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Empirical relevance of the Hillman condition for revealed comparative advantage: 10 stylized facts

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The theoretically necessary and sufficient condition for the correspondence between 'revealed' comparative advantage and pre-trade relative prices derived by Hillman (1980) is analysed empirically for virtually all countries of the world over an extended period of time. This yields 10 stylized facts, including that (i) violations of the Hillman condition are small as a share of the number of observations, but substantial as a share of the value of world exports, (ii) violations occur relatively frequently in the period 1970–1984 and more rarely in the period 1985–1997 and (iii) violations occur foremost in primary product and natural resource intensive sectors and for countries in Africa, the Middle East, Latin America and Central and Eastern Europe. An additional bonus of verifying the Hillman condition in empirical research is its ability to identify erroneously classified trade flows.

I. Introduction

The concept of 'revealed' comparative advantage (RCA), introduced by Liesner (1958) but refined and popularized by Balassa (1965) with his concomitant index, is widely used empirically to identify structural trade-related patterns across countries. It is the starting point for Peterson's (1988) analysis of the export performance in travel services; Porter (1990) uses it to identify strong sectoral clusters; it is the basis for Amiti's (1999) analysis of specialization patterns in Europe; Bojnec (2001) employs it for his study of Central and Eastern European agricultural trade; Fertö and Hubbard (2003) use it to analyse the competitiveness of Hungarian agri-food sectors; Hinloopen and van Marrewijk (2004) use it to analyse the dynamics of Chinese comparative advantage and Svaleryd and Vlachos (2005) examine to what extent a related index value is instrumental for explaining a country's level of financial development. The dynamics of (the distribution of) the Balassa index as such are considered in Proudman and Redding (1998, 2000) and Hinloopen and van Marrewijk (2001).

Balassa (1965), in fact, proposes two measures, one based on relative export shares (the one labelled 'Balassa index' throughout the remainder of this article) and one using export–import ratios.

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Meanwhile, both indices have been discussed in detail (for an overview of the discussions on measuring RCA, see Webster, 1991) and the prevailing consensus is that proper measures of export performance should be based on relative export shares. First, trade interventions could compromise the effectiveness of the export–import measure as import data reflect trade restrictions more readily. Balassa (1977) therefore, shied away from its use focusing only on the measure using relative export shares. Second, in the modern 'new trade' era, a problem of the use of net export data is the difficulty with which they can identify successful intra-industry trade clusters. These are readily identified when using relative export shares. Third and most importantly, a solid theoretical foundation for the Balassa index is provided by Hillman (1980). He diagrammatically develops a necessary and sufficient condition for the correspondence between the Balassa index and pre-trade relative prices in cross-country sector comparisons, the so-called Hillman condition. As Hillman (1980, p. 320) notes: 'Whether this condition obtains is a matter for empirical investigation'. It is precisely that question which we answer in this article.

Since the Hillman condition can be easily verified empirically, it is rather surprising that it is ignored by the large majority of empirical studies on RCA that have appeared since. The only empirical investigation to date of the Hillman condition as such is the study of Marchese and Nadal De Simone (1989), who analyse the exports of 118 developing countries at the 1-, 3-, 4- and 5-digit level of sector aggregation. They conclude that in the year 1985 (the only year considered in their study) the Hillman condition does not hold for about 9.5% of the value of exports of their group of developing countries. The only empirical study into comparative advantage that we are aware of that explicitly mentions to include only those sectors that meet the Hillman condition is Hinloopen and van Marrewijk (2001). They find that the Hillman condition does not hold for about 0.5% of the number of observations in their sample, which corresponds to about 7.0% of the value of exports.

In this article the empirical relevance of the Hillman condition is thoroughly investigated using a comprehensive dataset consisting of annual recordings on bilateral trade flows for 747 4-digit sectors, 165 countries and 28 years, yielding a total of slightly less than 18.4 million positive observations (indeed, not every possible bilateral trade flow actually occurred; see also Feenstra, 2000). This dataset allows for an investigation of the Hillman index for virtually all countries of the world, over an extended period of time and for four different levels of sector aggregation (Appendix A contains a description of the dataset). The empirical relevance of the Hillman condition can thus be established.

As the dataset represents a large part of recent international trade flows, the empirical findings are presented as stylized facts. Among these are the observation that violations of the Hillman condition are small as a share of the number of observations, but often represent a disproportionally large value of trade. Including these observations in studies into (the dynamics of) RCA could thus yield quite inaccurate inferences. Further, two periods can be distinguished as to the severity with which the Hillman condition is violated. From 1970 through 1984 violations happen relatively frequently and they represent a significant fraction of the value of total trade, while from 1985 onwards, violations hardly ever occur and represent an insignificant fraction of total trade value. Hence 1985, the year analysed by Marchese and Nadal De Simone (1989), is not representative for the extent to which violations of the Hillman condition are empirically relevant. Also, violations do not occur randomly across sectors or countries. They occur foremost in sectors producing primary products or that are natural resource intensive and in countries located in Africa, the Middle East, Central and Eastern Europe and Latin America. The exclusive focus of Marchese and Nadal De Simone (1989) on a group of developing countries is, again, not representative for the empirical relevance of the Hillman condition.

An important by-product from restricting the analysis to those observations meeting the Hillman condition is that observations based on erroneously classified trade flows are identified (by the Hillman condition) and consequently can be dismissed. Indeed, the larger a country's market share in world exports for a particular commodity, the more likely the Hillman condition is violated. As erroneously aggregated trade flows yield artificially large market shares, they are identified by the Hillman condition. If only for this screening property of applying the Hillman condition, it is recommended that it is checked always in empirical studies into RCA.

The next section briefly introduces the Balassa index of RCA and the concomitant Hillman condition. Section III discusses the relation between violations of the Hillman condition and the extent of data aggregation. The ability of the Hillman condition to identify erroneously classified trade flow is illustrated in Section IV. All cases violating the Hillman condition are subsequently presented and discussed in Section V. Section VI summarizes and concludes.

II. The Balassa Index and the Hillman Condition

Since it is hard to gauge the importance of a sector without a frame of reference, Balassa (1965) introduced normalized export shares as an indicator of RCA:

$$\mathrm{BI}^j_{i,t} = \frac{X^j_{i,t}/X_{i,t}}{X^j_t/X_t}, \quad i \in I,\ j \in J, \tag{1}$$

where $X^j_{i,t}$ are country i's exports in sector j during period t, I is a group of reference countries, J is the bundle of potential export products, $X^j_t = \sum_i X^j_{i,t}$, $X_{i,t} = \sum_j X^j_{i,t}$ and $X_t = \sum_i \sum_j X^j_{i,t}$. If $\mathrm{BI}^j_{i,t} > 1$, country i is said to have a RCA in the production of commodity j in time period t as its export share for product j is larger than the concomitant export share in the group of reference countries I. This group may vary, as indeed it does in the studies referred to in the introduction and is most often determined by the largest set of reference countries for which reliable data are available.

Hillman (1980) examines the correspondence between the Balassa index and pre-trade relative prices in cross-country comparisons for a specific sector under homothetic preferences by forming a Hicksian composite commodity for all other sectors. More specifically, the question he answers is (Hillman 1980, pp. 317–18)[1]: 'if two countries, $j = 1$, 2, are observed to be exporting a particular good i in the world market, does $\beta^1_i > \beta^2_i$ imply that, with respect to a common numéraire good, good i was relatively less expensive in country 1's autarkic equilibrium than it was in country 2's autarkic equilibrium?'. Answering this question affirmatively implies that one can draw valid inferences regarding a country's true comparative advantages based on empirical observations of the Balassa index. As the concomitant transformation of the Balassa index has to be monotonic, Hillman's condition can be interpreted as a monotonicity condition for scaling a country's exports by a measure of its (sector) size. In particular, the Hillman condition states that:

$$1 - \frac{X^j_{i,t}}{X^j_t} > \frac{X^j_{i,t}}{X_{i,t}}\left(1 - \frac{X_{i,t}}{X_t}\right). \tag{2}$$

Condition (2) must be met for the value of the Balassa index (1) to be in concordance with pre-trade relative prices. Note that the Hillman condition (2) consists of three parts that all have a distinct economic interpretation:

- *market share*, as measured by $X^j_{i,t}/X^j_t$, i.e. the share of a country's exports in a particular sector relative to the total exports in that sector of the group of reference countries;
- *degree of export specialization*, as measured by $X^j_{i,t}/X_{i,t}$, i.e. the share of a country's exports in a particular sector relative to that country's total exports;
- *country size*, as measured by $X_{i,t}/X_t$, i.e. the share of a country's total exports relative to total exports of the group of reference countries.

As Hillman (1980) notes, violations of (2) readily obtain in case a country exports one commodity only (in which case $X^j_{i,t} = X_{i,t}$ and the degree of export specialization is equal to one) or when a country is the sole supplier of a particular product (in which case $X^j_{i,t} = X^j_t$ and the market share is equal to one). In general, the Hillman condition is violated if a country has a significantly high market share in the supply of the particular commodity in combination with a 'high enough' degree of export specialization.[2]

Figure 1 divides the market share – export specialization space into two sub-areas, indicating whether the Hillman condition is violated or not, for an infinitely small country size. For larger country sizes, the dividing line shifts clockwise outwards (see Fig. A2 in the Appendix for a three-dimensional image), indicating that the Hillman condition is somewhat less stringent for large countries. In case of violations, an increase in a country's exports in a particular sector increases this sector's export share in

[1] In the quote, β^j_i refers to country j's Balassa index for good i. Hillman (1980) also shows that a similar condition regarding cross-sector comparisons cannot be derived.

[2] Indeed, as Marchese and Nadal de Simone (1989) consider developing countries only, countries that typically export a small number of commodities (i.e. raw materials) for which they hold relative large (world) market shares, they find trade flows violating the Hillman condition to represent a higher percentage of total trade (9.5%) than reported here (for the sample year considered by Marchese and Nadal de Simone (1989) these percentages are, 1.67, 1.23, 0.68 and 0.04, at, respectively, the 1-, 2-, 3- and 4-digit level of sector aggregation; see also Stylized fact 10 subsequently). On the other hand, Hinloopen and van Marrewijk (2001) consider EU countries only, also as the group of reference countries, thereby generating relatively large export market shares. Violations of the Hillman condition are thus also more likely, *ceteris paribus*. These violations represent 7% of total trade in their sample compared to the 3.4% recorded here for the same level of sector aggregation (see also the subsequent Stylized fact 1).

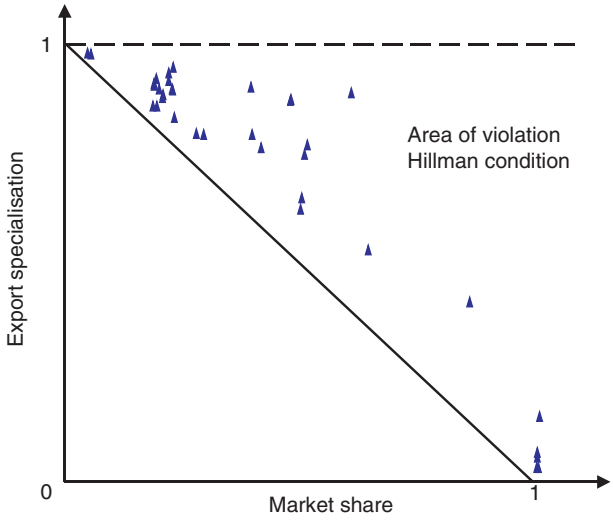

Fig. 1. Violations of the Hillman condition in market share – export specialization space[a]
Note: [a]The demarcation line is for infinitely small countries; the observations correspond to the 4-digit observations in Table 4, see Section V (see also Fig. A1 in Appendix 2).

world trade more than that it increases the sector's national export share. As a result, the Balassa index drops in value, which contradicts the notion of RCA.

III. Data Aggregation

Before discussing in detail the characteristics of all observations violating the Hillman condition, the impact of sector aggregation on the Hillman condition being violated or not needs to be addressed. At lower levels of aggregation, where more sectors are identified, it becomes 'easier' in principle for a country to realize a large market share in a specific sector. This tends to increase the likelihood that the Hillman condition is violated. On the other hand, the degree of export specialization falls at lower levels of aggregation, which tends to decrease the likelihood of violation. The net result of these two forces rules the likelihood of violating the Hillman condition in relation to data aggregation.

Table 1 summarizes the violations of the Hillman condition for different levels of data aggregation. As a share of the number of observations, the violations are virtually insignificant; as a share of the value of total exports, the violations are substantial. These findings suggest that in practice, violations of the Hillman condition do not happen often, but when they do occur they usually involve (very) large trade flows. These observations lead to

Table 1. Aggregation and share of exports not satisfying Hillman's condition, 1970–1997

	1-digit	2-digit	3-digit	4-digit
Number of observations	73	79	88	35
Share of number of observations (%)	0.2148	0.0477	0.0176	0.0051
Value of exports (billion US$)	1319	1263	1291	127
Share of value of exports (%)[a]	2.8802	3.4266	2.6672	0.5287
Average market share	0.0758	0.1395	0.1965	0.3988
Average export specialization	0.9809	0.9278	0.8881	0.7319
Average country size	0.0128	0.0132	0.0132	0.0073
Number of violations attributed to[b]				
• market share	0	1	2	8
• export specialization	73	78	86	27
Share of total trade covered (%)	100.00	99.67	99.46	60.39

Notes: [a]As a percentage of total trade available at the respective levels of data aggregation.
[b]Violations are attributed to market share if market share exceeds 50%, see Table 4 for details.

the first empirical regularity:

Stylized fact 1. *Violations of the Hillman condition occur in* 0–0.2*% of all cases*; *these violations represent* 0–3.4*% of total trade*.

Table 1 also shows that sector aggregation matters. The average market share of violation cases increases with more refined sector definitions, while at the same time both average export specialization and, to a lesser extend, country size decrease. Although an increasing market share and a decreasing country size enhance the probability of violation, going through the 1-, 2-, 3- and 4-digit sector aggregations shows that these effects are on average more than corrected for by the concomitant reduction in export specializations. That is:

Stylized fact 2. *The higher is the degree of sector aggregation*, *the higher is the probability that the Hillman condition is violated*.

At the same time, the value of total trade involved in the violation cases is about the same for the 1-, 2- and 3-digit levels of sector aggregation. The reduction in trade value represented by all observations violating the Hillman condition at the 4-digit sector aggregation level is attributable to the reduced coverage of total trade. Accordingly:

Stylized fact 3. *The value of trade represented by all cases violating the Hillman condition is hardly affected by the level of sector aggregation*.

Stylized fact 1 indicates that the set of observations violating the Hillman condition represents a substantial part of total trade. In 2002, 1% of total trade corresponded to about US$ 80 billion (World Bank, 2004). Stylized fact 3 reveals that this value is hardly affected by the level of sector aggregation; no matter at which level of sector aggregation RCA is examined, the group of observations violating the Hillman condition remains equally important as to the value of trade they represent. Checking for the validity of the Hillman condition and dismissing those observations not passing the test thus seems to be an obvious routine to be used under all circumstances.

An obvious stylized fact would be the classification of violations along the 'market share' and 'export specialization' component of the Hillman condition.[3] However, no objective measures exist to classify an observation as representing a too large market share and/or a too high degree of export specialisation. Yet some insights along these components are illustrative. Table 1 therefore identifies all violations along these two components whereby a market share of 50% or more is taken to be decisive. That is, if the Hillman condition is violated and the related market share exceeds 50%, it is attributed to a too large market share. In all other cases the violation is attributed to a too high degree of export specialization.

Classified in this way, almost all violations at the 1-, 2- and 3-digit level of data aggregation are attributed to a too high degree of export specialization, indicating that the country in question is exporting virtually only one commodity at that level of aggregation. On the other hand, at the 4-digit level of data aggregation a substantial share (23%) of the violations is attributed to a too large market share. Given that at lower levels of data aggregation more narrowly defined markets are identified, this classification is in line with expectations.

Finally, the reduction in coverage of total trade at the 4-digit level of sector aggregation is due to yet another problem: erroneous trade flow classifications. Indeed, erroneous data aggregation is a problem in applied research if it remains unnoticed. For empirical studies into RCA, the Hillman condition appears to be an effective screening device for detecting these errors.

IV. Data Classification

An important advantage of analysing trade flows in general and comparative advantage in particular at lower, more detailed levels of aggregation is the increased coherence and homogeneity of the specific markets analysed and therefore the more precise identification of RCA. An important disadvantage is that some part of all trade is not specified at lower levels of aggregation, such that a lower share of total trade is represented by the data. Table 1 shows that it is especially relevant here at the 4-digit level of sector aggregation, which represents only some 60% of total trade.

Identifying and subsequently ignoring the remaining 40% is important however. At the 4-digit level, raw data could contain trade flows effectively classified at the 3-digit level. For the dataset used here this occurs, for instance, for category 752X 'automatic data processing machines & units thereof' which could refer to trade flows in any of the more detailed true 4-digit SITC (Standard International Trade Classification) categories 7521, 7522, 7523, 7524, 7525 or 7528, as the '*X*' refers to 'unallocated products in SITC group 752' (Feenstra, 2000, p. 5). On the other hand, category 752A stands for combinations of 'two or more SITC Revision 2 codes' that have been 'rolled up' in order to create a commodity classification that is usable for all countries included in the dataset (Feenstra, 2000, p. 5). It means that for some countries, some export flows reported within a 4-digit industry beginning its code with 752 have been combined such that they match with the 3-digit classification 752, as the country's industry description at the 4-digit level does not match with the SITC listing. The '4-digit' industries, 752A and 752X, thus contain observations that effectively aggregates at the 3-digit level. Similar problems apply to data classifications at the 2-digit and 3-digit levels of aggregation. In all these cases, export flows are inflated, possibly to a very large extent, yielding artificially high values of the Balassa index.[4]

For illustrative purposes, the Hillman condition is re-examined for all countries, sectors and years at the 3-digit level, this time including the 1-digit and 2-digit 'aggregates' that are reported at the 3-digit level in the raw data. This yields in total 188 violations of the Hillman condition (compared to

[3] Violations are never related to country size as these are small in all cases.

[4] This lack of information regarding the exact classification of trade flows at lower levels of data aggregation is of course not unique to the dataset employed here. Most if not all empirical studies into RCA encounter this problem.

Table 2. Violations of the Hillman condition and erroneous sector aggregation, 1970–1997

Code	Description	Country	Years
010	Meat and meat preparations	Hungary	88, 89, 91, 94
020	Dairy products and birds' eggs	Hungary	78–83
040	Cereals and cereal preparations	Hungary	73, 76, 81, 92
050	Vegetables and fruit	Hungary	71
100	Beverages and tobacco	Sri Lanka	74
110	Beverages	Hungary	93, 94
200	Crude materials, inedible, except fuels	China	70–72, 74–78, 80, 81
		Austria	93
300	Mineral fuels, lubricants and related materials	Czechoslovakia	76, 78
		Guinea-Bissau	80
		Austria	93
320	Coal, coke and briquettes	Former USSR	80
		Hungary	95
330	Petroleum, petroleum products and related material	Former USSR	86
400	Animal and vegetable oils, fats and waxes	China	70–76
		Czechoslovakia	78
420	Fixed vegetable oils and fats	Hungary	92, 94, 95
500	Chemicals and related products n.e.s.	China	71, 75
		Papua New Guinea	79, 80
		Austria	93
600	Manufactured goods classified chiefly by material	Guinea-Bissau	79
		Germany	82–87, 89–92, 94, 96, 97
700	Machinery and transport equipment	Zaire	76
		Guinea-Bissau	79
		Germany	82–87, 90–92, 94, 96
790	Other transport equipment	Hungary	94
800	Miscellaneous manufactured articles	Ireland	70–72
		Neth Antilles	78
		Guinea-Bissau	79
		Germany	82–87, 90–92, 94, 96, 97
840	Articles of apparel and clothing accessories	Mauritius	96
900	Commodities and trans. not classified elsewhere	Ireland	70
		Czechoslovakia	78, 79
		Germany	90–94, 96, 97

88 violations in case only 'true' 3-digit sectors are considered), 108 of which are attributable to erroneous data classification. These are listed in Table 2.

For 85 out of these 108 cases (or 79%) the violation of the Hillman condition is the result of the respective country having a reported 'monopoly'. For all cases, the market share is at least 92.6%. In the 1980s and 1990s, e.g. Germany is frequently the only country classifying products at the 'miscellaneous' 1-digit level, the categories '600', '700', '800' and '900' in Table 2, resulting in an artificial monopoly. Similarly, while most other countries take the trouble to identify if the exported 'dairy products and birds' eggs are either 'milk and cream', 'butter', 'cheese and curd', or 'eggs and yolks, fresh, dried, or otherwise preserved', Hungary simply lists them as 'dairy products and birds' eggs. Although not leading to a monopoly for Hungary in the years 78–83, the Hillman condition does pick up this classification problem, as it does for Hungary's classification of sectors '010', '040' and '050'. Clearly, the Hillman condition is most useful in identifying observations based on erroneous trade flow classifications:

Stylized fact 4. *The Hillman condition is an effective screening device for identifying observations of RCA that are based on erroneously classified trade flows.*

At the same time, because of erroneous data classifications, the number of true violations of the Hillman condition dropped from 88 to 80. This is due to the effect of artificially enlarged trade flows on all computed Balassa index values (1) and the concomitant Hillman condition (2). For eight cases, this means that they are not identified as violating the Hillman condition when aggregate trade flows are erroneously classified at the 3-digit level, while they are identified as such when restricting the analysis to

Table 3. Violations of the Hillman condition masked by erroneous trade classification

SITC Code	Country	Year	BI value	Market share	Export specialization	Country size
333	Iraq	71	16.52	0.0633	0.9413	0.0038
333	Iraq	81	6.08	0.0335	0.9743	0.0055
999	Former USSR	71	11.74	0.3921	0.6685	0.0334
999	Former USSR	72	12.35	0.4193	0.6114	0.0340
999	Former USSR	76	12.98	0.4666	0.5588	0.0359
999	Former USSR	79	12.29	0.4554	0.5701	0.0370
999	East Germany	70	12.59	0.1689	0.8508	0.0134
999	East Germany	71	14.76	0.1777	0.8403	0.0120

true 3-digit level trade flows only. These observations are listed in Table 3 and give rise to the following:

Stylized fact 5. *The Hillman condition suffers from a masking effect in that mild violations remain undetected if grotesque violations are present.*

Since for most countries about 90% of all (2-digit) sectors have a Balassa index below 4 (Hinloopen and van Marrewijk, 2001), all observations in Table 3 would stand out in a study into RCA. Meanwhile, these observations do not refer to RCA proper and should thus be dismissed.

Stylized facts 4 and 5 jointly imply a natural research sequence. Given any dataset compute for all observations the Balassa index and the related Hillman condition. Examine the thus identified observations not passing the Hillman test and dismiss those observations that are suspect of pertaining to erroneous data classifications. Re-calculate the Balassa index and the concomitant Hillman condition for all remaining sectors, whereby it is important to include for total country trade flows observations that are exclusively recorded at higher levels of sector aggregation in order not to underestimate these cumulative values.

All calculations of the remainder of this article are performed only at the appropriate level of sector aggregation, whereby a country's true total trade flows in any given year are used, thus including trade flows classified exclusively at higher levels of aggregation. The same then applies for the calculation of total world trade.

V. Empirical Violations of the Hillman Condition

For all 165 sample countries, the Hillman condition is verified for all 28 sample years at the four different levels of sector aggregation. In what follows, the concomitant empirical regularities are ordered along three dimensions: time (section 'Empirical violations of the Hillman condition over time'), sectors (section 'Impirical violations of the Hillman condition across sectors') and countries (section 'Empirical violations of the Hillman condition across countries').

Empirical violations of the Hillman condition over time

Table A2 in Appendix 2 lists for each sample year and all four levels of sector aggregation the observations that violate the Hillman condition as a fraction of the total (annual) number of observations and of total (annual) trade. The annual average violations correspond reasonably well to the sample totals in Table 1, both in terms of the number of violations and in terms of the value of trade represented by these observations.

Considering the evolution of violations over time reveals, however, quite a different picture. Figure 2 illustrates this development for the four different levels of aggregation, both as a share of the number of observations (Panel A) and as a share of total trade (Panel B). For all years, the number of observations violating the Hillman condition is small (as a fraction of all annual observations never to exceed 0.4% in any given year) and decreasing over time. This reduction is even more pronounced in Panel B; violations of the Hillman condition are very valuable in the period 1970 to 1984, with a peak of 10.14% at the 1-digit level in 1974, to become much less important and to virtually disappear in the period 1988 to 1997. Hence:

Stylized fact 6. *Concerning violations of the Hillman condition over time, two periods can be distinguished:* (*i*) 1970–1984, *during which violations occur relatively frequent and represent a substantial fraction of total trade and* (*ii*) 1985–1997, *during which violations hardly ever occur and represent an insignificant fraction of total trade.*

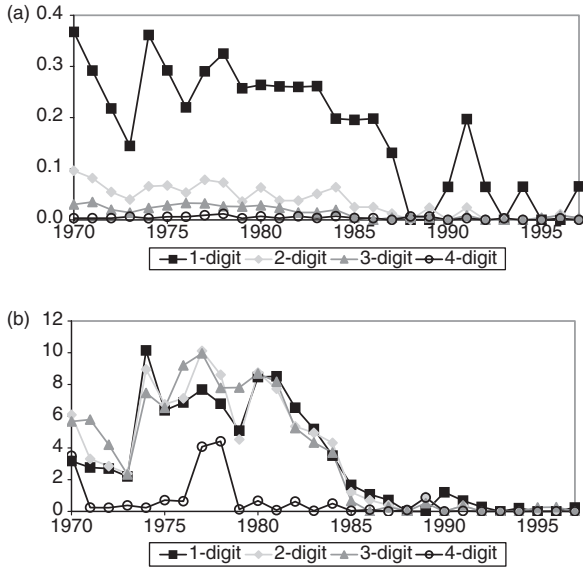

Fig. 2. Development over time of violations of the Hillman condition, 1970–1997
Notes: (a) Panel A–Share of sectors (in number of sectors) violating the Hillman condition; (b) Panel B–Share of sectors (in value) violating the Hillman condition.

It follows that the year 1985, the single year investigated by Marchese and Nadal De Simone (1989), is not representative for the empirical relevance of the Hillman condition. Violations are much more pronounced in the 15 years preceding the year 1985, while in the following years their importance gradually vanished. It also means that studies into RCA that ignored the Hillman condition are more prone to errors if they include observations from the seventies until the mid-eighties of the last century.

Factors responsible for the pattern described in Stylized fact 6 emerge from Table 4, which lists all observations violating the Hillman condition for the four different levels of sector aggregation. Of foremost importance here are the two oil crises of the seventies. These shocks gave rise to such drastic price movements that related market shares (in value) increased thereby challenging the validity of the Hillman condition. In the period 1970 to 1984, violations of the Hillman condition occurred primarily for oil-related exports.

Empirical violations of the Hillman condition across sectors

At the 1-digit level of sector aggregation, violations of the Hillman condition occur in two sectors only: 'Food and live animals chiefly for food' (SITC code 0) and 'Mineral fuels, lubricants and related materials' (SITC code 3). Going from this 1-digit level to the 2-digit level of sector aggregation the 'nonferrous metals' sector (SITC code 68) joins the group of violating sectors. At the 3-digit level, four additional sectors are included: 'Fertilizers, crude' (SITC code 271), 'Radio-active and associated materials' (SITC code 286), 'Copper' (SITC code 524) and 'Ships, boats and floating structures'(SITC code 793). The latter two sectors leave the basket of violators again if sectors are considered at the 4-digit level of aggregation.

It thus appears that more detailed sector definitions encompass the group of sectors violating the Hillman condition at higher levels of sector aggregation (the narrowing scope of violating sectors when going from the 3-digit level of sector aggregation to the 4-digit level is related to the concomitant reduction in trade flow coverage). At the same time, at lower levels of sector aggregation, violations occur in sectors that are not identified as violators at higher sector aggregation levels. Accordingly:

Stylized fact 7. *The correlation between sectors violating the Hillman condition across levels of sector aggregation is asymmetric*; *violations at lower levels of sector aggregation are likely to occur at higher levels as well*, *while violations at higher levels of sector aggregation need not occur at lower levels*.

Stylized fact 7 implies that the validity of the computed value for RCA at high levels of data aggregation cannot be taken as evidence for the validity at lower levels of data aggregation. For instance, the fact that the Balassa index for Reunion in 1997 for 'machinery and transport equipment' (1-digit SITC code 7) of 2.58 relates to a true comparative advantage (as the related Hillman condition is not violated) does not mean that this holds for all Reunion sectors at lower levels of aggregation that fall in this 1-digit industry. Indeed, according to Table 4 the RCA recorded for Reunion at the 3-digit SITC industry 'ships, boats and floating structures' does not constitute a true comparative advantage.

A further sector classification is obtained when taking into account the related factor intensity. This leads UNCTAD/WTO to distinguish between six sector categories, which are described in detail in van Marrewijk (2002). Appendix 3 lists this classification for all 3-digit SITC sectors:

A. *Primary products* (83 sectors); e.g. meat, dairy, cereals, fruit, coffee, sand, minerals, oil, natural gas, iron ore and copper ore.

Table 4. Observations not satisfying the Hillman condition, 1970–1997

SITC code	Description	Country	Years
1-digit			
0	Food and live animals chiefly for food	St Pierre Miqu	79
3	Mineral fuels, lubricants and related materials	Algeria	79–87, 91, 92, 94, 97
		Libya	70–83, 85, 86
		Venezuela	70, 74
		Kuwait	70–72, 74
		Qatar	70, 71
		Saudi Arabia	70–84, 90
		Iran	74–78, 83
		Oman	75
		Iraq	77, 78, 80, 85–87
		United Arab Emirates	78
		Nigeria	81, 82, 84, 91
		Paraguay	91
2-digit			
06	Sugar, sugar preparations and honey	Cuba	75–78
33	Petroleum, petroleum products and related material	Libya	70–81, 83, 86
		Venezuela	70
		Kuwait	70–72, 74
		Qatar	70, 71
		Saudi Arabia	70–84
		Iraq	71, 77, 78, 80, 83–89
		Iran	74–78, 83, 84
		Oman	75
		Nigeria	81, 82, 84, 85, 91
35	Electric current	Paraguay	91
68	Nonferrous metals	Zambia	70–74
93	Special transactions and commod., not class. to kind	South Africa	80
99	Nonidentified products	Former USSR	70, 77, 78
		Zimbabwe	79
		Romania	80, 82, 84[a]
		East Germany	89
		Reunion	96
3-digit			
061	Sugar and honey	Cuba	75–78
271	Fertilizers, crude	Morocco	74
286	Ores and concentrates of uranium and thorium	Niger	78–80, 81[a]
333	Petrol. oils & crude oils obt. from bitumin. minerals	Libya	70–77, 80, 81
		Qatar	70, 71, 76
		Saudi Arabia	70–84
		Iran	74–78, 83, 84
		Oman	75
		Iraq	71, 77–81
		Nigeria	79, 81–85, 87, 91
		Kuwait	95, 96
351	Electric current	Paraguay	91
524	Radio-active and associated materials	Niger	88
682	Copper	Zambia	70–77
793	Ships, boats and floating structures	Reunion	97
931	Special transactions & commod., not class. to kind	South Africa	80
999	Nonidentified products	Former USSR	70–72, 76–79
		Zimbabwe	79
		Romania	80, 82, 84[a]
		East Germany	70, 71, 89
		Reunion	96
4-digit			
0611	Sugars, beet and cane, raw, solid	Cuba	75–77, 78[a]
2479	Pit props, poles, piling, posts & other wood in rough	Indonesia	73[a]
2814	Roasted iron pyrites, whether or not agglomerated	Brazil	86[a], 88[a]
		Papua New Guinea	93[a]

(*continued*)

Table 4. Continued

SITC code	Description	Country	Years
2873	Aluminium ores and concentrates (includ.alumina)	Guinea	78, 82–85, 91
		Jamaica	80, 81
3359	Petroleum oil prep & residues nes	Neth Antilles	88[a], 89[a]
6821	Copper and copper alloys, refined or not, unwrought	Zambia	71–78
9999	Nonidentified products	Former USSR	70, 77, 78
		Zimbabwe	79
		Romania	80, 82, 84[a]
		East Germany	89
		Reunion	96

Note: [a]Indicates violation caused by high market share (more than 50%).

B. *Natural resource intensive products* (21 sectors); e.g. leather, cork, wood, lime, precious stones, pig iron, copper, aluminum and lead.
C. *Unskilled-labour intensive products* (26 sectors); e.g. pipes, various textiles, clothing, glass, pottery, ships, furniture, footwear and office supplies.
D. *Technology-intensive products* (62 sectors); e.g. various chemicals, medicaments, plastics, engines, generators, machines, tools, pumps, telecommunications and photo equipment, optical equipment and aircraft.
E. *Human capital intensive products* (43 sectors); e.g. synthetic colours, pigments, perfumes, cosmetics, rubber and tires, tubes, pipes, various types of steel and iron, cutlery, televisions, radios, cars, watches and jewellery.
F. *Not classified* (5 sectors).

Violations of the Hillman condition are predominantly in primary products and to some extent in natural resource intensive products.[5] Considering Hillman condition (2) this comes not as a surprise. It is precisely in these two categories more likely for countries to enjoy a (natural) large market share of world trade and/or to specialize exclusively in the export of these commodities. Alternatively, to the extent that these are agricultural goods, it could be that violations are caused by tighter trade restrictions.

Stylized fact 8. *At all levels of aggregation, violations of the Hillman condition occur almost exclusively in primary product sectors and to some extent in natural resource intensive sectors.*

Do note that studies that did not include primary product sectors and/or natural resource intensive sectors are not exempt from possible inclusion of erroneous observations on RCA. This would be the case only if these industries *are* included when calculating total trade for all sample countries.

Observe furthermore that sectors in which violations of the Hillman condition occur, typically are inter-industry trade sectors, as opposed to intra-industry trade sectors (such as human capital intensive and technology-intensive sectors). As such, this provides an additional reason for examining the Hillman condition: it points to sectors that are foremost characterized by inter-industry trade. One explanation for this finding is that intra-industry trade is more important among high-income countries and that it therefore comes with smaller market shares and lower degrees of export specialization.

Empirical violations of the Hillman condition across countries

Further empirical regularities can be distinguished if the sample of violations is examined along the country dimension. All countries hosting observations that violate the Hillman condition at the 2-digit level of sector aggregation are present in the group of violators at the 3-digit sector aggregation level, while 9 of the 13 countries with violations at the 1-digit sector aggregation level are home to violators at the 2-digit level of sector aggregation as well. The consequences of the reduction in trade flow coverage when considering the 4-digit level of sector aggregation is quite apparent in this context: only 7 out of 20 countries remain listed as the home country of sectors violating the Hillman condition at the 3-digit level of sector aggregation. This drop in trade flow coverage should not blur the following:

Stylized fact 9. *The correlation between countries hosting sectors that violate the Hillman condition across levels of sector aggregation is asymmetric*;

[5] At the 3-digit level, e.g. 62 violations are in primary products, nine are in natural resource intensive products, and one is in unskilled labour intensive product (and 16 are in the noninformative 'not classified' category).

violations at lower levels of sector aggregation are likely to occur at higher levels as well, while violations at higher levels of sector aggregation need not occur at lower levels.

Finally, for identifying stylized facts across groups of countries, the set of sample countries needs to be ordered. For that the classification of the World Bank of all countries into seven distinct geographical regions is used (World Bank, 2003): East Asia and Pacific (EAP, 25 countries), Europe and Central Asia (ECA, 29 countries), North America (NAM, 3 countries), Latin America and the Caribbean (LAC, 35 countries), Middle East and North Africa (MNA, 21 countries), South Asia (SAS, 8 countries) and Sub-Sahara Africa (SSA, 44 countries). As there is a good, but not perfect, correspondence between the country labelling of the World bank and the set of sample countries used in this study, a congruence is constructed (see Appendix 1 for details). Examining then all observations violating the Hillman condition yields:

Stylized fact 10. *At all levels of sector aggregation, violations of the Hillman condition occur foremost for observations involving countries in Africa* (*including the Middle East*) *and*, *to a lesser extend*, *involving countries in Latin America*, *the Caribbean and Eastern Europe*.

The explanation for Stylized fact 10 has been alluded to earlier (Footnote 2); for countries that specialize in their exports it is likely that a RCA is recorded that does not meet the Hillman condition. It is precisely those countries identified in Stylized fact 10 that have (highly) specialized export flows. Observe again that studies into RCA that did not include countries in Africa, the Middle East, Latin America, the Caribbean and Eastern Europe are not flawless *a priori* as sectors from these countries contribute to total world trade and hence affect the calculated value of the Balassa index (1) and the concomitant Hillman condition (2). At the same time, studies where countries from the regions identified in Stylized fact 10 are over represented, are likely to find high shares of total trade to be represented by all observations violating the Hillman condition (as in Marchese and Nadal de Simone, 1989 who focus exclusively on a set of developing countries; see also Footnote 2).

Finally, observe that countries hosting sectors that violate the Hillman condition are more active in inter-industry trade than in intra-industry trade. The same explanation as that provided in section 'Empirical violations of the Hillman condition across sectors' applies; intra-industry trade is more prevalent among high-income countries which make the realization of a large market share and/or a high degree of export specialization less likely. Relatedly, the Hillman condition identifies countries which are mainly involved in inter-industry trade, i.e. developing countries.

VI. Summary and Conclusions

Using a comprehensive dataset of annual bilateral trade flows for 1056 4-digit SITC sectors among 183 countries for the years 1970–1997, the empirical relevance is examined of the necessary and sufficient condition for the correspondence between RCA, as measured by the Balassa index and pre-trade relative prices, the so-called Hillman condition. The findings on the empirical relevance of this Hillman condition are presented as stylized facts because of the exhaustive representation of the dataset.

Violations of the Hillman condition are small as a share of the number of observations (Stylized facts 1 and 2), but often represent a disproportionally large value of trade (Stylized fact 3). From 1970 through 1984, violations happen relatively frequently and represent a significant fraction of the value of total trade, while from 1985 onwards violations rarely occur and represent a smaller fraction of total trade value (Stylized fact 6). Moreover, if violations are identified at low levels of sector aggregation, they are most likely to be identified at higher aggregation levels as well, while the opposite does not hold (Stylized facts 7 and 9).

Examining then in detail those observations that relate to violations of the Hillman condition shows that these occur in sectors that are producing primary products or, to a lesser extent, that are natural resource intensive. Also, violations are recorded foremost for countries located in Africa, the Middle East and Latin America. Both characteristics point to the same type of trade flow underlying the violation: inter-industry trade. Indeed, as intra-industry trade occurs foremost between high-income countries, it is expected that in these cases neither large market shares nor high degrees of export specialization are obtained. Accordingly, the Hillman condition is an identification device for sectors that involve inter-industry trade.

The Hillman condition is further revealed to be an effective screening device in that it detects observations that suffer from erroneously classified data (Stylized fact 4). At the same time, after eliminating incorrectly classified data, the Hillman condition still identifies problematic sectors which would otherwise

have gone unnoticed (Stylized fact 5). This leads to a natural screening phase to be followed in applied trade analysis: given any dataset compute first for all observations the Balassa index and the related Hillman condition, examine next the thus identified observations not passing the Hillman test and dismiss those observations that are suspect of pertaining to erroneous data classifications. Indeed, this procedure is not restricted to analyses into comparative advantage, it should be used in any empirical study to identify data irregularities. This holds *a fortiori* if developing countries are involved, the trade flows considered are of primary products, or both (as in, e.g. Devadoss and Wahl, 2004; Gómez-Plana and Devadoss, 2004; Endoh, 2005).

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Appendix 1. Data

Two separate datasets provided by the Center for International Data, University of California, Davis (CID/UCD), were merged, the first covering the years 1970 through 1993 (Feenstra *et al*., 1997) and the second covering the years 1980 through 1997 (Feenstra, 2000). For the overlapping years, the data from the latter source are used. The dataset contains bilateral trade flows between 183 trading partners, including n.e.s. (not elsewhere specified) regions for trade flows that could not be classified further than within a broad geographical region (such as 'Middle East', or 'North Africa'), an 'Areas n.e.s.' region for trade flows that cannot be attributed to any country or to any of the used broad geographical

regions but that do come from a well-defined geographical region and an 'Unknown Partner' category for trade flows that could not be attributed at all due to various reasons (Feenstra, 2000).

This leaves a sample of 165 genuine countries that are grouped in Table A1 according to the World Bank classification of world regions (World Bank, 2003). In some cases, the latter is more detailed than the sample of countries used here. For instance, The World Bank distinguishes between Bosnia, Croatia and Slovenia. Here, all of these three countries fall under the heading '(former) Yugoslavia'. As long as the countries that are grouped together belong to the same geographical region as identified by the World Bank, the classification of the latter still applies. This always turns out to be the case. On the other hand, countries that are distinguished here but not as such in the World Bank classification are grouped according to their geographical location. This was done for the Falkland Islands, Guadeloupe, Reunion, St. Helena and St. Pierre Miqu. Finally, the constructed database contains three entries for Yemen: Former Democratic Republic of Yemen, Former Yemen and Yemen. The World Bank classification includes Yemen only. Needless to say that all three identified countries belong to the same geographical area (in the subsequent Table A1, these are not further distinguished).

The bilateral trade flows are decomposed into 1249 sectors, comprising 747 genuine 4-digit sectors, based on SITC, revision 2. The remaining 502 sectors refer to aggregates at the 1-, 2-, or 3-digit level and a 'Nonidentified products' category. The 4-digit subset contains 60.39% of all trade, the 3-digit subset covers 99.46% of all trade and the 2-digit subset comprises 99.67% of all trade.

The data were first compiled by Statistics Canada and made available through the CID/UCD (Feenstra, 2000). The former makes use of various sources (according to Statistics Canada 87% of all trade flows is based on independent sources of *both* imports and exports, while 98% is based on reports of at least one side of trade), yielding a rather complete coverage of world trade flows. The CID/UCD transforms the data such that trade flows for all years, all countries and all industry groups are consistent and presented in a unified manner. Each observation in the raw data consists of four entries: importing country, exporting country, sector and size of the trade flow (in 1000 US$). The data are thus classified according to the importing country. This is *not* to say that the data are based on import sources only, as explained earlier. After merging the two separate datasets a second dataset is created by 'inverting' the data, in that all trade is classified according to the exporting country.

Table A1. Sample country classification according to World Bank regions

East Asia & Pacific (EAP); 25 countries		
Australia	Laos	Philippines
Brunei	Malaysia	Solomon Islands
Cambodia	Mongolia	Thailand
China	Myanmar (Burma)	South Korea
Fiji	New Zealand	Singapore
Hong Kong	North Korea	Taiwan
Indonesia (including Macau)	New Caledonia (including French Polynesia and Vanuata)	
Japan	Papua New Guinea	Vietnam
Kiribati (including Tonga and Tuvalu)		
Europe & Central Asia (ECA); 29 countries		
Albania	Greece	Poland
Austria	Greenland	Portugal
Belgium-Luxemburg	Germany	Romania
Bulgaria	Hungary	Spain
Cyprus	Iceland	Sweden
Czechoslovakia	Ireland	Switzerland
Denmark (including Faroe Islands)	Italy	Turkey
(former) East Germany	Netherlands	United Kingdom
Finland	Norway	(former) USSR
France	(former) Yugoslavia (including. Croatia and Slovenia)	
North America (NAM); 3 countries		
Bermuda	Canada	USA

(*continued*)

Table A1. Continued

Latin America & Caribbean (LAC); 35 countries		
Argentina	Ecuador	Mexico
Bahamas	El Salvador	Nicaragua
Barbados	Falkland Islands	Panama
Belize	French Guiana	Paraguay
Bolivia	Guadeloupe (including Martinique)	Peru
Brazil	St. Kitts & Nevis (including Dominica, Montserrat, St. Luca, St. Vincent and Grenada)	
Cayman Islands	Guatemala	St. Pierre Miqu
Chile	Guyana	Surinam
Colombia	Haiti	Trinidad & Tobago
Costa Rica	Honduras	Turks Caicos Islands
Cuba	Netherlands Antilles	Uruguay
Dominican Republic	Jamaica	Venezuela
Middle East & North Africa (MNA); 21 countries		
Algeria	Iraq	Oman
Bahrain	Jordan	Qatar
Djibouti	Kuwait	Saudi Arabia
Egypt	Lebanon	Syria
Gibraltar	Libya	Tunisia
Israel	Malta	United Arab Emirates
Iran	Morocco	Yemen
South Asia (SAS); 8 countries		
Afghanistan	India	Pakistan
Bangladesh	Maldives	Sri Lanka
Bhutan	Nepal	
Sub-Saharan Africa (SSA); 44 countries		
Angola	Ghana	Rwanda
Benin	Guinea	Senegal
Burkina Faso	Guinea-Bissau (including Cape Verde)	Seychelles
Burundi	Kenya	Sierra Leone
Cameroon	Liberia	Somalia
Central African Republic	Madagascar	South Africa
Chad	Malawi	St. Helena
Comoros	Mali	Sudan
Congo	Mauritania	Tanzania
Cote dÍvoire	Mauritius	Togo
Democratic Republic Congo (Zaire)	Mozambique	Uganda
Equatorial Guinea	Niger	Western Sahara
Ethiopia	Nigeria	Zambia
Gabon	Reunion	Zimbabwe
Gambia	Republic Congo	

Appendix 2. Violations of the Hillman Condition

Table A2. Annual violations of the Hillman condition, 1970–1997[a]

	Share of no. of observations (%)				Share of value of exports (%)			
Year	1-digit	2-digit	3-digit	4-digit	1-digit	2-digit	3-digit	4-digit
1970	0.37	0.10	0.03	0.00	3.17	6.08	5.67	3.50
1971	0.29	0.08	0.03	0.00	2.77	3.31	5.79	0.24
1972	0.22	0.05	0.02	0.00	2.70	2.86	4.20	0.23
1973	0.14	0.04	0.01	0.01	2.21	2.38	2.33	0.38
1974	0.36	0.07	0.02	0.00	10.14	8.96	7.46	0.23
1975	0.29	0.07	0.03	0.01	6.37	6.75	6.53	0.71
1976	0.22	0.05	0.03	0.01	6.87	7.13	9.20	0.64
1977	0.29	0.08	0.03	0.01	7.68	10.12	9.96	4.08
1978	0.33	0.07	0.03	0.01	6.78	8.61	7.79	4.42
1979	0.26	0.04	0.03	0.00	5.09	4.53	7.81	0.12
1980	0.26	0.06	0.03	0.01	8.47	8.75	8.69	0.67
1981	0.26	0.04	0.02	0.00	8.52	7.73	8.17	0.08
1982	0.26	0.04	0.01	0.01	6.53	5.36	5.25	0.62
1983	0.26	0.05	0.01	0.00	5.20	4.96	4.34	0.04
1984	0.20	0.06	0.02	0.01	3.51	4.32	3.71	0.50
1985	0.20	0.02	0.00	0.00	1.67	1.21	0.66	0.04
1986	0.20	0.02	0.00	0.00	1.07	0.71	0.00	0.10
1987	0.13	0.01	0.00	0.00	0.71	0.40	0.29	0.00
1988	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.09
1989	0.00	0.02	0.00	0.01	0.00	0.92	0.52	0.87
1990	0.06	0.00	0.00	0.00	1.21	0.00	0.00	0.00
1991	0.20	0.02	0.01	0.00	0.68	0.36	0.36	0.03
1992	0.06	0.00	0.00	0.00	0.28	0.00	0.00	0.00
1993	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
1994	0.06	0.00	0.00	0.00	0.20	0.00	0.00	0.00
1995	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00
1996	0.00	0.01	0.01	0.00	0.00	0.00	0.27	0.01
1997	0.07	0.00	0.00	0.00	0.25	0.00	0.00	0.00
Annual average	0.18	0.04	0.01	0.00	3.29	3.41	3.55	0.63

Note: [a]The total number of cases not satisfying the Hillman condition in the period 1970 – 1997 is 73 at the 1-digit level, 79 at the 2-digit level, 88 at the 3-digit level and 35 at the 4-digit level.

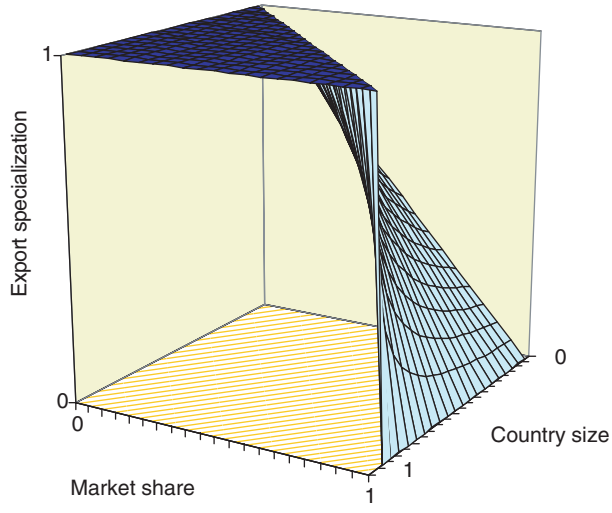

Fig. A1. Area of violations of the Hillman condition[a]
Note: The condition is fulfilled to the left of (and below) the demarcation. It is violated to the right of it.

Appendix 3. Sector Classifications According to Factor Intensity

Table A3. 3-digit sector classification[a]

Primary															
001	011	012	014	022	023	024	025	034	035	036	037	041	042	043	044
045	046	047	048	054	056	057	058	061	062	071	072	073	074	075	081
091	098	111	112	121	122	211	212	222	223	232	233	244	245	246	247
248	251	261	263	264	265	266	267	268	269	271	273	274	277	278	281
282	286	287	288	289	291	292	322	323	333	334	335	341	351	411	423
424	431	941													
Natural resource intensive															
524	611	612	613	633	634	635	661	662	663	667	671	681	682	683	684
685	686	687	688	689											
Unskilled labour intensive															
651	652	653	654	655	656	657	658	659	664	665	666	793	812	821	831
842	843	844	845	846	847	848	851	894	895						
Technology intensive															
511	512	513	514	515	516	522	523	541	562	572	582	583	584	585	591
592	598	711	712	713	714	716	718	721	722	723	724	725	726	727	728
736	737	741	742	743	744	745	749	751	752	759	764	771	772	773	774
775	776	778	792	871	872	873	874	881	882	883	884	893	951		
Human capital intensive															
531	532	533	551	553	554	621	625	628	641	642	672	673	674	675	676
677	678	679	691	692	693	694	695	696	697	699	761	762	763	781	782
783	784	785	786	791	885	892	896	897	898	899					
Not classified															
911	931	961	971	999											

Note: [a]All industry descriptions can be found at at www.few.eur.nl/few/people/vanmarrewijk/eta/intensity.htm