Trade and Specialisation in Pollution Intensive Industries: North-South Evidence

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Trade and Specialisation in Pollution Intensive Industries: North-South Evidence

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Abstract

The pollution haven hypothesis (PHH) and the capital-labour hypothesis (KLH) state that the relative level of a country’s environmental regulations and capital and labour endowments determines its comparative advantage respectively. Since these hypotheses lead to conflicting predictions as to whether the North or the South will specialise in pollution-intensive production, this paper examines whether changes in trade and specialisation patterns allow us to distinguish between pollution haven and factor endowment effects. We employ a methodology that enables us to present North-South trade patterns over time and to identify those periods when trade patterns were consistent with either the PHH and/or the KLH as a foundation for undertaking more detailed econometric studies.

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JEL Classification: F18, O13, L60, L50

A.K.M. Azhar would like to acknowledge research funding from UPM Fundamental Research Grant number 55170. Elliott would like to gratefully acknowledge the support of Leverhulme Trust grant number F/00094/AG.
1. Introduction

The effect of trade liberalisation on the natural environment is the subject of intense debate among academics and policy makers. The last three decades have been characterised by both a steady decrease in global trade barriers and a steady increase in environmental regulation, primarily in the developed world. During this time, a large volume of literature has emerged that examines many aspects of the trade-environment relationship from the theoretical contributions of Siebert et al. (1980), Chichilnisky (1994), Copeland and Taylor (1994, 1995 and 2004) to the empirical work of Antweiler et al. (2001), Cole and Elliott (2003a), Ederington et al. (2004) and Ederington et al. (2005). Within this literature, two competing hypotheses have emerged regarding the impact of trade openness on future levels of environmental quality.

First, the capital-labour hypothesis (KLH) predicts that trade liberalisation will result in trade patterns consistent with the Heckscher-Ohlin-Samuelson (HOS) theory of comparative advantage based on factor endowment differentials. From the general premise that pollution intensive goods are relatively capital intensive (Antweiler et al. 2001 and Cole and Elliott 2003b, 2005), it is assumed that pollution-intensive (hereafter “dirty”) industries will relocate production from countries in the relatively labour abundant South to those in the relatively capital abundant North. The KLH is supported by the observation that historically high polluting industries in the South were often heavily protected. As a result of trade liberalisation any inefficiencies are exposed, resulting in a relocation of production from the South to the North. Studies that model the impact of trade on the environment are just beginning to take into account the role of factor endowments (Antweiler et al. 2001 and Cole and Elliott 2003).¹

The competing hypothesis, known as the pollution haven hypothesis (PHH), is derived from changes in environmental legislation that in turn can distort existing patterns of comparative advantage. In the developed world the costs of complying with environmental regulations appear to be increasing steadily over time and, for the USA

¹ The KLH is related to and in a sense encompasses the second and third hypotheses tested in Ederington et al. (2005) who argue that some industries are less geographically mobile that others due to factors such as transportation costs, plant fixed costs, agglomeration economics and the cost of regulations as a proportion of total costs.
alone, were estimated to be $184 billion in 2000, equivalent to 2.6% of US GNP. Since the stringency of environmental regulations increases with income and economic development (for example Dasgupta et al. 1995) the PHH assumes that developing countries possess a comparative advantage in pollution-intensive production. The manifestation of the PHH, in direct conflict with the KLH, is that dirty industries may relocate from the North to the South (foreign direct investment), or simply that, dirty industries from the developed world become displaced from the world market by similar industries from developing countries. This phenomenon has been cited as one explanation for the inverted-U relationship often estimated between per capita income and emissions of local air pollution (e.g. Grossman and Krueger 1995 and Cole et al 1997). It is a moot point whether developing countries have a lower social tolerance for pollution. This may be the case if the developed country has a higher absorptive capacity in which case the relocation from the North to the South may be “beneficial” to the environment although it has also been argued that developing regions actually have a lower absorptive capacity (Zarsky 1999). Taylor (2004) provides a useful overview of the theoretical and empirical foundations of the PHH.

The opposing forces of the PHH and KLH might also explain why the empirical literature that tests the PHH finds mixed results. Lucas et al. (1992) and Birdsall and Wheeler (1992) find some support for the PHH and claim that the growth in pollution intensity in developing countries was highest in periods when OECD environmental regulations were strengthened. Mani and Wheeler (1998) examine the import-export ratio for dirty industries and also find evidence consistent with the PHH, although they claim that such havens appear to have been temporary. Rock (1996) finds that developing countries with outward-orientated policies have higher pollution intensities than those following inward-orientated policies. In contrast, Van Beers and Van den Bergh (1997), Tobey (1990) and Janicke et al. (1997) find no evidence to suggest that the stringency of a country’s environmental regulations is a determinant of its net exports of

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2 US Environmental Protection Agency (1990) estimated in 1992 US dollars. This is an estimate of private sector compliance costs and therefore omits personal consumption abatement, government abatement and government regulation and monitoring.
3 Even if foreign direct investment (FDI) is not driven by lower environmental regulations in the host nation, it is possible that the new firms will perform badly when they get there. The alternative view of FDI is that is will raise local standards (driven by technological improvements) and create a so-called pollution-halo effect (Zarsky 1999). See Cole and Elliott (2005) for an overview.
4 Theoretical models of pollution havens include Pethig (1976), McGuire (1982) and importantly Baumol and Oates (1988) who conclude that those countries that do not control pollution emissions, whilst others
dirty products. In a review of the literature, Jaffe et al. (1995) conclude that there is little evidence to suggest that stringent environmental regulations have a significant effect on the industrial competitiveness of developed countries. Finally, Ederington et al. (2004) in a paper relatively close to this one, use industry level data on imports from 1972-1994 into the US to examine whether the apparent specialisation of the US into clean industries can be traced to the significant trade liberalisation. They find no evidence that there is a connection between trade liberalisation and imports and also no evidence that pollution intensive industries have been disproportionately affect by tariff changes (these results are consistent with Ederington et al. 2005 who show that dirty industries are less geographically footloose than clean industries and thus less sensitive to changes in tariff rates, a result that is also consistent with the KLH).

One useful approach is the recent work by Levinson and Taylor (2001), Fontagne (2001) and Keller and Levinson (2002) who, after controlling for endogeneity between trade and regulations, find some renewed support for the PHH. Ederington and Minier (2003) claim that environmental regulations should be treated as a secondary trade barrier i.e. a means of protecting domestic industry. If this is the case, then the stringency of regulations may be a function of trade as well as trade being a function of regulations. When treated as an endogenous variable, both Levinson and Taylor (2001) and Ederington and Minier (2003) find that US environmental regulations do influence US trade patterns although Cole and Elliott (2003) find little supporting evidence in a cross-country test of the Heckscher-Ohlin-Samuelson (HOV) model controlling for endogeneity but do find some support when examining so called “new” trade or imperfect competition models.

Given the ambiguous theoretical and empirical findings, this paper attempts to shed some light on the underlying empirical relationships behind the regression results of the majority of papers in this area. First, given that trade liberalisation has been a gradual process we concentrate on the resultant trade pattern changes as a means of identifying trade induced relocation of production effects. After Grossman and Krueger (1993), these changes may be referred to as the composition effect associated with trade

do, will ‘voluntarily become the repository of the world’s dirtiest industries’ (Baumol and Oates 1988 p. 265).
We aim to ascertain whether the composition effect is positive or negative in terms of the environment in the North and South, with this sign depending on which of the two hypotheses, PHH or KLH, is dominant. In recent years the nature and magnitude of trade flows between the North and South have changed significantly. More specifically, large increases in the levels of total trade and intra-industry trade, the simultaneous import and export of goods from the same industry, have been observed. This will help us ascertain whether changes in the structure of trade and the increasingly important role of intra-industry trade (IIT), is consistent with the pollution haven and/or capital-labour endowment hypothesis. By employing a large and up-to-date time series and a methodology developed by Azhar et al. (1998) we observe changes in the degree, duration and nature of trade induced effects not possible in previous studies.

Our results suggest that pollution havens may be transitory in nature, an issue first raised by Mani and Wheeler (1998). There is an indication that over recent decades, factor endowment and pollution haven effects may have cancelled each other out, perhaps explaining in part the ambiguous results of many of the previous studies. Such an observation is hard to extract from standard regression analysis alone.

Second, we investigate the hypothesis that the detection of pollution havens (and therefore the composition effect) is influenced and masked by a “categorical aggregation” issue in the relatively aggregated data employed in previous studies, an issue touched upon by Levinson and Taylor (2001). An examination of our industrial nomenclature reveals considerable variation in the pollution intensities of 3-digit and 4-digit International Standard Industrial Classification (ISIC) sectors. The implication is that within each 2-digit sector a country may be increasing its specialisation into or out of the cleaner and dirtier 4-digit sectors respectively although these changes in specialisation patterns may be missed at the aggregate level where potentially important intra-sectoral changes may be cancelling each other out.

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5 Grossman and Krueger (1993) split the environmental impact of trade liberalisation into scale, technique and composition effects. *Ceteris paribus*, the scale effect refers to the increased pollution likely to result from the economic growth generated by increased market access, whilst the technique effect refers to the changing techniques of production which accompany increasing incomes due to the increased demand for environmental regulations.

6 See Appendix B for a listing of 3-digit ISIC sectors and relative and total pollution intensities.
Third, we investigate the role of consumption as a determinant of the location of dirty production. For instance, an increase in the specialisation of production of goods from dirty industries in the developing South may arise because of an increase in their share of dirty consumption in total consumption rather than a result of the relocation of dirty industries from the North. Of course, it is possible that both of these phenomena are true. In order to investigate specialisation changes that are driven by the PHH and/or the KLH from those driven by changes in consumption patterns, we also examine changing trade patterns relative to consumption patterns.

The paper is organised as follows: Section 2 examines trade flows between developed and developing countries/regions, for the period 1961-1996 and considers the role of categorical aggregation and an analysis of trade in conjunction with consumption. Section 3 concludes.

2. Trade Flows, Consumption and Categorical Aggregation

2.1 The industry trade box

Large post-war increases in intra-industry trade across all industries mean it is important to examine, not only changes in net trade between trade partners but also all other components of trade flows. The industry trade box methodology of Azhar et al. (1998) enables us to present historical trade patterns within an analytical framework. This allows us to break down existing historical trade patterns into their constituent components, namely total trade ($TT$), net trade ($NT$), intra-industry trade ($IIT$) and the Grubel and Lloyd ($GL$) index. In addition, we calculate a trade intensity index to measure the degree to which imports have changed relative to exports for any given period. Numerous papers employ the Azhar et al. (1998) methodology as a standard tool to examine changes in trade.

$GL_i = 1 - \frac{|X_i - M_i|}{(X_i + M_i)}$

where $X_i$ and $M_i$ are the exports and imports of industry $i$ during a particular time period, usually one year. The index can take any value between 0 and 1 where the upper bound represents all trade being intra-industry in nature. See Appendix A for details of the trade box construction and the accounting definitions for $TT$, $NT$ and $IIT$. 

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7 The $GL$ index has been the standard share measure of $IIT$ since its empirical discovery (Grubel and Lloyd 1975). The $GL$ index measures the share of trade in total trade that is intra-industry. For industry $i$ for a given country the $GL$ index is given by;
patterns and to answer questions related to the changes in the structure of trade over time (see e.g. Clark et al. 2001 and Clark 2002).

It is assumed that if evidence for either competing hypothesis exists, either permanently or temporarily, during the period under investigation it will be revealed, in part, by correlations between pollution intensities and changes in the magnitude and direction of trade. In its simplest form, if exports from the North fall (rise) and imports rise (fall), it is suggestive of evidence of a pollution haven (factor endowment) effect. We acknowledge that the determinants of the relocation of industry can only be fully understood by means of a fully specified coherent model with numerous explanatory variables within a panel or bilateral trade model. However, by illustrating general trends in trade and dirty good production we are presenting a series of stylised facts to be explained by such models.

A trade box consists of a perfect square dissected along the leading diagonal by a 45-degree line. Any industry/product for any year can be represented where the top left triangle refers to the net exporter (NE) plane (exports of a product are greater than imports) and the bottom right triangle represents the net importer (NI) plane. Crucially, the dimensions of any box are defined by the largest value during the period of study. The exports and imports for a given industry and given year give us a unique trade point that can be in either the net importer or net exporter plane. Over time, trade patterns change and the trade point representing the industry under investigation will relocate to another equilibrium trade point in another area of the trade box. For each point, representing a new equilibrium, there are eight alternative categories (in each of the NE and NI planes) where that point may be relocated.

By examining consecutive trade point moves it means we can observe not only how total trade and net trade changes but also how IIT and the GL index change. This provides valuable information on the trade-induced implications for the structure of industry and the role of imperfect competition and economies of scale. In the trade literature there is a growing strand of work that investigates the smooth adjustment hypothesis, the idea

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8 The size and pattern of trade flows are not the cause of environmental quality change per se, rather, trade flows are influenced by underlying factor endowments, FDI, demand patterns, technologies and policy regimes etc.

9 See Appendix A and Figure A1 for a geometric representation of each category and a review of the trade box methodology.
that trade expansion that is intra-industry in nature results in less forbidding adjustment costs than trade changes that are inter-industry in nature, under the premise that factors of production are more easily reallocated within rather than between industries. Balassa (1966) was the first to mention the SAH directly although many authors including Krugman (1981), OCED (1994) and Cadot et al (1995) have since alluded to it directly or indirectly. See Brülhart et al. (2006) for a recent empirical study.

Our descriptive analysis concentrates on the major developing regions of Asia and Latin America, considered, with Africa, to encompass the general definition of the South. Although the South can not entirely be considered as a homogeneous entity, for this paper our distinction between the North and South is in terms of the general propensity of the South to import manufactured products and export primary goods (although this is a declining trend against a pattern of gradual trade liberalisation between 1960 and the present day). For example, the share of food and agricultural raw materials as a percentage of the South’s exports fell from 77 per cent in 1955, to 55 per cent in 1970 and 45 per cent in 1978, likewise, manufactures in 1988 account for over 58 per cent of the South’s exports, up from 27 per cent in 1970 (Sen 1995).

The main trade relationships considered in this paper are USA-Asia, UK-Asia, Japan-Asia and USA-Latin America.¹⁰ We include the US, UK and Japan as our developed countries under the assumption that, as three of the most capital intensive, high income and technologically-advanced economies, their environmental regulations will be amongst the strictest in the world and their production techniques the cleanest. Latin America and Asia are considered to be the regions in which pollution havens are most likely to have emerged, due to their rapid rates of economic growth, relatively low level of environmental regulations (or low levels of enforcement), high labour intensity and their well-formed trade links with the North. A number of authors have undertaken firm level studies on individual developing countries that allow us to benchmark our results (for example Hettige et al 1996, Hartman et al 1995, Dasgupta et al 1998, Cole et al. 2006) but they generally find that firm level environmental performance is not closely related to foreign involvement.

¹⁰ Where Asia is the total geographical region excluding Japan.
To identify those industries of interest we use data provided by Hettige et al (1994). Table 1 presents the ISIC 2-digit manufacturing sectors with the highest total pollution intensities that, for the purposes of this paper, are classified as being dirty sectors.\(^{11}\)

\textit{Table 1: Classification of Dirty ISIC Sectors}

<table>
<thead>
<tr>
<th>ISIC</th>
<th>Dirty Sectors:</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>Manufacture of wood and wood products, including furniture</td>
</tr>
<tr>
<td>35</td>
<td>Manufacture of chemicals and chemical, petroleum, coal, rubber and plastic products</td>
</tr>
<tr>
<td>36</td>
<td>Manufacture of non-metallic mineral products, except products of petroleum and coal</td>
</tr>
<tr>
<td>37</td>
<td>Basic metal industries</td>
</tr>
</tbody>
</table>


In 1995, 23\% of total US trade was conducted with Asia and 15\% with Latin America. The UK’s trade with Asia forms 9\% of its total trade whilst, for Japan, 41\% of trade is with Asia. Figure 1 presents trade boxes for our four trade pairs for total trade in pollution intensive industries for the period 1961-1996. Note, all data are deflated to 1995 US\$.\(^{12}\)

\(^{11}\) See Appendix C for further information on the pollution intensity data.  
The immediate observation is that total trade has steadily increased for all trade pairs.\textsuperscript{13} In absolute value terms Japan-Asia and UK-Asia provide the highest and lowest volumes respectively.

Evidence in support of a pollution haven effect (assuming constant production/consumption) occurs when a fall in exports is coupled with a rise in imports at times of increasing environmental regulation (this would be represented by a shift down and to the right in a trade box and would be consistent with PHH behaviour). This would

\textsuperscript{13} Any movement away from the origin (0,0) represents an increase in total trade. See Appendix A for how to conceptualise IIT and NT from trade box diagrams. Generally speaking, the closer a point is to the X=M line, the lower NT and the higher the GL index. Absolute IIT is higher, the greater and closer to the top right hand corner of the trade box.
suggest that firms in the North have shut down operations and either relocated to the South (FDI) or have been displaced by Southern producers (facing lower costs). In either case, assuming constant demand this will result in lower exports and higher imports. Likewise, the KLH would predict the opposite and that exports would increase relative to imports.

At this aggregated level, US-Asian and US-Latin American trade boxes do seem to indicate changes in trade patterns that are consistent with both pollution haven and factor endowment effects but are of a temporary nature. For example, for US-Latin America, the proportion of imports relative to exports grew considerably during the 1970s (a movement away from the \( X=M \) line) before returning to the original levels of the 1960s in the final decade. A similar story is presented for US trade with Asia, although interestingly there seems to be a lead-time of approximately ten years so imports increased disproportionately during the 1980s. This reinforces the temporary pollution haven story of Mani and Wheeler (1998) albeit with the host region changing over time. Interestingly, our results are entirely consistent with the Ederington et al. (2004) results where they show that cleaner US manufacturing is not offset of more polluting imports but rather that the composition of imports has become even cleaner.

If the factor endowment effect were prevalent we would expect to see the North’s exports increasing relative to imports. The strongest evidence for this is between Japan and Asia during the 1970s and for the US directly following the temporary pollution haven effects. In both cases, the North seems to be specialising in dirty production. However, levels of IIT remain consistently strong and are generally increasing during this period, reinforced by rising GI indices. Thus, there has been a large increase in two-way trade in different varieties of dirty goods. A factor overlooked in the existing literature. See Cole and Elliott (2003) for a fully specified model of the relationship between new trade theory, IIT and environmental regulations.

2.2 Specialisation and the Role of Categorical Aggregation

Another aspect of the trade and environment debate largely overlooked in the existing literature is the role of categorical aggregation where the structure of our industrial nomenclature means we may be missing important intra-sectoral changes in trade and
production structures. The variability in pollution intensities within ISIC sectors 34-37, means important information may be hidden. Taking the same trade relationships depicted in Figure 1, Table 2 presents the results for changes in all trade components at the 4-digit level for UK-Asia, Japan-Asia, US-Asia and US-Latin America. A total of 88 trade-pair specific sectors are considered (22 sectors for each of the 4 trade pairs).\footnote{The versatility of this approach means we can examine any time period, for any trade pairing for any level of sectoral aggregation. ISIC 3521 (drugs and medicines) is excluded from the sample, as it has no recorded trade between 1961 and 1970.}

Columns $C$ and $D$ depict changes in trade plane from net exporter to net importer or vice-versa. If exports are greater than imports ($X>M$) in both periods, the industry will be located in column $A$. If imports are greater than exports ($M>X$), then the industry will be located in column $B$.

For evidence consistent with the PHH we would expect to observe a large number of sectors moving from the net exporter to net importer plane or sectors remaining as net exporters but experiencing a decline in net exports (or remaining as net importers but experiencing an increase in net imports). In contrast, for KLH consistent behaviour we would expect to observe the opposite. Furthermore, we can also identify more subtle effects, such as those implied by changes in the GL index.

<table>
<thead>
<tr>
<th>Category</th>
<th>Possible Trade Changes</th>
<th>A $\Delta$TT&gt;0, $\Delta$NT&gt;0, $\Delta$IIT&lt;0, $\Delta$GL&lt;0 (%)</th>
<th>B $\Delta$TT&gt;0, $\Delta$NT&lt;0, $\Delta$IIT&lt;0, $\Delta$GL&gt;0 (%)</th>
<th>C $\Delta$TT&gt;0, $\Delta$NT&lt;0, $\Delta$IIT&gt;0, $\Delta$GL&lt;0 (%)</th>
<th>D $\Delta$TT&gt;0, $\Delta$NT&lt;0, $\Delta$IIT&lt;0, $\Delta$GL&gt;0 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>$\Delta$TT&gt;0, $\Delta$NT&gt;0, $\Delta$IIT&lt;0, $\Delta$GL&lt;0</td>
<td>1 0 0 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>$\Delta$TT&gt;0, $\Delta$NT&gt;0, $\Delta$IIT&gt;0, $\Delta$GL&lt;0</td>
<td>5 6 0 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>$\Delta$TT&gt;0, $\Delta$NT&gt;0, $\Delta$IIT&gt;0, $\Delta$GL&gt;0</td>
<td>48 0 2 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>$\Delta$TT&gt;0, $\Delta$NT&lt;0, $\Delta$IIT&gt;0, $\Delta$GL&gt;0</td>
<td>9 1 14 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>$\Delta$TT&lt;0, $\Delta$NT&lt;0, $\Delta$IIT&gt;0, $\Delta$GL&gt;0</td>
<td>1 0 9 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VI</td>
<td>$\Delta$TT&lt;0, $\Delta$NT&lt;0, $\Delta$IIT&lt;0, $\Delta$GL&gt;0</td>
<td>0 0 0 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VII</td>
<td>$\Delta$TT&lt;0, $\Delta$NT&lt;0, $\Delta$IIT&lt;0, $\Delta$GL&lt;0</td>
<td>0 0 0 0</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>VIII</td>
<td>$\Delta$TT&lt;0, $\Delta$NT&gt;0, $\Delta$IIT&lt;0, $\Delta$GL&lt;0</td>
<td>0 0 0 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>64 10 25 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL (number of sectors)</td>
<td>88</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: OECD trade statistics and authors' own calculations. The eight sections refer to those described in appendix A. $\Delta$TT= change in total trade, $\Delta$NT= change in net trade, $\Delta$IIT= change in intra-industry trade, $\Delta$GL= change in the GL index.
The first observation from Table 2 is that the vast majority (86%) of industries recorded an increase in total trade during this period ($\Delta TT > 0$ in categories I-IV). The majority (64%) of sectors remained net exporters (column A), with 53% experiencing an increase in net exports (column A, categories II and III). This pattern is supportive of the KLH and suggests that the North has increased its specialisation in many dirty sectors, a result that is perhaps not surprising but contrary to the PHH hypothesis.

However, we can also see that 25% of trade-pair specific sectors moved from being net exporters to being net importers (column C), whilst a further 10% remained net exporters but experienced falling net exports (column A, categories IV and V). These patterns are consistent with the PHH. Furthermore, although 64% of sectors remained net exporters, 58% also experienced an increased GL index implying that the share of imports in total trade increased whilst the share of exports fell (column A, categories III-V). Thus, over the period 1969-96 we find descriptive evidence that is supportive of both the PHH and the KLH and may explain why regression results find little evidence for the PHH.

Within the framework of the trade box we develop a simple measure of specialisation that records how net trade has changed relative to total trade changes. This enables us to view geometrically these specialisation changes across pollution intensive industries. This precludes the use of more traditional measures of specialisation such typical revealed comparative advantage (RCA) and Herfindahl type indices. We employ a measure of specialisation based on the change in net export intensity within each trade pair defined as;

$$\text{SPEC}_{\text{Sth}} = \left[ \frac{\Delta NT}{\Delta TT} \right] = \left[ \frac{X_{t+N} - M_{t+N}}{X_{t+N} + M_{t+N}} \right] - \left[ \frac{X_t - M_t}{X_t + M_t} \right] \text{ for } t \in N, N = \{1, 2, 3, \ldots \ n\} \tag{11}$$

where $X$ and $M$ represent exports and imports, respectively, and subscript $t$ denotes some initial period. The relationship between countries in the developed North ($N_{th}$) and the less developed South ($S_{th}$) is given by;

$$\text{SPEC}_{N_{th}} = -\text{SPEC}_{S_{th}} \tag{12}$$
and takes a value between -2 and 2 where the upper value indicates that in the initial period $X=0$ and hence total trade is made up entirely of imports whilst in the later period $M=0$ and total trade consists entirely of exports. If $\text{SPEC}_{St} = -2$ then the opposite must have happened. For example, if exports fall from 10 to 0 and imports rise from 0 to 10, $\text{SPEC}_{St}$ will record a value of −2, implying a total reversal in the direction of net trade.

Negative $\text{SPEC}_{Nth}$ values would therefore be consistent with pollution haven effects since they indicate that net exports as a proportion of total trade have fallen over time whilst positive values are more likely to be associated with the factor endowment effect. The closer to −2 (+2) the $\text{SPEC}_{Nth}$ index is, the greater the support for the PHH (KLH). We examine bilateral trade pair indices for five periods between 1969 and 1996. Table 3 provides $\text{SPEC}_{Nth}$ values for our trade pairings at the 2-digit ISIC level.


<table>
<thead>
<tr>
<th>Year</th>
<th>Japan-Asia</th>
<th>ISIC 34</th>
<th>ISIC 35</th>
<th>ISIC 36</th>
<th>ISIC 37</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1969-1975</td>
<td></td>
<td>0.10</td>
<td>-0.14</td>
<td>-0.14</td>
<td>0.32</td>
<td>0.08</td>
</tr>
<tr>
<td>1976-1982</td>
<td></td>
<td>-0.06</td>
<td>-0.18</td>
<td>0.06</td>
<td>-0.12</td>
<td>-0.16</td>
</tr>
<tr>
<td>1983-1989</td>
<td></td>
<td>0.18</td>
<td>0.06</td>
<td>-0.54</td>
<td>-0.30</td>
<td>-0.12</td>
</tr>
<tr>
<td>1990-1996</td>
<td></td>
<td>-0.42</td>
<td>0.24</td>
<td>0.06</td>
<td>0.12</td>
<td>-0.20</td>
</tr>
<tr>
<td>1969-1996</td>
<td></td>
<td>-0.46</td>
<td>-0.24</td>
<td>-0.52</td>
<td>-0.10</td>
<td>-0.22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>UK-Asia</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1969-1975</td>
<td></td>
<td>-0.14</td>
<td>0.06</td>
<td>0.00</td>
<td>0.04</td>
<td>0.06</td>
</tr>
<tr>
<td>1976-1982</td>
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<td>-0.20</td>
<td>-0.04</td>
<td>-0.02</td>
<td>0.54</td>
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</tr>
<tr>
<td>1983-1989</td>
<td></td>
<td>-0.18</td>
<td>-0.28</td>
<td>-0.50</td>
<td>0.22</td>
<td>-0.20</td>
</tr>
<tr>
<td>1990-1996</td>
<td></td>
<td>0.00</td>
<td>0.02</td>
<td>0.06</td>
<td>-0.28</td>
<td>-0.02</td>
</tr>
<tr>
<td>1969-1996</td>
<td></td>
<td>-0.46</td>
<td>-0.30</td>
<td>-0.46</td>
<td>0.02</td>
<td>-0.22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
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<th></th>
<th></th>
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<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1969-1975</td>
<td></td>
<td>-0.12</td>
<td>-0.24</td>
<td>0.18</td>
<td>0.20</td>
<td>-0.06</td>
</tr>
<tr>
<td>1976-1982</td>
<td></td>
<td>0.02</td>
<td>0.16</td>
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<td>1983-1989</td>
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<td>-0.18</td>
<td>-0.38</td>
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<td>-0.08</td>
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<tr>
<td>1990-1996</td>
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<td>-0.10</td>
<td>0.30</td>
<td>-0.02</td>
<td>-0.24</td>
<td>0.06</td>
</tr>
<tr>
<td>1969-1996</td>
<td></td>
<td>-0.44</td>
<td>-0.24</td>
<td>-0.32</td>
<td>-0.32</td>
<td>-0.22</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>USA-Latin America</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1969-1975</td>
<td></td>
<td>0.02</td>
<td>-0.10</td>
<td>-0.14</td>
<td>0.44</td>
<td>-0.10</td>
</tr>
<tr>
<td>1976-1982</td>
<td></td>
<td>-0.18</td>
<td>0.04</td>
<td>-0.04</td>
<td>-0.44</td>
<td>-0.02</td>
</tr>
<tr>
<td>1983-1989</td>
<td></td>
<td>-0.28</td>
<td>0.32</td>
<td>-0.60</td>
<td>0.08</td>
<td>0.26</td>
</tr>
<tr>
<td>1990-1996</td>
<td></td>
<td>-0.04</td>
<td>0.14</td>
<td>0.14</td>
<td>0.02</td>
<td>0.10</td>
</tr>
<tr>
<td>1969-1996</td>
<td></td>
<td>-0.52</td>
<td>0.30</td>
<td>-0.86</td>
<td>-0.56</td>
<td>0.06</td>
</tr>
</tbody>
</table>

Source: OECD trade data and authors’ own calculations
The profusion of negative signs for all trade pairs in Table 3 indicates that many sectors have experienced declining net export intensity throughout the period 1969-96. This finding complements Figure 1 and Table 2 by indicating that even where the North remains a net exporter (for example Japan-Asia and UK-Asia in Figure 1), imports are often rising relative to exports. ISIC sectors 34 (wood and wood products) and 36 (non-metallic minerals) are notable in that all trade pairs return negative values for the full period 1969-96. Across all sectors, USA-Latin America provides some of the largest absolute values. Evidence for the factor endowment effect seems a lot weaker although ISIC 35 (Chemicals and Petroleum) and ISIC 37 (Basic Metals) provide some indication of a factor endowment effect for certain periods especially for the US-Latin America. These results make intuitive sense with the north specialising in the more capital intensive, high skilled, less mobile sectors.

To provide a more robust link between trade changes and environmental quality, Table 4 presents Spearman’s rank correlation coefficients between the magnitude of our net trade intensity index and relative pollution intensities for four equal periods for 23 4-digit sectors.15

**Table 4. Net Trade and Pollution Intensities for North-South Trade Pairs, 1969-96**

<table>
<thead>
<tr>
<th>Period</th>
<th>USA-Asia</th>
<th>Japan-Asia</th>
<th>UK-Asia</th>
<th>USA-Lat. Am.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spearman rank correlations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1969-1975</td>
<td>0.17</td>
<td>0.65*</td>
<td>0.44*</td>
<td>0.05</td>
</tr>
<tr>
<td>1976-1982</td>
<td>-0.05</td>
<td>-0.24</td>
<td>-0.26</td>
<td>-0.23</td>
</tr>
<tr>
<td>1983-1989</td>
<td>0.11</td>
<td>-0.12</td>
<td>0.02</td>
<td>-0.04</td>
</tr>
<tr>
<td>1990-1996</td>
<td>-0.13</td>
<td>0.45*</td>
<td>0.04</td>
<td>-0.59*</td>
</tr>
<tr>
<td>1969-1996</td>
<td><strong>0.26</strong></td>
<td><strong>0.55</strong></td>
<td><strong>-0.53</strong></td>
<td><strong>-0.19</strong></td>
</tr>
</tbody>
</table>

* statistically significant at 95% confidence level

A negative correlation between pollution intensity and net trade intensity in Table 4 implies exports have declined the most (relative to imports) in industries with large total

15 The Spearman’s rank correlation is not susceptible to serious influence by extreme values so valid tests can be undertaken for very general population distributions. The resulting test is non-parametric. The Spearman’s correlation tests the null hypothesis of no association between a pair of random variables. For a sample size, \( n \), tabulated values are \( r_{n} \) that are exceeded with probability \( \alpha \) by the rank correlation when the null is true. We test against the alternative of some association where the cut-off point for the distribution for 23 pairs of observations is \( r_{23,0.05} = 0.35 \) and \( r_{23,0.025} = 0.42 \). We assume that the relative ‘dirtiness’ of an industry is unchanged over this period, 1969-1996.
pollution intensities. A positive correlation suggests that the North is increasing its exports of “dirty” products relative to imports.

Interestingly, the strongest evidence of pollution haven consistent behaviour is again found for USA-Latin America. Evidence for USA-Asia is mixed while for Japan-Asia and UK-Asia positive correlations are estimated indicating increasing specialisation in pollution intensive activity. This is perhaps the best evidence for a factor endowment effect and is especially strong for Japan-Asia. These results re-emphasise the importance of using disaggregated data and looking at bilateral trade relationships.

A final point regarding the issue of aggregation concerns the large variance in pollution intensities within sectors. This could mean that evidence for a composition effect may only show up at a highly disaggregated level where firms in the North may continue to produce goods within the same aggregate industry definition but then specialise in the relatively cleaner products (with more advanced technology).

Trade boxes generated at high levels of disaggregation demonstrate significant differences within sectors in terms of trade pattern and volume. In Table 5 we calculate rank correlations within ISIC 35.

Table 5. Net Trade and Pollution Intensities for Developed-LDC trade Pairs, 1969-96, ISIC 35 (Manufacture of chemicals, petroleum, coal, rubber and plastic products)

<table>
<thead>
<tr>
<th>Period</th>
<th>USA-Asia</th>
<th>Japan-Asia</th>
<th>UK-Asia</th>
<th>USA-Lat. Am.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Spearman's rank correlations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1969-1975</td>
<td>-0.33</td>
<td>0.35</td>
<td>0.38</td>
<td>0.28</td>
</tr>
<tr>
<td>1976-1982</td>
<td>0.51*</td>
<td>-0.25</td>
<td>0.10</td>
<td>-0.34</td>
</tr>
<tr>
<td>1983-1989</td>
<td>0.14</td>
<td>0.19</td>
<td>-0.37</td>
<td>0.06</td>
</tr>
<tr>
<td>1990-1996</td>
<td>0.43</td>
<td>0.23</td>
<td>0.14</td>
<td>-0.43</td>
</tr>
<tr>
<td>1969-1996</td>
<td>0.23</td>
<td>0.27</td>
<td>0.29</td>
<td>-0.03</td>
</tr>
</tbody>
</table>

* statistically significant at 90% confidence level

Table 5 shows that there is relatively little evidence of the North specialising in the cleaner varieties of that sector’s output at home and moving production of the dirtiest products to the South as we may have expected. However, Table 5 does provide some

16 Trade boxes at the 4-digit level are available from the authors upon request.
17 ISIC 35 is the only sector that has enough 4-digit industries (twelve) to be statistically meaningful. We compare pollution intensities for each 4-digit sector with its export intensity.
support for the robustness of our aggregate results in the preceding Section. The large number of positive values in this highly capital-intensive industry also lends support to the factor endowment hypothesis with all parts of the Chemicals and petroleum industry locating in the already industrialised nations.

2.3. Trade and Consumption

Whilst trade and specialisation patterns provide useful information in the search for PHH and KLH consistent activity, Janicke et al. (1997) argue that increasing specialisation in dirty industries in developing countries may result from an increase in their share of consumption of dirty output, rather than from the relocation/displacement of such industries from developed regions. Similarly, any falling specialisation in dirty industries in the developed world may be due to a falling share of world consumption, rather than due to developed country demand now being met by developing country production. By the same reasoning, the KLH may only be considered to hold if trade liberalisation results in an increase in a developed country's specialisation in capital intensive production relative to its consumption of that production (and vice versa for a developing country).

Consider a measure of a developed country’s net exports from the dirty sector, with the developing region, as a proportion of the developed country’s total consumption from that sector. This is defined as follows;

\[
NETXC_{ikt}^{j} = \frac{X^{j}_{ikt} - M^{j}_{ikt}}{C^{j}_{ikt}}
\]  

(13)

where,

\[
C^{j}_{ikt} = P^{j}_{ikt} - X^{w}_{ikt} + M^{w}_{ikt}
\]  

(14)

and \(X, M\) and \(P\) represent exports, imports and production, respectively, in developed country \(i\), developing country/region \(j\), sector \(k\) and time period \(t\). Superscript \(w\) denotes world.
The PHH would predict that NETXC for a pollution intensive sector, calculated from the North's point of view, would decline over time in the face of increased trade liberalisation (or increasing environmental regulations). In contrast, the KLH would argue that NETXC, again for a dirty sector, would increase over time, given that pollution intensive sectors are typically capital intensive. Given this reasoning, we investigate the degree of correlation between the pollution intensity of a sector and the rate of change of NETXC. We estimate the rate of change of NETXC for the period 1977-95 and for the sub-periods 1977-85 and 1985-95, for the 23 4-digit ISIC sectors within the four 2-digit sectors.\(^{18}\) This sector-specific rate of change variable is then correlated against each sector's pollution intensity. Spearman rank correlation coefficients are presented in Table 6.

<table>
<thead>
<tr>
<th>Period</th>
<th>USA-Asia</th>
<th>Jap-Asia</th>
<th>UK-Asia</th>
<th>USA-Lat.Am.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977-85</td>
<td>-0.49*</td>
<td>-0.13</td>
<td>0.51*</td>
<td>0.08</td>
</tr>
<tr>
<td>1985-95</td>
<td>0.54*</td>
<td>-0.11</td>
<td>-0.04</td>
<td>-0.05</td>
</tr>
<tr>
<td>1977-95</td>
<td>-0.15</td>
<td>0.1</td>
<td>0.28</td>
<td>0.04</td>
</tr>
</tbody>
</table>

Note: * statistically significant at 95% confidence level.

For USA-Asia we find statistically significant PHH evidence for the first half of the period, with similarly significant evidence of the KLH for the latter half of the period. This is broadly compatible with Figure 1 and, in particular, with the strong movement from net exporter to net importer during the early 1980s, a movement that is PHH consistent. For Japan-Asia we find mixed evidence, whilst for UK-Asia we again find KLH consistent activity in the early part of the period and for the period as a whole. Table 4 made a very similar finding.

Our findings appear varied but are perhaps more consistent than they at first appear. Our results clearly indicate that neither the PHH nor the KLH can singularly explain the observed changes in trade patterns. We have periods that are PHH consistent and periods that are KLH consistent, and these periods vary by trade pair. This finding raises 2 possibilities; (i) both hypotheses are ‘correct’ and are at work with one dominating the

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\(^{18}\) To avoid the rate of change being influenced too heavily by the years 1977 and 1995, it is calculated as the difference between the mean of the last three years and the mean of the first three years, as a proportion of the mean of the first three years.
other at certain times, depending on temporal and/or trade-pair characteristics, or (ii) both theories are invalid and other forces are driving trade patterns. Cole and Elliott (2003) explore these possibilities further using regression techniques to test for the determinants of trade in pollution intensive industries for old and new trade theories. The results are broadly supportive of the analytical results in this paper.

3. Conclusions

The complex interrelationships between trade, environmental regulations and the composition of the global economy have become a focal point for international policy makers. With this in mind, this paper has examined trade patterns to ascertain whether comparative advantage in pollution intensive production is driven by environmental regulation differentials (the PHH) and/or factor endowment differentials (the KLH).

Since the PHH and the KLH generate opposing forces, if both exist simultaneously they will tend to cancel each other out. We have therefore tried to identify the periods and trade-pairs when one force dominated the other. An examination of the components of trade (NT, TT, IIT, GL) indicates that, over the period 1969-96, there are periods for which certain trade-pairs behaved in a manner consistent with the PHH and other periods when behaviour was more consistent with the KLH. We also demonstrate that there is considerable variation in the behaviour of 4-digit sectors that would not necessarily be identified at the more aggregated 2-digit level. Our SPEC and NETXC measures find temporary, statistically significant, evidence of both the PHH and the KLH. The best evidence for the PHH is found for USA-Latin America and USA-Asia, whilst evidence of the KLH is strongest for Japan-Asia and UK-Asia.

To conclude, we find evidence to suggest that differences in environmental regulations and factor endowments are, to some extent, influencing global trade patterns. This raises the possibility of conflicting forces in operation that may cancel each other out during certain periods. These discoveries are only made through an examination of North-South trade pairs, through an examination of sub-periods within our large time series. Future research may wish to extend this analysis by means of a fully specified panel or bilateral trade model with explanatory variables to allow the researcher to quantify the degree to
which changes in trade patterns influence changes in the location of the production of dirty goods.
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Appendix A. Industry trade box and equi-trade components

The components of international trade flows consist of exports \((X)\), imports \((M)\), total trade \((TT)\), net trade \((NT)\), intra-industry trade \((IIT)\), and the Grubel-Lloyd \((GL)\) index. For any industry in any period, \(X\) and \(M\) must always be greater than or equal to zero. The accounting relationships between each component is as follows: Firstly, \(TT\) is the sum of \(M\) and \(X\) and can be decomposed into its constituent components namely \(NT\) and \(IIT\) where \(TT=NT+IIT\). Secondly, the \(GL\) index measures the share of \(IIT\) in \(TT\).

Suppose that a hypothetical study of international trade flows for industry \(i\) consists of the set of all \(X\) and \(M\) for \(n\) years.\(^{19}\) i.e. \(N = \{1,2,3,....n\}\) and \(\forall t \in N\), we have \(X_t,M_t,TT_t,NT_t,IIT_t,GL_t \geq 0\). An industry trade space can therefore be constructed that is equivalent to the first quadrant of a Cartesian co-ordinate plane where all trade components are positive. We define the dimensions of the industry trade box as follows:

\[
\text{max}(TT) = \text{max}(X) + \text{max}(M)
\]

\[
\text{max}(NT) = \text{max}(|X - M|)
\]

And \(\text{max}(|X - M|) = \text{max}(X) - \text{min}(M)\) or \(\text{max}(M) - \text{min}(X)\)

\[
\text{max}(IIT) = \text{max}(2\text{min}(X,M))
\]

Suppose that \(\forall t \in N\), \(\text{max}(X_t) > \text{max}(M_t)\),

if \(X > M \Rightarrow XX = X^2 > MM = M^2\)

\(\Rightarrow X^2 > MX; \ X^2 > NT; \ X^2 > IIT \Rightarrow X^2 = \text{max}(X_t)\ \text{max}(X_t)\).

Each respective industry's trade box will have sides equal to \(\text{max}(X_t)\) or \(\text{max}(M_t)\) and the area or dimensions of the trade box is given by \(D = \left[\text{max}(X_t^2, M_t^2)\right]\).

The main 45° diagonal from the origin bisects the box into two equal triangles (see Fig. A1) and is simply the locus of balanced trade where \(X=M\). The two triangular planes are

\(^{19}\) Trade values are ordinarily available at certain uniformly spaced time intervals, monthly, quarterly or annually. This means we are able to define \(X\) and \(M\) as having an initial time, denoted by \(t = 0\) and subsequent time periods, \(t = 1, \ t = 2, \ etc. \) Hence, can study the behaviour of the trade components that
an upper triangle containing co-ordinate points \((X_t, M_t)\) where \(X_t > M_t\) (defined as the net exporter \((NE)\) plane) and the lower triangle where \(M_t > X_t\) (defined as the net importer \((NI)\) plane). The loci of equi-trade components are presented in Figure A1. Any two points on a given line share the same value (the arrows refer to increasing values of the respective trade component).

**Figure A1. Hypothetical Industry Trade Box with Adjustment Regions**

Assuming a starting point at either \(A\) or \(B\) in the NE or NI plane respectively, the numbered regions refer to all possible trade component changes. For example, a move from \(A\) to region \(IV_{ne}\) means that industry would experience an increase in \(TT\), the \(GL\) index and \(IIT\) but a fall in \(NT\). Likewise, a move to region \(III_{ni}\) would mean all four trade-components increase. The regions in Figure A1 match those in Table 2.

---

*consist of the various functional forms of these export and import values over this discrete set of values. All \(X\) and \(M\) values in each period are assumed to be deflated to constant prices.*
Table B1. Pollution Intensities from Hettige et al. (1994)\textsuperscript{20}

<table>
<thead>
<tr>
<th>2 digit ISIC sectors</th>
<th>3 digit ISIC sectors</th>
<th>Pollution Intensities</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td>TOTAL Pollution</td>
</tr>
<tr>
<td>37</td>
<td></td>
<td>60310</td>
</tr>
<tr>
<td>371</td>
<td></td>
<td>60800</td>
</tr>
<tr>
<td>372</td>
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</tbody>
</table>

Table B1 provides pollution intensities for the four dirtiest 2-digit sectors. The 3-digit sectors are ranked, in descending order, within each 2-digit sector, according to total pollution intensity. The 2-digit sectors are similarly ranked. Pollution intensities are measured in pounds of pollution per million 1987 US dollars of output. Total pollution intensity is a sum of the individual intensities for sulphur dioxide (SO\textsubscript{2}), nitrogen dioxide (NO\textsubscript{2}), volatile organic compounds (VOC), carbon monoxide (CO) and very fine particulate matter (PM\textsubscript{10}). These intensities are estimated by Hettige et al. (1994) who merged manufacturing census data from over 200,000 factories throughout the USA with US Environmental Protection Agency data on air pollution emissions. Whilst these intensities are for the USA alone, they are also used for the UK and Japan in the absence of any alternative data. Although the calculation of a total pollution-intensity may be criticised on the grounds that one pound of one pollutant may have a very different impact from one pound of another, this total pollution intensity is only used to rank the individual sectors. In most cases the rankings would be very similar if based on the intensities of each individual pollutant.

\textsuperscript{20} Intensities for 4-digit ISIC sectors have not been included for reasons of space.