countries specialize in the production of particular goods, the pattern of specialization could (partially) be explained by comparative cost advantages. One source of comparative advantages is the endowment or access to input factors. As the neoclassical theory of trade (Heckscher-Ohlin-Vanek, hereafter: HOV) predicts, countries will specialize in the production of goods which use the relatively abundant factor intensively. To test this hypothesis, Leamer (1980) shows that in case of capital abundant countries, the capital intensity in production will be higher than the capital intensity in consumption. This means that such a country is a net exporter of capital *embodied* in the traded goods. Applied to the question which country will specialize on goods which make intensively use from environmental services, we should expect that countries with a larger environmental endowment (biocapacity) and a less strict or not strictly enforced environmental policy have a comparative advantage for pollution-intensive goods. Thus we should expect that they become net exporters of environment embodied in the traded goods. This idea is closely related to, but not identical with the “Pollution Haven” hypothesis (PHH) which claims that countries with a weak environmental policy attract pollution-intensive industries which should result in larger FDI inflows to these sectors and a higher pollution level.

One main problem of empirically investigating the pattern of specialization and trade with respect to the use of environment is that we need data of environmental use in production and in consumption, or alternatively the environmental services embodied in exported and imported goods. In this study we use the Ecological Footprint (EF) as a very broad measure of environmental use. The methodology of this measure is based already on the distinction between production and consumption and is therefore an ideal measure for this purpose. The fact that the EF statistics do not reveal the

particular trade flows among regions is not a shortcoming for our analysis because we are mainly interested in the amount and especially the sign of the net exports of the EF, not in regional trade flows.

One important critique against globalization is that it enables consumers especially in rich countries to externalize ecological damages by “outsourcing” dirty productions to other (poor) countries and to re-import the final or intermediate goods. Thus, ecologically unequal trade allows the “greening” of net importing countries to the expense of net exporting countries which have to carry the environmental burden. International specialization and trade is thus seen as one driver of ecological deprivation. This anti-trade bias in the Ecological Footprint literature has been criticized by Van den Bergh and Verbruggen (1999) and Van den Bergh and Grazi (2014). However, independent from the fact that the global level of environmental use is too high and not sustainable – as it is pronounced by the concept of the EF – it would be ecologically efficient to make more use of environment in regions where environment is more abundant and to reduce pollution-intensive production in regions with a low biocapacity.

Beside testing the prediction of the HOV approach which relates EF embodied in net exports to the biocapacity and the strength and enforcement of environmental policy, we also consider the influence of other important variables such like GDP per capita and eco-productivity of production and consumption as explanatory variables. In order to understand the mechanisms which drive specialization patterns it is also useful to account for FDI flows because capital flows might contribute to the emergence of the particular pattern of specialization.

Our approach considers the environment *embodied* in traded goods, not pollution intensities or levels. By doing so, we are using the Ecological Footprint dataset in a novel manner. In contrast to other empirical studies based on the same indicator, we are not interested in absolute levels and therefore not interested in its interpretation as a sustainability measure. We are only using the *net exports* of the EF. Our findings shed light on the issue which countries are more likely to become net exporters of environment, whether global specialization is harmful for ecological efficiency, and which role environmental policy and its enforcement as well as FDI flows play in this context.

The paper is structured as follows: chapter 2 discusses the theoretical background regarding the comparative advantages as a driver of specialization and trade, and it reviews the literature on the Pollution Haven hypothesis which is one element of the comparative advantages. Chapter 3 describes data and methodology with a focus on description of the Ecological Footprint data and their use in our analysis. Based on the theoretical considerations, the main hypotheses are formulated which will be tested. Chapter 4 summarizes the results of various panel regressions and chapter 5 concludes.

## 2 Comparative advantages, specialization and the environment

### 2.1 Theoretical background

The theory of comparative advantage posits that trade is beneficial for both partners by enabling each to specialize in goods which can be produced at lower opportunity costs. According to the neoclassical approach, comparative price advantage results from relative factor abundance. If a country has a relatively abundant factor of production, the factor price will be cheaper as compared to those with scarce endowment (Deardorff and Staiger (1988)). The HOV model of international trade states that a country will specialize in the production and exports of goods which use its abundant factor intensively (Vanek (1968)). To test this hypothesis empirically, Leontief (1953) used input-output analysis to compare capital and labor intensity of exported and imported commodities in the US. Leontief surprisingly concluded that the US had labor surplus and capital scarcity. This was apparently opposed to the conventional view that the American economy is featured as having a comparative surplus of capital and a relative scarcity of labor. To resolve the so-called Leontief Paradox, Leamer (1980) pointed out that it is inappropriate to compare capital and labor intensity of traded products but the factor content embodied in produced and consumed bundle of goods should be compared. Leamer showed that the capital intensity in production is higher than the capital intensity in consumption in the US and the reverse holds for labor which is in line with the predictions of the HOV model.

The production process also utilizes the environment, either by directly using natural capital as an input factor, or by using the assimilation capabilities for various emissions (see Rauscher (2005)). However, environment is an Allmende good. Unlike capital and labor in the HOV model there are typically no “markets” for purchasing environmental services. Nevertheless, it is reasonable to assume that the cost of appropriation of the environment depends on the abundance of the biocapacity. Additionally, the access to these Allmende goods is regulated by environmental policy which either forces producers to use more expensive technologies or to pay for emissions. A more stringent policy makes the appropriation of environmental resources and emission of pollutants become relatively more expensive (see Chichilnisky et al. (1993)). Therefore, countries with abundant biocapacity and/or a lax environmental policy have comparative advantage in environmentally intensive produced goods.

A specialization pattern in line with the predictions of the HOV model has some implications regarding the allocative efficiency also for the environment. For input factors which are purchased on competitive markets the HOV model predicts an equalization

of marginal productivities (and henceforth factor prices) across the countries which improves allocative efficiency. In case of the environment (Allmende good) things are different because there are no competitive markets and therefore no adjustment of factor prices to marginal productivity. Another important difference to labor and capital is that the environment can be “overexploited” which means that the use of the environment is not limited by the biocapacity as the country could also “live from its substance” and also impose global externalities. Nevertheless we can consider a marginal productivity of the environment in the sense that increasing use also increases the marginal pressure on the absorptive capacities and stability of the ecosystems. Allocative efficiency is then improved if the same bundle of goods can be produced with less pressure on the environment, or in other words, if the marginal environmental impact is equalized across countries.

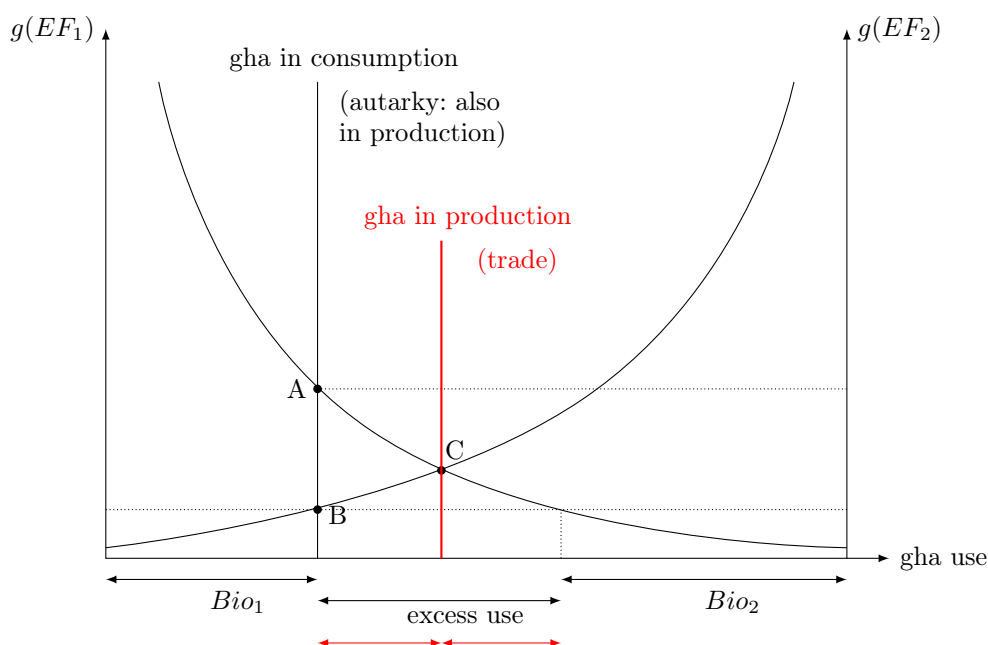


Figure 1: Efficient use of environment by specialization

This is illustrated in figure 1: consider two countries (country 1: left-side origin, country 2: right-side origin). The marginal impact on the environment is characterized by an increasing function of the Ecological Footprint,  $g(EF)$ . The  $EF$  is defined by the relation of the global hectares ( $gha$ ) in use in relation to the biocapacity (for details see section 3.1). A footprint  $EF > 1$  means that a country overexploits its biocapacity. The biocapacities might differ but the marginal impact is considered to be the same if the  $EF$  is identical. With a given technology the  $EF$  increases with the GDP. Assume that country 1 has a relatively low GDP and  $EF = 1$  while country 2 has a high GDP and (thus) exceeding its biocapacity. In autarky, the produced and consumed bundle of goods is identical within each country, implying an identical  $EF$  in production

and consumption. The corresponding marginal environmental effects are depicted by the points A and B. Consider a re-arrangement of the production pattern such that environment-intensive production partially moves from country 2 to country 1 but keeping everything else constant (*ceteris paribus*). This means that the environmental use embodied in the consumed bundle of goods is the same as before but the *EF* of production changes. In point C, country 2 would be an importer of environment embodied in the traded goods while country 1 has become an exporter of environment, now also exceeding its biocapacity. However, the marginal pressure on the environment has been equalized and the efficiency gains (reduction of total pressure) is given by the triangle ABC. Empirically such a situation occurs if country 2 either has a relatively low biocapacity and/or a relatively high GDP (see the hypotheses in section 3.2).

This analysis has of course (at least) two limitations: first, the impact on the environment is seen as a local or regional phenomenon. If, instead, every use of the environment is a global externality then there is no re-allocation of environmental use because each production, irrespective of its location, uses the same global biocapacity. But as long as at least some of environmental damages are not global externalities it makes sense to think about allocative efficiency. Second, specialization and trade might improve allocative efficiency also for the environmental use but on the other hand it typically leads to an increased total production which is *ceteris paribus* harmful for the environment. As long as the globalization process is in line with the theory of comparative advantages we have thus to consider ambiguous effects on the environment.

## 2.2 The Pollution Haven Hypothesis

The global economic structure has changed drastically during last few decades, with the trend to shift manufacturing industries from developed countries to developing countries (Han and Chatterjee (1997), Reinert et al. (2009)). There are several reasons for the structural change, such as technological progress, economic reforms and industrialization in East Asia with some emerging economies like China and India. Another reason could be attributed to the so-called pollution haven hypothesis which posits that trade liberalization induces a migration of pollution-intensive industries from countries with stringent environmental regulation to loosely regulated countries. In many forms of the PHH, nations with weak environmental policies have low-income level, therefore, the poor become *pollution havens* because of a high concentration on industrial pollution. The intuition is that a tightening up of pollution regulation reduces international competitiveness in manufacturing sectors which are pollution-intensive in their production.



The argument that stringency of environmental regulation could affect comparative advantages, thus changing international trade patterns has substantial theoretical support. Pethig (1976) created the first, simplest pollution haven model based on a two-country model, which are identical except for exogenous differences in pollution taxes. Pethig showed that a country with less stringent law will specialize in *dirty* goods and a country with stricter regulation will specialize in *clean* goods. Copeland and Taylor (1994) constructed the first pollution haven model with endogenous environmental regulation such that it relies on income level. They argued that income induced from trade creates demand for better environmental quality and the governments are responsive to impose more stringent environmental regulation. Based on the assumption that variations in environmental costs are the only incentive for trade, the poor will specialize in the production and export of pollution-intensive goods and become pollution havens.

While the PHH has obtained considerable support from theoretical work, it has mostly failed to find significant support from empirical literature. A growing body of empirical work has attempted to test the effect of environmental regulation on trade flows. Early studies like Tobey (1990) and Grossman and Krueger (1991), evaluated the relationship between pollution regulation and the US net exports based on the HOV model in which factor endowment is a source of comparative advantages. Pollution abatement cost (PAC) recorded by the US firms is used as a proxy for the stringency of environmental regulation. Using cross-nation and cross-sector dataset, their findings reveal that environmental policy has no statistically significant effect on the US trade flows.

The lack of empirical evidence of the PHH can be explained by several reasons. First, environmental compliance costs are a small component of total production costs. In particular, Tobey (1990) showed that the environmental costs account for only 2 - 3% of production costs, even in the most pollution-intensive industries. Second, endogeneity of environmental regulations and heterogeneity in correlation between environmental policy and trade, investment flows have been omitted in previous research. Ederington et al. (2005) tested the effect of PAC on net imports of the US manufacturing sectors. They showed that the average effect of environmental regulation on the US net imports over all industries is insignificant. However, when considering industry characteristics, they found evidence that a rise in PAC is strongly correlated with increased net imports in *footloose* industries which are relatively mobile.

Levinson and Taylor (2008) developed both theoretical and empirical models with endogenous environmental regulation to examine the impacts of environmental policy on the US trade flows with Mexico and Canada. By using a set of instrumental variables for PAC based on geographic diffusion of industries across the US states, they found a significant positive correlation between environmental regulation and net imports

which lends support for the PHH. Particularly, an increase in 1% of PAC leads to a rise in 2% net import from Mexico and 4% increase in net import from Canada.

Considerable empirical literature have focused on investment flows, measured by FDI, to find support for the PHH. Eskeland and Harrison (2003) attempted to answer a question of whether FDI outflows from strictly regulated countries to those with weak environmental regulation. The result shows no robust correlation between investment in developing economies and PAC in developed economies. When PAC is replaced by different measures of pollution, they found that FDI is highly concentrated in industries that generate air pollution intensively. On the contrary, in case of water pollution and toxicity, FDI concentrates less in manufacturing sectors which produce high emissions.

Xing and Kolstad (2002) examined the relationship between FDI outflows of the US manufacturing industries and environmental regulation in foreign host countries. They developed a model that discloses the looseness of environmental regulations and relates it to pollution measured by  $SO_2$  emission. Using population density and infant mortality rate as instrument variables, they argued that these exogenous variables represent the extent to which pollution is dispersing among populations and the social consciousness in a nation. Their empirical results show that an increase in  $SO_2$  emission induced from weakening environmental regulation is strongly associated with FDI outflow from US chemical multinational firms (MNFs) but the lenience of pollution regulation is not a significant factor of FDI flows in less polluting manufacturing sectors.

Two recent papers present evidence of environmental policy affecting different types of FDI. Rezza (2013) evaluated the impact of environmental regulatory stringency and its enforcement in host countries on FDI outflows from Norway. They categorized investment into vertical and horizontal FDI. The result shows a negative relationship between vertical FDI and environmental stringency in host countries but horizontal FDI is not affected by local regulation. They explained that vertical FDI is more sensitive to environmental costs because MNFs always have an alternative of choosing other locations.

Tang (2015) investigated how different types of the US outward FDI, export-oriented and local-market oriented, respond to changes in environmental policy in host countries. Their findings indicate that environmental regulation has a statistically significant effect on both types of FDI but MNFs with export-oriented FDI is more sensitive to adjustment in pollution regulations than those with local-market-oriented FDI. They additionally presented that FDI in host nations is not only influenced by local pollution regulation but also affected by environmental policies in other nearby countries.

Several papers have investigated the effect of environmental regulation on location decision of plants. Manderson and Kneller (2012) added to the literature by explicitly

considering firm heterogeneity which has been ignored in previous literature. By using cross-sectional data of UK manufacturing firms, their result suggests that UK MNEs in *dirty* industries are not more likely to establish foreign affiliates than those in *clean* industries. They additionally showed that MNEs with high environmental costs do not have larger probability to locate subsidiaries in foreign host nations with less stringent environmental regulation than MNEs with low environmental compliance costs. These findings are, to some extent, consistent with the result of Raspiller and Riedinger (2008) who, using French firms' data, explored that environmental regulation is not an important determinant of location decision of French firms.

Other studies are using the Environmental Policy Stringency (EPS) variable to explore the pollution haven effect. Sauvage (2014) employed EPS to estimate the effect of environmental regulations on trade patterns in environmental goods such as solar water heaters and wind turbines. The empirical evidence indicates that there is a significantly positive effect of a country's regulatory stringency on its exports of environmental products. Therefore, strictly regulated countries will specialize in the production and exports of environmental goods. The finding proposes that trade might not be as ecologically harmful as often presumed or there might be congruity between trade and environmental goals. Koźluk and Timiliotis (2016) investigated the effect of EPS on bilateral trade patterns. The study employs a gravity model for manufacturing sectors in 23 OECD and BRIICS from 1990 to 2009. The finding reveals that the differences in EPS between trading nations rather than their actual levels of EPS determine the patterns of specialization. Particularly, a tightening of environmental regulation enables countries to gain competitiveness in *clean* industries while loosely regulated economies gain comparative advantage in *dirty* industries. The additional result is that regulatory stringency of a country is positively correlated with its imports of pollution-intensive goods which lends support for the PHH.

To sum up, previous work has studied the PHH by estimating the impact of environmental regulation on trade flows, investment flows and firm location. These studies have encountered mixed results. This paper provides a new approach to test the PHH. We contribute to the literature by testing how environmental stringency and its enforcement change environmental use embodied in international trade, measured by the ecological footprint.

## 3 Data and methodology

### 3.1 The Ecological Footprint

Several concepts and measures have been applied to assess the environmental effects of globalised trade. These are composed of ecological footprint, carbon footprint (e.g., Wackernagel and Rees (1996), Jorgenson (2005), Hertwich and Peters (2009)), energy-related concepts (e.g., Cortés-Borda et al. (2015)) and material flow accounting and analysis (e.g., Giljum and Eisenmenger (2004), Fischer-Kowalski et al. (2011)). The most widely adopted measure is the first indicator which is also used in this paper.

The concept of EF was originally developed by Wackernagel and Rees (1996) to convert the ecological impacts of all human activities on the global ecosystem into an equivalent indicator of land. The Ecological Footprint is defined as the aggregate area of productive land (and aquatic ecosystems) needed to produce the resources used, and to assimilate the wastes generated, by a defined population, wherever on Earth that land is located (Wackernagel and Rees (1996), pp.51-52). Since this accounting tool assesses the overall amount of productive land use and waste absorption needed to satisfy human's consumption, it has an advantage of quantifying environmental pressures of consumption no matter where environmental services come from (York et al. (2003)). In other words, it calculates how much environment a given population *consumes*. The EF is generally measured in unit of global hectare. Global hectare is a unit of the world average biologically productive area in a given year. The EF is also presented in global hectare per capita which refers to the total bioproductive land and water available per person on the Earth. Since the first publication of the EF in 1996, its methodology has been improved and developed over time with various methods such as compound-based approach (Simmons et al. (2000), Kuzyk (2012)), component-based approach (Barrett (2001)) and input-output analysis (Wiedmann et al. (2006), Ferng (2009)). The standard method employed by the *Global Footprint Network* is the compound-based approach which uses aggregate indicators including production, consumption, imports and exports of goods and services. The calculation of footprint employs *equivalence factors* to account for variations in global average productivity among various types of land and *yield factors* to account for variations in biological productivity among nations (see recent method of the EF in Borucke et al. (2013)). The Ecological Footprint has been broadly used as a measure of environmental sustainability in many studies (e.g., Wackernagel et al. (1999), Stöglehner (2003)). A comparison of EF with biological capacity at a global level reveals that land requirement for a population surpasses land availability to that population, thus making the Earth unsustainable for future generations if they wish to live as we do now. This situation is known as ecological deficit. In case of overshooting, a country must either deplete its own envi-

ronmental resources or import biological capacity from foreign countries. The National Footprint Accounts 2016 show that the world’s EF in 2012 is 20.1 billion hectares (ha) as compared with 12.2 billion ha of the Earth’s biocapacity. The world’s average EF is 2.8 global hectares per capita (gha) as compared to only 1.7 gha of available biological capacity per capita. This means that we are currently using 1.6 Earths.

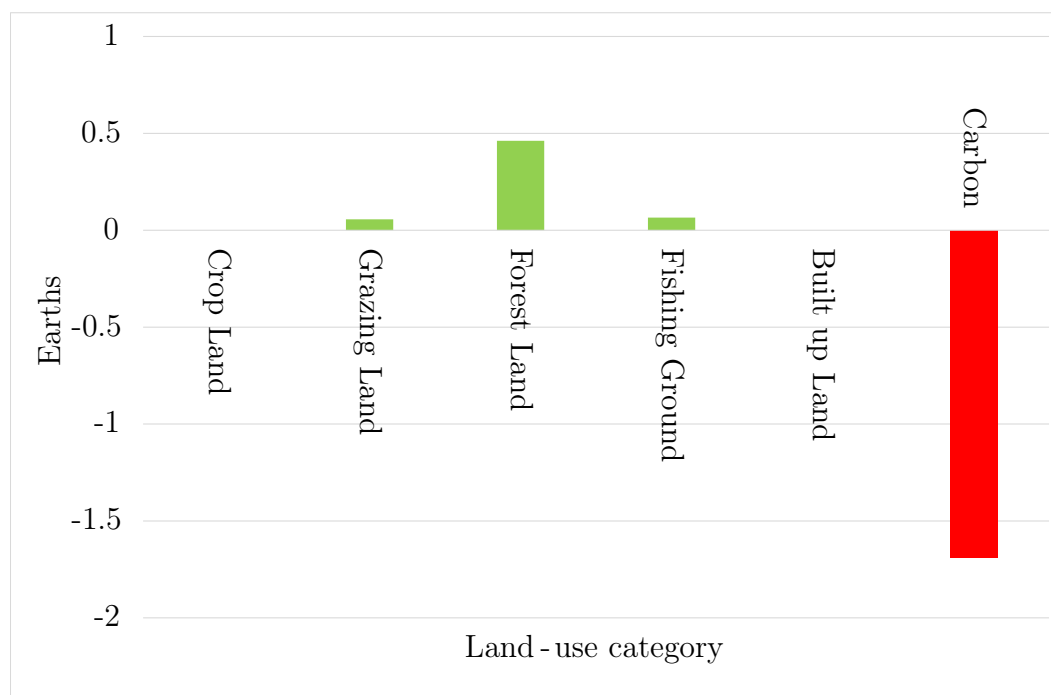


Figure 2: Differences in average ecological footprint and biocapacity by category in 2012.

For cropland and built-up land, the available biological capacity equals their footprints at a global level. The situation, however, is different for grazing land, forest land and fishing ground. The global biocapacity of such components exceeds their footprints. Therefore, the ecological deficit is only a result of carbon footprint (see figure 2).

Despite its popularity, the EF method has been intensively criticized due to a number of limitations of both conceptual and methodological aspects, remarkably Van den Bergh and Verbruggen (1999), Moffatt (2000), Jorgensen et al. (2002), Van den Bergh and Grazi (2014). Van den Bergh and Verbruggen (1999) argued that several inputs to the EF have the same weights in spite of their distinct environmental impacts. For example, EF land use for housing and transportation have the same weight even though environmental impact generated by transportation is greater than that of housing. Costanza (2000) and Moffatt (2000) further claimed that the EF is a static aggregated measure. This implies an omission in the role of technological progress which can improve the efficiency of resource use and lower ecological degradation by applying environmentally friendly (*green*) technology. Furthermore, the concept of EF is criticized for

its insufficiency in reflecting the ecological impacts of all human activities because it does not consider the appropriation of non-renewable resource, soil (land) degeneration (see Moffatt (2000)) and pollutants other than carbon dioxide such as nitrous oxide, methane and sulphur which have huge environmental consequences (Ayres (2000)). Lin et al. (2015) contended that only natural resources and pollutants which can be quantified with regard to bio-productive surfaces are added to the EF. The overlook of different environmental burdens leads the EF to underestimate the actual aggregate environmental impacts. Moreover, much criticism has emphasised on carbon footprint which is the major component of the EF in most nations. Critics argue that there are other solutions which are less land-intensive to assimilate carbon emission than forestation such as improving energy efficiency and switching from fossil fuels to other energy sources (Van den Bergh and Verbruggen (1999)). The EF in fact tells us nothing more than unsustainable carbon emissions which greatly exceeds the regenerative capacity of the atmosphere.

Notably, Van den Bergh and Verbruggen (1999), Van den Bergh and Grazi (2014) pointed out that the EF approach has an *anti-trade bias*. A direct comparison between national consumption (measured by the EF) and ecological capacity available within the boundary of a country indirectly implies a preference for autarkic system. The EF concept seems to suggest that global sustainability is declining because trade encourages regions to over-exploit their environmental resources (Andersson and Lindroth (2001)). This is reflected in normative attributions like “ecologically unbalanced trade” (e.g., Jorgenson et al. (2009), Moran et al. (2013)), suggesting that the greening of production in the rich countries is possible by shifting the ecological burden to the less developed countries (see also Hertwich and Peters (2009) for the case of carbon dioxide emission). However, without trade, densely populated countries like Japan, Singapore, or Europe will have the EF above their own biocapacity, thus imposing huge pressures on the environment when they have to entirely depend on their national environmental resources. On the other hand, big countries with low population density like Canada will have the EF much below their biological capacity. Since ecological resources are unevenly distributed over space, there are environmentally comparative advantages which induce gains from allocative efficiency if specialization and trade make use from these comparative advantages. International trade and specialization can spatially re-allocate the environmental burdens among ecosystems (Van den Bergh and Verbruggen (1999)). In this paper, we support the view that specialization and trade, especially the “ecologically unequal” one, could improve the efficiency of environmental use.

## 3.2 Hypotheses

As argued in the previous sections, the efficiency of global environmental use could be improved if the ecological side of specialization pattern would be consistent with the prediction of the HOV model. The latter can be tested by analysing the relationship between biocapacity per capita as a measure of relative abundance of environment and the net export of ecological footprint.

**Hypothesis 1:** *Net export of ecological footprint increases with higher relative abundance of the environment (biocapacity per capita).*

As discussed above, a strict environmental policy leads to higher costs for appropriating natural resources and emitting pollutants. Assumed that the difference in environmental regulation across nations affect the relative cost of appropriating the environment, firms in strictly regulated countries will migrate polluting industries to countries with less stringent policy to exploit low environmental costs. Consequently, the footprint embodied in produced goods is decreasing. At the same time, they import environmental resources for domestic consumption which leads to increased consumption footprint. Therefore, we should expect the ecological footprint of consumption exceeds that of production in case of having strict environmental policy.

**Hypothesis 2:** *Net export of ecological footprint increases with less stringent environmental policy.*

The Environmental Kuznets Curve proposes that economic growth is initially harmful for the environment but after income increases to a certain level, the environmental quality starts to improve. The explanation is that at the primary stage of development, countries give high priority to the economic growth, so they lower environmental standards in order to attract investment and capital in affected industries even if it is damaging the environment (Kearsley and Riddel (2010)). As income is improved, inhabitants in high-income countries demand for better ecological quality (or give priority to the environmental protection), so they will tighten the law to protect the environment even if it might obstacle economic development. Moran et al. (2013) found that high-income nations have more ecologically intensive imports than low-income countries. Also Peters et al. (2011) argued that less emission-intensive production in the rich economies partially depends on the indirect use of the environment in poor countries via trade.

**Hypothesis 3:** *Rich countries are more likely to become net importers of ecological footprint.*

In response to a tightening of environmental policy, countries can either migrate polluting industries to weakly regulated economies or apply advanced technology and

innovation for better resource utilization and lower pollution generation. Technological progress can be represented by high eco-productivity of production which leads to lower footprint of production. At the same time, environmental regulation could also correlate with a change of consumption patterns. Consumers in prosperous countries demand for stricter pollution policy because of environmental preferences. This change in consumption patterns reduces the environmental pressures embodied in consumed goods. Therefore, countries with greener consumption tend to become net exporters of environmental use. If such a nexus exists it would partially countervail the argument that consumers in the rich and highly regulated countries are just living at the expense of the environment of the poor countries.

**Hypothesis 4:** *Net export of ecological footprint decreases with the greener production and increases with the greener consumption.*

The pattern of specialization emerges by re-allocation of production factors towards the sectors with the comparative advantage. The resource allocation process also includes FDI flows. If FDI plays a role for the ecological aspects of specialization and trade then we should expect – in line with the PHH – that those countries which are (or become) net exporters of the EF attract FDI because of abundance of environment and/or because of lax environmental policy regulations. For EF net importing countries, however, the net inflow of FDI will be driven by other factors. Biocapacity and environmental policy should not play a significant role there.

**Hypothesis 5:** *The higher the biocapacity per capita and the less stringent the environmental policy, the higher is the net FDI inflow in case of EF net exporting countries.*

### 3.3 Econometric model

The econometric model is based on the HOV approach:

$$NetExEF_{it} = \beta_0 + \beta_1 \cdot EPSCPI_{it} + \beta_2 \cdot Biocapacity_{it} + \alpha \cdot X_{it} + u_i + \theta_t + \varepsilon_{it} \quad (1)$$

where  $i$  indicates the country and  $t$  indicates the year.  $NetExEF$  is the net export of ecological footprint per capita,  $EPSCPI$  denotes the environmental policy and its stringency (see table 6 in the Appendix for details),  $Biocapacity$  denotes biological capacity per capita,  $X$  is a vector of control variables which includes *GDP per capita* and either *eco-productivity of production* or *eco-productivity of consumption*,  $u$  is a country fixed-effect,  $\theta$  is a time fixed-effect, and  $\varepsilon$  is an error term. First, we estimate a simplified econometric model which excludes control variables. Then, we include such variables to examine other determinants of the EF net export. A significantly negative coefficient of  $\beta_1$  and positive coefficient of  $\beta_2$  will provide evidence to support the



pollution haven hypothesis which is also consistent with the prediction of the HOV theorem. We show how the simplified-form estimating equation links net export of the EF to access to the environment.

Later, we use a similar econometric model to examine which factors make a country become a net exporter of carbon footprint:

$$NetExCF_{it} = \beta_0 + \beta_1 \cdot EPSCPI_{it} + \alpha \cdot X_{it} + u_i + \theta_t + \varepsilon_{it} \quad (2)$$

in which *NetExCF* denotes the net export of carbon footprint; *X* is a vector of control variables which include *GDP per capita* and either *eco-productivity of production* or *eco-productivity of consumption* in which environmental impact is measured by carbon footprint; other factors have the same meaning as denoted in equation 1. We exclude biocapacity variable because carbon dioxide can unlimitedly emit to the air without being constrained by regionally available productive land.

The regression model used in order to show the impact of certain economic variables on international investment behaviour is as follows:

$$\frac{FDI_{it}}{GDP_{it}} = \beta_0 + \beta_1 \cdot EPSCPI_{it} + \beta_2 \cdot Biocapacity_{it} + \alpha \cdot X_{it} + u_i + \theta_t + \varepsilon_{it} \quad (3)$$

where the dependent variable is the share of a country's net inward FDI over its GDP; *X* is a vector of control variables including GDP per capita, Openness to trade and the amount of accumulated inward FDI stock to check for agglomeration effects; other factors have the same meaning as denoted in equation 1.

### 3.4 Data description

The dataset used in this paper is balanced panel data of 32 countries (26 selected OECD and 6 non-OECD countries or BRIICs) over a period of 1996-2012. They are among the top 40 countries with the largest share of trade volume which account for 75% of global trade. The set of nations and the period are limited by the measure of environmental policy stringency in which the data is only available for OECD and some emerging economies. The list of countries is shown in table 5 in the Appendix.

#### 3.4.1 Dependent variables

The dependent variables in equation 1 and 2 are net export of ecological footprint and net export of carbon footprint per capita from 1996 to 2012, respectively. The net export of footprint is measured by the difference between production footprint and consumption footprint. The Global Footprint Network has developed National Footprint

Accounts (NFAs) to provide detailed accounting of annual ecological footprint, biological carrying capacity, total exported and imported EF of more than 150 countries over a period of 1961-2012.

A further dependent variable is the share of a country's net inward FDI over its GDP. Some studies like Eskeland and Harrison (2003), Kellenberg (2009) and Tang (2015) used data on investment behaviour from the US to find evidence on how several environmental policy measures influence the investment behaviour while Poelhekke and van der Ploeg (2010), Poelhekke and van der Ploeg (2013) used a unique dataset from the Dutch Central Bank on foreign affiliate sales from Dutch MNFs. Asiedu (2013) argued that the lack of empirical evidence to support the PHH might come from the fact that these studies focus on outward FDI flows of a single country which can bias the econometric relation of FDI and its explanatory variables. The reason might be that investors from the US or the Netherlands put less weight on the institutional quality of the host countries but investors from other nations may do. Following Asiedu (2013) who adopted net FDI/GDP in a study of dynamic relationship between FDI, natural resources and institutions, we use net inward FDI over GDP at country level as the dependent variable. This data is obtained from World Development Indicators (WDI) provided by the World Bank.

### **3.4.2 Key independent variables**

**The measure of environmental policy stringency:** this paper follows Kellenberg (2009), Poelhekke and van der Ploeg (2015) who constructed environmental policy index by combining environmental stringency with its enforcement. It is argued that not only the strictness of environmental regulation but also its enforcement are important for analysing the effect of environmental policy on economic activities. The reason is that the written laws might not be implemented properly and consistently in many countries due to corruption. In case of high corruption and weak political institutions, effective environmental policy might be much lower than it should be from legal standards. In this paper, the (enforced) environmental policy index is constructed by multiplying environmental policy stringency (EPS) with corruption perceptions index (CPI). CPI is obtained from Transparency International. The index ranges from 0 to 10 in which 0 indicates highly corrupted and 10 indicates very clean or no corruption. EPS is a composite index developed by OECD (see Botta and Koźluk (2014)). The index ranges from 0 to 6 in which 0 indicates the least stringent and 6 indicates the most stringent. The data on EPS are available for 26 OECD countries and BRIICS over the years from 1990 to 2012, however, the analysis in this paper covers only the period from 1996 to 2012 due to the shortage of data on CPI. As compared to other measures of environmental stringency such as stringency of environmental regulation and

environmental performance index reported by World Economic Forum, EPS provides longer time dimension.

**Biocapacity per capita:** biocapacity is the ability of an ecosystem to produce useful biological materials and to absorb carbon dioxide emissions. It represents the endowment of a nation's environmental resources. Biocapacity is obtained from NFAs 2016 dataset.

### 3.4.3 Additional independent variables

**GDP per capita:** we measure the affluence of a country based on Gross Domestic Product (GDP) per capita which are obtained from World Development Indicators and measured in current US dollars. Per capita GDP is probably one of the most widely used variables in cross-sectional studies of environmental impacts (Turner et al. (2007), Kellenberg (2009), Frankel (2009)). GDP per capita is transformed to log (ln) value to minimize skewness.

**Eco-productivity of production and eco-productivity of consumption:** the eco-productivity is calculated as follows:

$$Eco - productivity_j = \frac{GDP}{EF_j}, \quad j = \{p, c\} \quad (4)$$

In which  $Eco - productivity_j$  denotes eco-productivity of production and of consumption, respectively;  $EF_j$  denotes ecological footprint or carbon footprint of production and consumption, accordingly. An increase in the eco-productivity of production (consumption) means that production (consumption) becomes greener.

**Openness:** the degree of openness of countries is measured by (exports + imports)/GDP. Export and import data are taken from WDI database.

**Inward FDI stock:** according to Wagner and Timmins (2009), ignoring the existence of agglomeration externalities that affect the flows of FDI will bias the results in the presence of pollution havens. Therefore we include inward FDI stock of a country as a proxy for agglomeration effects. This data is taken from the United Nations Conference on Trade and Development database. Table 7 in the Appendix shows some descriptive statistics for these variables.

## 3.5 Research methodology

With panel data in the present study, we use fixed effect (FE) and random effect (RE) models that account for potential unobserved heterogeneity (Borenstein et al. (2010)). Unobserved heterogeneity refers to the differences between identities and over years that are not measured in regression models. FE controls for time-invariant factors that are

unmeasured but affect dependent variables by allowing each to have its own intercept value (Allison (2009)). RE assumes that there is no correlation between individual specific effects and independent variables (Frees (2004)). In our regression analysis, some FE and RE models contain unreported time-specific effects (intercepts) that account for potential unobserved heterogeneity which is cross-sectionally invariant over years.

## 4 Results

### 4.1 Some descriptive results

To have a preliminary idea of which countries are net exporters and net importers of EF, we calculate the EF net export for groups of countries including OECD, BRIICS and developing nations as follows:

$$Net\ export\ of\ EF\ per\ capita = \frac{\sum_{i=1}^n Net\ export\ of\ EF}{\sum_{i=1}^n Population} \quad (5)$$

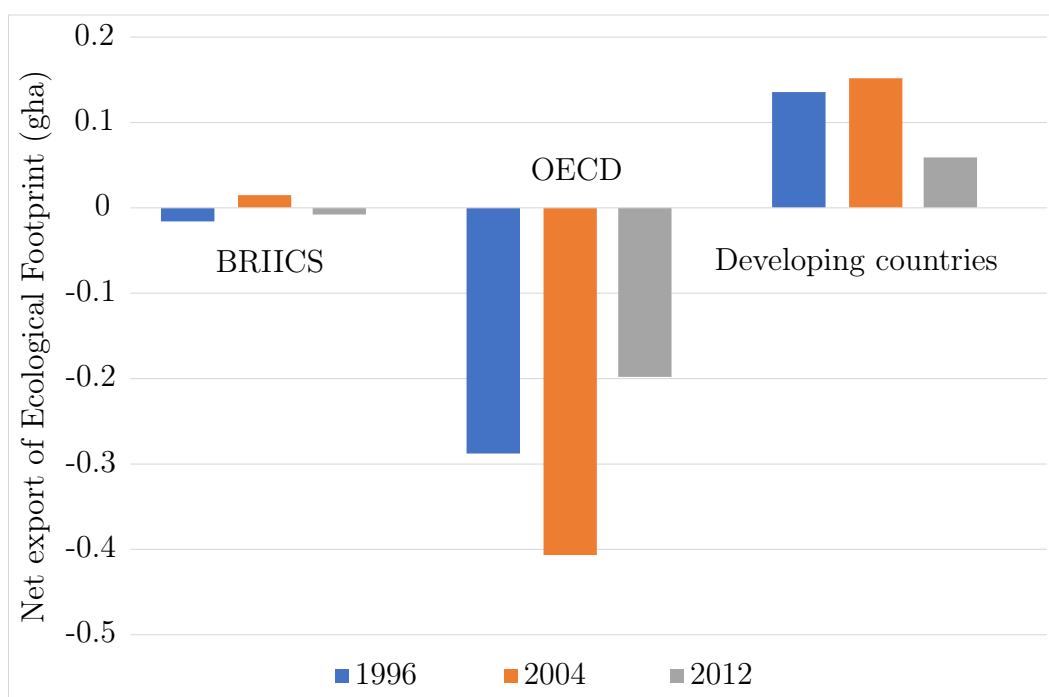


Figure 3: Net export of ecological footprint per person in selected regions.

Even though OECD countries are consistently net importers of EF over the given time series, the overall magnitude is significantly declining during the recent years (see fig. 3). The explanation might be that the effect of environmental policy on consumption

became stronger as compared to that of production. Alternatively, the production of exported goods in non-OECD countries might have become greener.

The carbon footprint accounts for approximately 60% of global ecological footprint in 2012 and it is the fastest growing factor. Bruckner et al. (2010) and Peters et al. (2011) measured carbon emissions transfer via globalised trade based on a consumption-based accounting approach. They argued that industrialized economies have strong power to outsource pollution-intensive industries to developing economies. Thus, they are able to improve domestic environmental quality and make their economies greener. Consistent with our observation in figure 4, Bruckner et al. (2010) showed that OECD economies are the largest  $CO_2$  net importers while major net exporters are emerging economies such as China. They also revealed that net carbon emission transfer has considerably grown from 1995 to 2005 and predicted to increase in the years to come. However, our finding shows that the net transfer of carbon dioxide increases from 1996 to 2004 but it has been decreasing over a period of 2004-2012.

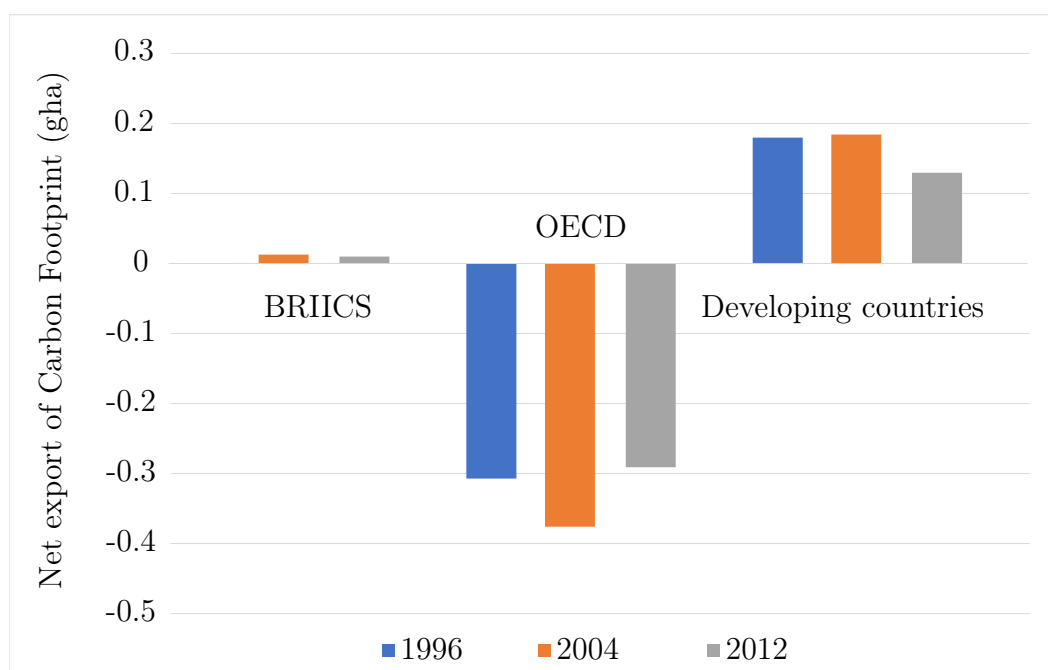


Figure 4: Net export of carbon footprint per capita in selected regions.

As the figures 5 – 7 in the Appendix show, the GDP per capita is strongly correlated with the stringency of environmental policy. The latter is highly correlated with both, the eco-productivity of production and consumption. Consequently, eco-productivity of production and consumption are also highly correlated with the GDP per capita.

## 4.2 Pairwise correlation analysis

Table 1: Pairwise correlation coefficients (ecological footprint)

	NetExEF	Biocapacity	EPSCPI	GDPCAP (ln)	ProdEF_Green	ConsEF_Green
NetExEF	1					
Biocapacity	0.854***	1				
EPSCPI	0.084	0.180***	1			
GDPCAP (ln)	0.072	0.249***	0.749***	1		
ProdEF_Green	-0.394***	-0.224***	0.626***	0.664***	1	
ConsEF_Green	0.049	0.070	0.758***	0.775***	0.800***	1

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 1 shows a correlation matrix between variables for regressions of EF net export. One might concern that there are high correlation coefficients between some variables which might be a signal of multicollinearity. Using Variance Inflation Factor we find no problem of multicollinearity between independent variables<sup>4</sup>. Of particular interest is the significant and positive correlation between the net export of EF and biocapacity (0.854) which is consistent with the HOV theorem. A country well-endowed with biocapacity becomes a net exporter of ecological use embodied in traded goods. Not surprisingly, there is a strongly positive relationship between income and environmental policy (see also figure 5 in the Appendix). The notion that more affluent nations impose stricter environmental regulation is broadly supported by both economic theory and empirical evidence in many studies (Rauscher (2005), Kearsley and Riddell (2010)). Additionally, it is well-known that income is positively associated with the ecological footprint, implying unsustainable consumption (lifestyle) in rich countries. Hence, we should expect a negative association between EF net export with GDP per capita and environmental policy. However, as observed in the simple correlation, the relationship between EF net export and income is positive but insignificant. Furthermore, there is no significant relationship between EF net export and environmental policy. The explanation for such insignificant and counter-intuitive relationship might be that the environmental policy and income have impacts on *both* eco-productivity of consumption and production (see fig. 6 in the Appendix). In other words, given a constant level of output, footprint embodied in consumption declines approximately as fast as the footprint embodied in production when there is a tightening in pollution regulation and an improvement in income. Finally, the eco-productivity of production and consumption are strongly correlated with GDP per capita and environmental policy. This implies that rich countries are unsustainable with regard to the absolute value of ecological footprint but nevertheless have greener production and consumption.

<sup>4</sup>Variance Inflation Factor table is available upon request

Regarding carbon footprint, table 8 in the Appendix shows that the correlations between net export of carbon footprint and other variables are pronounced and consistent with our expectation. Particularly, economies with higher income, more stringent environmental regulation are more likely to become net carbon importers. Furthermore, environmental policy does have positively significant effects on both eco-productivity of consumption and production but the effect on production seems to be stronger.

### 4.3 Empirical results

We start with the predictions of the HOV model of specialization and trade. According to hypotheses 1 and 2, a comparative advantage for environment-intensive production and thus for EF net export is given when a country is abundant of environment and has a lax regulation of appropriation of environmental goods (PHH).

Table 2: Findings for the regression of net export of ecological footprint in the simplified econometric model

	FE	RE	FE	RE
	NetExEF	NetExEF	NetExEF	NetExEF
Biocapacity	0.297*** (7.21)	0.340*** (11.78)	0.313*** (7.55)	0.349*** (12.03)
EPSCPI	-0.006* (-1.85)	-0.005 (-1.55)	-0.011** (-2.42)	-0.011** (-2.40)
Constant	-0.997*** (-5.13)	-1.194*** (-4.98)	-1.018*** (-5.05)	-1.185*** (-4.83)
<i>N</i>	544	544	544	544
Year effect	No	No	Yes	Yes
$R^2$ within	0.135	0.134	0.192	0.192
$R^2$ between	0.748	0.748	0.751	0.750
$R^2$ overall	0.733	0.732	0.736	0.736

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ ; t statistics in parentheses

FE denotes fixed effect model, RE denotes random effect model

Table 2 reveals the findings for ecological footprint analysis of the simplified estimation model. Four models are recorded: FE and RE with and without period-specific effect. Generally speaking, the empirical finding gives support for both hypotheses. Particularly, the coefficient of biocapacity is statistically significant at the level 1% for all regressions and signed precisely to support the hypothesis 1. The standardized coefficient (0.297) in FE is smaller than in RE model (0.340) but they are all larger when we consider year effect (0.313 for FE and 0.349 for RE model, accordingly). This result is, to some extent, aligned with the finding of Aşıcı and Acar (2016) who found that biological capacity of a nation is positively associated with footprint of production while it is negatively correlated with footprint of imports. The reason is that resources-rich countries are able to utilize more environmental services for production, thus less depending on imports.

Another variable of our interest is environmental policy. The result shows that there is a statistically significant relationship between the environmental policy and net export of ecological footprint in most of models at either 10% or 5% level except for RE model without year-effect. The coefficient holds a negative sign which is in line with our expectation. This gives support for hypothesis 2, the Pollution Haven effect.

As the descriptive statistics have shown, there are strong correlations between the GDP per capita, the stringency of policy, and the eco-productivity of production and consumption, these variables should contribute to an explanation of the empirical findings. Thus we include them as control variables into the panel regression.

Table 3 presents the empirical results for analysis of net export of ecological footprint in the extended estimation models which additionally include the control variables. The first FE model consists of biocapacity, environmental policy and GDP per capita variables. Eco-productivity of production is added to the second FE model and eco-productivity of consumption is included in the third FE model. The same group of variables are entered in RE models. We record the same kinds of coefficients, t statistics and R-squared values as previous series of estimations. Slightly different from the analysis of the simplified estimation model, all regression models in this part control for year effect in which the intercepts are unreported in the result. Consistent with the results in table 2, the sign of coefficients for biocapacity and environmental policy remain the same while the magnitude of the impacts is slightly greater. This gives an impression that the empirical evidence to support the PHH and the HOV model is quite robust across different regression models.

The net export of environmental effect is negatively correlated with GDP per capita in all FE and RE models. Hypothesis 3 is confirmed because the coefficient of per capita GDP has a negative sign and is statistically significant at the level 1%. The coefficient



Table 3: Findings for the regression of net export of ecological footprint in the extended econometric model

	FE	FE	FE	RE	RE	RE
	NetExEF	NetExEF	NetExEF	NetExEF	NetExEF	NetExEF
Biocapacity	0.314*** (7.64)	0.321*** (7.89)	0.343*** (8.38)	0.359*** (12.53)	0.361*** (13.17)	0.375*** (13.51)
EPSCPI	-0.014*** (-3.06)	-0.012** (-2.54)	-0.021*** (-4.38)	-0.012*** (-2.84)	-0.009** (-2.12)	-0.020*** (-4.40)
GDP CAP (ln)	-0.245*** (-3.11)	-0.277*** (-3.53)	-0.253*** (-3.26)	-0.234*** (-3.29)	-0.244*** (-3.50)	-0.258*** (-3.71)
ProdEF_Green		-0.042*** (-3.48)			-0.045*** (-3.79)	
ConsEF_Green			0.060*** (4.34)			0.063*** (4.66)
Constant	1.288* (1.68)	1.679** (2.19)	1.093 (1.45)	0.970 (1.39)	1.182* (1.73)	0.987 (1.45)
<i>N</i>	544	544	544	544	544	544
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
<i>R</i> <sup>2</sup> within	0.208	0.227	0.237	0.207	0.226	0.237
<i>R</i> <sup>2</sup> between	0.760	0.765	0.777	0.764	0.775	0.777
<i>R</i> <sup>2</sup> overall	0.746	0.752	0.763	0.750	0.762	0.763

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ ; t statistics in parentheses

FE denotes fixed effect model, RE denotes random effect model

of -0.245 for GDP per capita can be interpreted that when GDP per capita increases by 1%, net export of ecological footprint decreases by 0.00245 gha. The magnitude of this coefficient is very small but relatively stable across models. While all other things held constant, we should expect the ecological footprint of consumption exceeds that of production in high-income countries. This result is widely supported in previous literature. Chen and Chang (2016) found that ecological footprint of consumption increases at a faster rate in high-income nations than in low- and middle-income economies. On the basis of the economic theory of ecologically unequal exchange, York et al. (2003), Jorgenson and Burns (2007) and Jorgenson et al. (2009) further argued that unbalanced exchange system allows powerful economies to externalize environmental impacts related to their domestic material consumption. While a large volume of environmental resources is extracted in less-developed nations, the majority of them are used for the production of exported goods to more-developed countries. This explains why the rich are more likely to become net importers of environmental use and the poor are more likely to become EF net exporters.

Notably, a negative coefficient for eco-productivity of production (-0.042) and positive coefficient for eco-productivity of consumption (0.060) in FE models mean that the EF net export decreases with the greenness of production and increases with the greenness of consumption. These coefficients are significant at the level 1% in all reported models. This finding confirms hypothesis 4.

An analogous test is conducted for carbon footprint. Table 9 and 10 in the Appendix reveal a negative coefficient for environmental policy and it is statistically significant at the level of 1% in both FE and RE regression. This shows a similar pattern to the result in table 3. Therefore, we should expect carbon footprint of consumed goods exceeds that of produced goods in case of having strict environmental regulation. The estimated coefficient for income variable is consistently negative and significant in all reported models which indicates that rich countries are more likely to become net importers of carbon footprint.

Finally, we analyse the role of FDI for the emergence of the global specialization pattern. Table 4 shows the results of FE and RE models for three cases: full sample, and separately for EF net exporting and EF net importing countries. As there are many different motives for FDI and as we know from literature that environmental policy plays only a minor role when looking to aggregate FDI decisions in the full sample of countries, we could nevertheless expect differences when looking to EF net exporters and EF net importers. We expect (hypothesis 5) that environmental abundance and stringent policy should play a role only for those investors who invest into environment-intensive sectors in countries which have a comparative advantage for that. So if we find a correlation with these factors in EF net exporting countries, FDI seems to play a role in creating the specialization pattern.

In table 4, the estimated coefficient of openness is positive and highly significant for all three samples and for both regression models. This indicates that FDI flows more to a country with less trade frictions and barriers. Regarding GDP per capita, the coefficient is consistently insignificant in all models. It is a counter-intuitive result because a higher income level leads to higher domestic consumption that makes an economy more attractive for foreign investors (Asiedu (2013)). Regarding the environmental policy, we find empirical evidence to support hypothesis 5 since the estimated coefficient is significant and negative in net EF exporting countries while it has no significant effect on FDI flows to net EF importing countries. This indicates that EF net exporters – recall that these are mainly low/medium income countries with weak environmental regulations – are more seen as a production platform for investors because of relatively easier access to environmental resources. The coefficient for biocapacity per capita is, however, insignificant in all models which suggests that biological capacity does not

Table 4: Findings for the regression of net FDI inflows (% GDP), fixed effect and random effect models

	Full sample		EF net exporters		EF net importers	
	FE	RE	FE	RE	FE	RE
Biocapacity	0.008 (0.01)	0.038 (0.35)	0.171 (0.13)	0.074 (0.52)	3.815 (0.94)	-0.332 (-0.48)
EPSCPI	-0.131* (-1.85)	-0.107* (-1.82)	-0.195* (-1.68)	-0.179** (-2.18)	-0.092 (-0.96)	-0.121 (-1.43)
GDPCAP (ln)	-0.420 (-0.33)	0.093 (0.17)	1.226 (0.68)	1.043 (1.30)	-2.429 (-1.27)	-0.498 (-0.61)
Openness	0.088*** (3.12)	0.098*** (7.83)	0.079** (2.24)	0.070*** (4.49)	0.104** (2.15)	0.142*** (5.96)
FDI stock (ln)	1.027 (1.43)	1.002*** (2.97)	0.285 (0.27)	0.587 (1.36)	2.175** (2.09)	1.112** (2.18)
Constant	-8.711 (-1.00)	-14.51*** (-3.06)	-16.17 (-1.24)	-16.59*** (-2.58)	-11.25 (-0.69)	-11.78* (-1.66)
<i>N</i>	533	533	237	237	296	296
$R^2$ within	0.043	0.041	0.048	0.046	0.058	0.050
$R^2$ between	0.608	0.676	0.667	0.702	0.164	0.773
$R^2$ overall	0.244	0.269	0.209	0.217	0.072	0.353

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ ;  $t$  statistics in parentheses

FE denotes fixed effect model, RE denotes random effect model

play an important role in creating trade pattern. For inward FDI stock, we find the agglomeration effect on net FDI inflow only in case of EF net importing countries.

## 5 Conclusion

According to the theoretical prediction of the HOV model countries with a comparative advantage in producing environment-intensive goods will specialize on these goods and thus becoming net exporters of the factor environment embodied in the traded goods. In this paper we use the Ecological Footprint as a measure of environmental use because (a) it is defined very broadly, and (b) its methodology provides the required information about the EF in production and EF in consumption. We take the biocapacity per capita as a measure of relative abundance, but also the stringency of environmental policy as an indicator of comparative advantage because both influence the cost of appropriation

of the environmental goods. The dependency on the policy relates our analysis to the Pollution Haven hypothesis.

Using panel data of 32 countries for the years 1996-2012 we run regressions with fixed effects and random effects. We find clear evidence that both factors contribute to the explanation which countries become net exporters or net importers of the EF. Controlling for further variables it turns out that high income countries are more likely to be EF net importers while many less developed countries are net EF exporters which is in line with the existing empirical literature. This is at least partially explained by the fact that richer countries have a more stringent environmental policy. But also the correlation with the relative endowment of environmental factors is very robust. As the EF is strongly correlated with the output, globalization could be criticised for its role in fostering global growth. But this effect is at least partially dampened by the enhanced allocative efficiency of using the global environment. Therefore, as ecologically “unequal” trade might imply a more efficient use of the environment, we do not see this specialization pattern as an argument against trade *per se*. Moreover, it turned out that in the recent years the EF net flow embodied in traded goods from less to highly developed countries became significantly smaller. This could be, to some extent, explained by the fact that not only production in the developed countries becomes greener but also the greenness of consumption in these countries is improved. The empirical picture is very similar if we account only for the Carbon Footprint rather than the entire Ecological Footprint.

We also analyse which role FDI plays for the emergence of this specialization pattern. Although the global picture is that environmental issues, especially policy regulations, do not have any significant impact on FDI decisions, the results are different when we look separately to EF net exporting and EF net importing countries. According to our finding the stringency of environmental policy is a significant determinant for FDI flows only for EF net exporting countries. However, we should *not* advocate the policy implication that a lax environmental policy creates comparative advantages and is thus beneficial for attracting FDI. Recall that a lax policy is clearly correlated with a low income. Also medium and high income countries are attracting FDI. But they are doing so because of other comparative advantages which are more important for the long-run development.

## Appendix

Table 5: List of 32 countries

OECD				BRIICs
Australia	France	Korea	Spain	Brazil
Austria	Germany	Netherlands	Sweden	China
Belgium	Greece	Norway	Switzerland	India
Canada	Hungary	Poland	Turkey	Indonesia
Czech Republic	Ireland	Portugal	United Kingdom	Russia
Denmark	Italy	Slovak Republic	United States	South Africa
Finland	Japan			

Table 6: Description of variables and sources

Variable	Definition and sources
Net export of ecological footprint ( <i>NetExEF</i> )	Global hectares per capita. Source: National Footprint Accounts 2016
Net export of carbon footprint ( <i>NetExCF</i> )	Global hectares per capita. Source: National Footprint Accounts 2016
Environmental policy stringency ( <i>EPS</i> )	A composite index based on actual policy. Range from 0 (least stringent) to 6 (most stringent). Source: OECD.stat
Corruption Perceptions Index ( <i>CPI</i> )	The misuse of public power for private benefit. Range from 0 (highly corrupt) to 10 (very clean). Source: Transparency International
Environmental policy ( <i>EPSCPI</i> )	A combination between EPS and CPI. Source: Calculated by the author
Biocapacity ( <i>Biocapacity</i> )	Global hectares per capita. Source: National Footprint Accounts 2016
GDP per capita ( <i>GDPCAP</i> )	A measure of average income per person in a country. Source: WDI
Eco-productivity of production ( <i>ProdEF_Green</i> or <i>ProdCF_Green</i> )	A ratio of GDP to ecological footprint of production or to carbon footprint of production (in thousands). Source: Calculated by the author
Eco-productivity of consumption ( <i>ConsEF_Green</i> or <i>ConsCF_Green</i> )	A ratio of GDP to ecological footprint of consumption or to carbon footprint of consumption (in thousands). Source: Calculated by the author
Net FDI inflows/GDP ( <i>FDI/GDP</i> )	(Equity capital + reinvestment of earnings + other long-term capital + short-term capital)/GDP. Source: WDI
Degree of openness ( <i>Openness</i> )	(Export + Import)/GDP. Source: WDI
Inward FDI stock ( <i>FDI stock</i> )	Inward FDI stock. Source: United Nations Conference on Trade and Development

Table 7: Summary statistics

<b>Variable</b>	<b>Obs</b>	<b>Mean</b>	<b>Std. Dev.</b>	<b>Min</b>	<b>Max</b>
NetExEF	544	0.202	2.153	-3.382	6.556
NetExCF	544	-0.255	0.771	-2.603	2.377
Biocapacity	544	4.268	4.825	0.399	20.567
EPS	544	1.730	0.948	0.333	4.408
CPI	544	6.264	2.272	1.7	10
EPSCPI	544	11.960	8.592	0.744	40.998
GDPCAP	544	25609	19005	408.24	101563
ProdEF_Green	544	4.782	3.943	0.269	31.262
ConsEF_Green	544	4.340	3.046	0.297	26.343
ProdCF_Green	544	8.874	7.126	0.401	47.316
ConsCF_Green	544	8.814	12.84	0.459	147.47
FDI/GDP	537	4.28	7.24	-16.07	87.44
Openness	544	75.79	39.72	14.16	200.2
FDI stock	539	296442	517532	2046	3915538

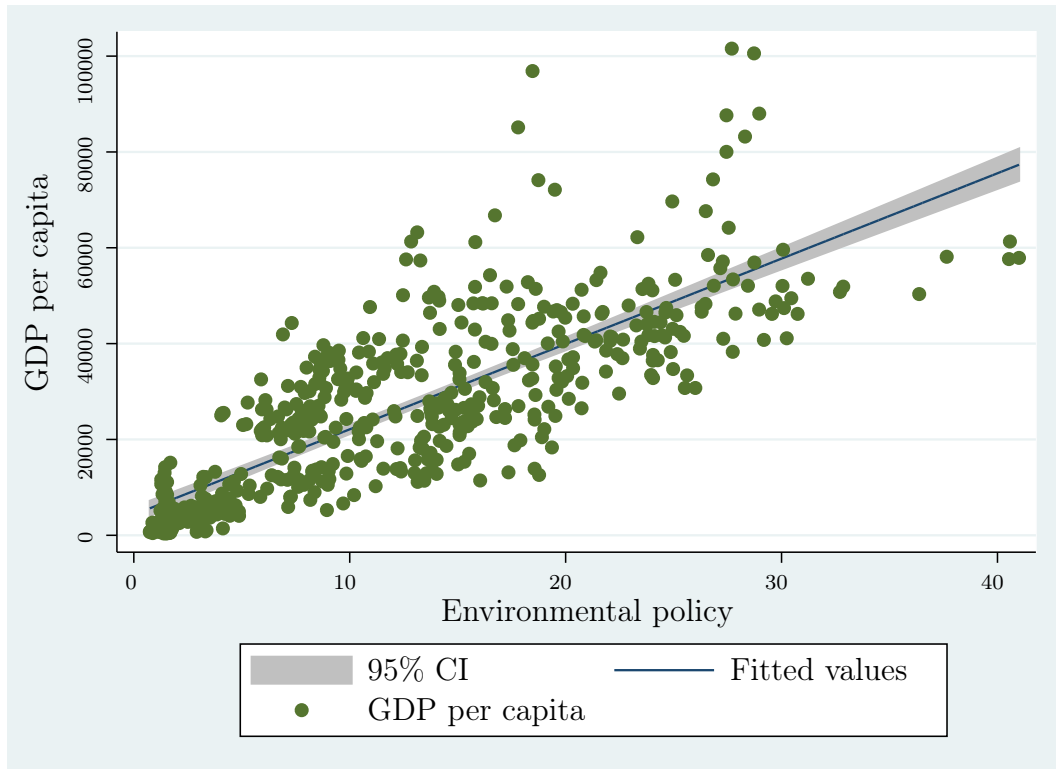


Figure 5: The relationship between income level and environmental policy stringency.

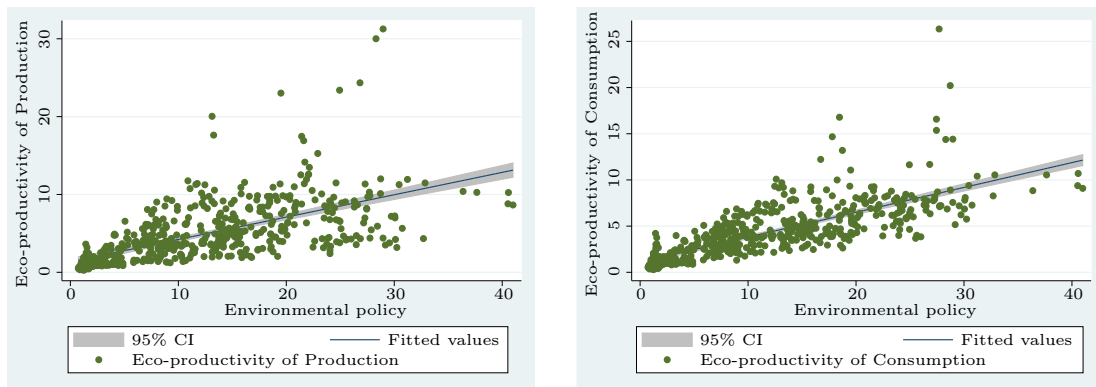


Figure 6: Environmental policy and eco-productivity of production (left) and of consumption (right).

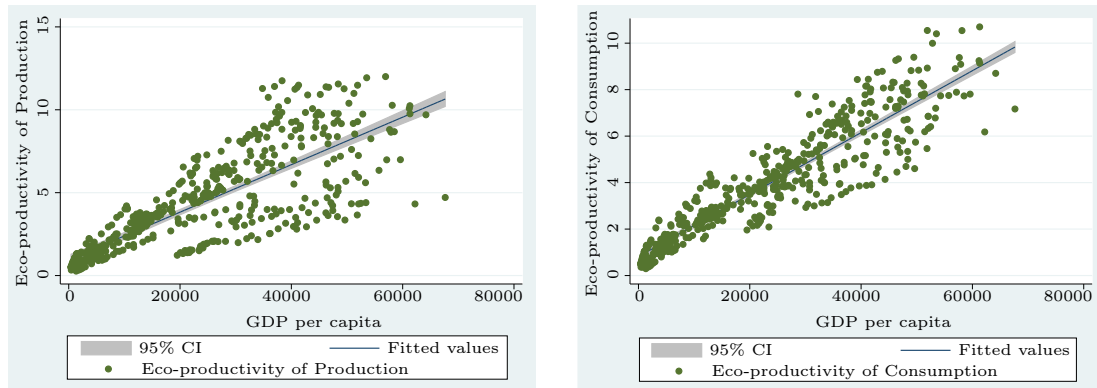


Figure 7: GDP per capita and eco-productivity of production (left) and of consumption (right) (without outliers Norway and Switzerland).

Table 8: Pairwise correlation coefficients (carbon footprint)

	NetExCF	EPSCPI	GDPCAP (ln)	ProdCF_Green	ConsCF_Green
NetExCF	1				
EPSCPI	-0.290***	1			
GDPCAP (ln)	-0.224***	0.749***	1		
ProdCF_Green	-0.414***	0.696***	0.675***	1	
ConsCF_Green	0.302***	0.341***	0.408***	0.567***	1

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$



Table 9: Findings for regression of net export of carbon footprint, fixed effect models

	NetExCF	NetExCF	NetExCF	NetExCF
EPSCPI	-0.012*** (-4.31)	-0.014*** (-4.93)	-0.009*** (-3.18)	-0.016*** (-5.77)
GDP CAP (ln)		-0.157*** (-3.15)	-0.172*** (-3.63)	-0.168*** (-3.51)
ProdCF_Green			-0.027*** (-7.23)	
ConsCF_Green				0.010*** (6.85)
Constant	-0.044 (-1.07)	1.436*** (3.05)	1.712*** (3.80)	1.487*** (3.30)
<i>N</i>	544	544	544	544
Year effect	Yes	Yes	Yes	Yes
$R^2$ within	0.179	0.195	0.272	0.265
$R^2$ between	0.092	0.067	0.118	0.186
$R^2$ overall	0.081	0.076	0.127	0.191

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ ; t statistics in parentheses

Table 10: Findings for regression of net export of carbon footprint, random effect models

	NetExCF	NetExCF	NetExCF	NetExCF
EPSCPI	-0.013*** (-4.52)	-0.014*** (-4.99)	-0.008*** (-3.01)	-0.016*** (-5.90)
GDP CAP (ln)		-0.144*** (-3.17)	-0.145*** (-3.35)	-0.157*** (-3.66)
ProdCF_Green			-0.027*** (-7.32)	
ConsCF_Green				0.010*** (7.19)
Constant	-0.040 (-0.30)	1.311*** (2.93)	1.449*** (3.39)	1.388*** (3.29)
<i>N</i>	544	544	544	544
Year effect	Yes	Yes	Yes	Yes
$R^2$	0.179	0.195	0.272	0.265
$R^2$	0.092	0.068	0.124	0.198
$R^2$	0.083	0.077	0.134	0.201

\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$ ; t statistics in parentheses

## References

- Allison, P. D. (2009), *Fixed effects regression models*, Vol. 160, Sage publications.
- Andersson, J. O. and Lindroth, M. (2001), 'Ecologically unsustainable trade', *Ecological Economics* 37(1), pp. 113–122.
- Aşıcı, A. A. and Acar, S. (2016), 'Does income growth relocate ecological footprint?', *Ecological Indicators* 61, pp. 707–714.
- Asiedu, E. (2013), 'Foreign direct investment, natural resources and institutions', *International Growth Centre, Working Paper Series* .
- Ayres, R. U. (2000), 'Commentary on the utility of the ecological footprint concept', *Ecological Economics* 32(3), pp. 347–349.
- Barrett, J. (2001), 'Component ecological footprint: developing sustainable scenarios', *Impact Assessment and Project Appraisal* 19(2), pp. 107–118.
- Borenstein, M., Hedges, L. V., Higgins, J. and Rothstein, H. R. (2010), 'A basic introduction to fixed-effect and random-effects models for meta-analysis', *Research Synthesis Methods* 1(2), pp. 97–111.
- Borucke, M., Moore, D., Cranston, G., Gracey, K., Iha, K., Larson, J., Lazarus, E., Morales, J. C., Wackernagel, M. and Galli, A. (2013), 'Accounting for demand and supply of the biosphere's regenerative capacity: The National Footprint Accounts' underlying methodology and framework', *Ecological Indicators* 24, pp. 518–533.
- Botta, E. and Koźluk, T. (2014), 'Measuring Environmental Policy Stringency in OECD Countries', *OECD Economics Department Working Papers* (1177).
- Bruckner, M., Christine, P. and Giljum, S. (2010), 'Counting CO<sub>2</sub> emissions in a globalised world: producer versus consumer-oriented methods for CO<sub>2</sub> accounting', *The German Development Institute Working Paper Series* 9.
- Chen, S.-T. and Chang, H.-T. (2016), 'Factors that affect the ecological footprint depending on the different income levels', *AIMS Energy* 4(4), pp. 557–573.
- Chichilnisky, G. et al. (1993), Global environment and north-south trade, Working paper.
- Copeland, B. R. and Taylor, M. S. (1994), 'North-South trade and the environment', *The Quarterly Journal of Economics* 109(3), pp. 755–787.
- Cortés-Borda, D., Guillén-Gosálbez, G. and Jiménez, L. (2015), 'Solar energy embodied in international trade of goods and services: A multi-regional input-output approach', *Energy* 82, pp. 578–588.
- Costanza, R. (2000), 'The dynamics of the ecological footprint concept', *Ecological Economics* 32(3), pp. 341–345.

- Deardorff, A. V. and Staiger, R. W. (1988), 'An interpretation of the factor content of trade', *Journal of International Economics* 24(1-2), pp. 93–107.
- Ederington, J., Levinson, A. and Minier, J. (2005), 'Footloose and pollution-free', *The Review of Economics and Statistics* 87(1), pp. 92–99.
- Eskeland, G. S. and Harrison, A. E. (2003), 'Moving to greener pastures? Multinationals and the pollution haven hypothesis', *Journal of Development Economics* 70(1), pp. 1–23.
- Ferng, J.-J. (2009), 'Applying input–output analysis to scenario analysis of ecological footprints', *Ecological Economics* 69(2), pp. 345–354.
- Fischer-Kowalski, M., Krausmann, F., Giljum, S., Lutter, S., Mayer, A., Bringezu, S., Moriguchi, Y., Schütz, H., Schandl, H. and Weisz, H. (2011), 'Methodology and indicators of economy-wide material flow accounting', *Journal of Industrial Ecology* 15(6), pp. 855–876.
- Frankel, J. A. (2009), 'Environmental effects of international trade', *HKS Faculty Research Working Paper Series RWP09-006* .
- Frees, E. W. (2004), *Longitudinal and panel data: analysis and applications in the social sciences*, Cambridge University Press.
- Giljum, S. and Eisenmenger, N. (2004), 'North-South trade and the distribution of environmental goods and burdens: a biophysical perspective', *The Journal of Environment & Development* 13(1), pp. 73–100.
- Grossman, G. M. and Krueger, A. B. (1991), 'Environmental impacts of a North American free trade agreement', *NBER Working Paper Series 3914*.
- Han, X. and Chatterjee, L. (1997), 'Impacts of growth and structural change on CO<sub>2</sub> emissions of developing countries', *World Development* 25(3), pp. 395–407.
- Hertwich, E. G. and Peters, G. P. (2009), 'Carbon footprint of nations: A global, trade-linked analysis', *Environmental Science & technology* 43(16), pp. 6414–6420.
- Jorgensen, A. E., Vigsoe, D., Krisoffersen, A. and Rubin, O. (2002), 'Assessing the ecological footprint. A look at the WWF's Living Planet Report 2002', *Danish Environmental Assessment Institute* .
- Jorgenson, A. K. (2005), 'Unpacking international power and the ecological footprints of nations: A quantitative cross-national study', *Sociological Perspectives* 48(3), pp. 383–402.
- Jorgenson, A. K., Austin, K. and Dick, C. (2009), 'Ecologically Unequal Exchange and the Resource Consumption/Environmental Degradation Paradox A Panel Study of Less-Developed Countries, 1970—2000', *International Journal of Comparative Sociology* 50(3-4), pp. 263–284.

- Jorgenson, A. K. and Burns, T. J. (2007), 'The political-economic causes of change in the ecological footprints of nations, 1991–2001: a quantitative investigation', *Social Science Research* 36(2), pp. 834–853.
- Kearsley, A. and Riddel, M. (2010), 'A further inquiry into the Pollution Haven Hypothesis and the Environmental Kuznets Curve', *Ecological Economics* 69(4), pp. 905–919.
- Kellenberg, D. K. (2009), 'An empirical investigation of the pollution haven effect with strategic environment and trade policy', *Journal of International Economics* 78(2), pp. 242–255.
- Koźluk, T. and Timiliotis, C. (2016), 'Do environmental policies affect global value chains?', *OECD Economics Department Working Papers* (1282).
- Kuzyk, L. W. (2012), 'The ecological footprint housing component: A geographic information system analysis', *Ecological Indicators* 16, pp. 31–39.
- Leamer, E. E. (1980), 'The Leontief paradox, reconsidered', *The Journal of Political Economy*, pp. 495–503.
- Leontief, W. (1953), 'Domestic production and foreign trade; the American capital position re-examined', *Proceedings of the American philosophical Society* 97(4), pp. 332–349.
- Levinson, A. and Taylor, M. S. (2008), 'Unmasking the pollution haven effect', *International Economic Review* 49(1), pp. 223–254.
- Lin, D., Wackernagel, M., Galli, A. and Kelly, R. (2015), 'Ecological Footprint: Informative and evolving—A response to van den Bergh and Grazi (2014)', *Ecological Indicators* 58, pp. 464–468.
- Manderson, E. and Kneller, R. (2012), 'Environmental regulations, outward FDI and heterogeneous firms: Are countries used as pollution havens?', *Environmental and Resource Economics* 51(3), pp. 317–352.
- Moffatt, I. (2000), 'Ecological footprints and sustainable development', *Ecological Economics* 32(3), pp. 359–362.
- Moran, D. D., Lenzen, M., Kanemoto, K. and Geschke, A. (2013), 'Does ecologically unequal exchange occur?', *Ecological Economics* 89, pp. 177–186.
- Peters, G. P., Minx, J. C., Weber, C. L. and Edenhofer, O. (2011), 'Growth in emission transfers via international trade from 1990 to 2008', *Proceedings of the National Academy of Sciences* 108(21), pp. 8903–8908.
- Pethig, R. (1976), 'Pollution, welfare, and environmental policy in the theory of comparative advantage', *Journal of Environmental Economics and Management* 2(3), pp. 160–169.

- Poelhekke, S. and van der Ploeg, F. (2013), ‘Do natural resources attract nonresource FDI?’, *Review of Economics and Statistics* 95(3), pp. 1047–1065.
- Poelhekke, S. and van der Ploeg, F. (2015), ‘Green havens and pollution havens’, *The World Economy* 38(7), pp. 1159–1178.
- Poelhekke, S. and van der Ploeg, R. (2010), ‘Do Natural Resources Attract FDI? Evidence from Non-stationary Sector Level Data’, *De Nederlandsche Bank Working Paper Series* 266.
- Raspiller, S. and Riedinger, N. (2008), ‘Do Environmental Regulations Influence the Location Behavior of French Firms?’, *Land Economics* 84(3), pp. 382–395.
- Rauscher, M. (2005), ‘International trade, foreign investment, and the environment’, *Handbook of Environmental Economics* 3, pp. 1403–1456.
- Reinert, K. A., Rajan, R. S. and Glass, A. J. (2009), *The Princeton Encyclopedia of the World Economy*, Vol. 2, Princeton University Press.
- Rezza, A. A. (2013), ‘FDI and pollution havens: Evidence from the Norwegian manufacturing sector’, *Ecological Economics* 90, pp. 140–149.
- Sauvage, J. (2014), ‘The stringency of environmental regulations and trade in environmental goods’, *OECD Trade and Environment Working Papers* (2014/03).
- Simmons, C., Lewis, K. and Barrett, J. (2000), ‘Two feet-two approaches: a component-based model of ecological footprinting’, *Ecological Economics* 32(3), pp. 375–380.
- Stöglehner, G. (2003), ‘Ecological footprint—a tool for assessing sustainable energy supplies’, *Journal of Cleaner Production* 11(3), pp. 267–277.
- Tang, J. (2015), ‘Testing the pollution haven effect: Does the type of FDI matter?’, *Environmental and Resource Economics* 60(4), pp. 549–578.
- Tobey, J. A. (1990), ‘The effects of domestic environmental policies on patterns of world trade: an empirical test’, *Kyklos* 43(2), pp. 191–209.
- Turner, K., Lenzen, M., Wiedmann, T. and Barrett, J. (2007), ‘Examining the global environmental impact of regional consumption activities—part 1: a technical note on combining input–output and ecological footprint analysis’, *Ecological Economics* 62(1), pp. 37–44.
- Van den Bergh, J. C. and Grazi, F. (2014), ‘Ecological footprint policy? Land use as an environmental indicator’, *Journal of Industrial Ecology* 18(1), pp. 10–19.
- Van den Bergh, J. C. and Verbruggen, H. (1999), ‘Spatial sustainability, trade and indicators: an evaluation of the ‘ecological footprint’’, *Ecological Economics* 29(1), pp. 61–72.

- Vanek, J. (1968), 'The factor proportions theory: The n—factor case', *Kyklos* 21(4), pp. 749–756.
- Wackernagel, M., Lewan, L. and Hansson, C. B. (1999), 'Evaluating the use of natural capital with the ecological footprint: applications in Sweden and subregions', *Ambio* 28(7), pp. 604–612.
- Wackernagel, M. and Rees (1996), *Our ecological footprint: reducing human impact on the earth*, number 9, New Society Publishers.
- Wagner, U. J. and Timmins, C. D. (2009), 'Agglomeration effects in foreign direct investment and the pollution haven hypothesis', *Environmental and Resource Economics* 43(2), pp. 231–256.
- Wiedmann, T., Minx, J., Barrett, J. and Wackernagel, M. (2006), 'Allocating ecological footprints to final consumption categories with input–output analysis', *Ecological Economics* 56(1), pp. 28–48.
- Xing, Y. and Kolstad, C. D. (2002), 'Do lax environmental regulations attract foreign investment?', *Environmental and Resource Economics* 21(1), pp. 1–22.
- York, R., Rosa, E. A. and Dietz, T. (2003), 'Footprints on the earth: The environmental consequences of modernity', *American Sociological Review* 68(2), pp. 279–300.