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International material-product chains: an alternative perspective on international trade and trade theories

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Abstract

The relationship between trade and material flows is examined by viewing the global economy from the perspective of international material-product chains (MPC). The international MPC covers the complete lifecycle of a material or a product in two or more regions, including extraction, production, consumption, waste management and transport. Products, waste, and associated material flows in the international MPC can run vertically or horizontally between segments. It is demonstrated how differences in factor requirements across segments of the international MPC in combination with factor productivity differences across developed and developing countries can cause specific trade patterns of inter-industry and intra-industry flows of materials and products. The implications of considering various trade theories in the context of the idea of an international MPC are examined. This interpretation of international trade sheds a new light especially on the physical dimension of international specialisation.

Keywords: International material-product chains; Trade theories; Environmental policy; Recycling.

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1. Introduction

The importance of international trade in the world economy is steadily increasing. During the last decades the volume of internationally traded materials and products has grown much faster than global production. Similarly, foreign direct investments have grown substantially and production factors have become more mobile. Financial capital can nowadays be transferred across the globe without much delay. It is no longer uncommon for labour to migrate in return for better wages. Modern communication technologies facilitate the dissemination of technical know-how among potential users. As a result, production and consumption patterns of different countries are now intertwined more then ever before. These trends are often summarised through the notion of globalisation. This refers to global economic integration of national economies into one global economy, through increased international trade and capital flows, communication (ITC), migration and interdependence of (financial) markets (Daly 1999).

The exact causes and effects of globalisation on the world economy are hard to decipher. Theoretically, increased trade enhances the exposure of domestic firms to international competition, which in turn leads to specialisation in and a higher efficiency of the international economy. The resulting welfare improvement is labelled as the gains of trade. Nevertheless, the distribution of these gains remains uncertain. Some countries could actually lose welfare, for example, by specialising in export activities that do not reflect external cost.

Trade has not only increased in terms of volume; also the diversity of traded goods and services has expanded. Originally, trade involved predominantly agricultural products and primary commodities. In the 20th century trade of intermediary and final goods took off. In recent decades, also recyclable and non-recyclable waste materials started to be traded internationally.[1] In other words, the full range of economic activities running from extraction, production, consumption to waste management is being allocated across nations. A novel way of analysing international trade is to view trading partners in terms of an internationally linked material-product chain (MPC). The international MPC covers the complete lifecycle of a material or a product in two or more regions, including extraction, production, consumption, waste management and transport. Products, waste, and associated material flows can run vertically or horizontally between segments of the international MPC.

This article examines to what extent the international MPC approach provides a useful tool in explaining trade patterns and international flows of materials and products. Besides being relevant from a theoretical perspective, the international MPC can help support economic and environmental policymaking in developed and developing countries. Economic and environmental policy can only be effective when all effects in the international MPC are taken into account. Focussing only on the domestic MPC can lead to unexpected externalities in the own or other regions, that is, generate sub-optimal policy prescriptions.

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[1] For example, Kellow (1999) reports how computer scrap is collected in Australia and exported to the Philippines for manual disassembly. Certain parts such as diodes and switches are exported to China for reuse. Printed circuit boards are sent back to Australia where gold, silver and copper are recovered with high-tech metallurgical processes.

The paper is structured as follows. In Section 2 the concept 'international MPC' is explained. In Sections 3 to 7 various trade theories are considered in relation to the international MPC. These theories include traditional trade theories, theories on trade and location, environment and demand-oriented trade theories, and trade theories involving technical change and capabilities. Section 8 presents conclusions.

2. International material-product chains

A material-product chain (MPC) is defined as a set of linked flows of materials and products so as to fulfil a certain service (Opschoor 1994). The MPC covers the complete lifecycle of a material or a product, including extraction, production, consumption, waste management and transport.[2] MPC analysis can be defined as the study of the economic structure of connected material and product flows (Kandelaars 1999). MPC analyses often include materials flows and mass balance relationships. Several attempts have been made to build models that include both physical flows and economic and behavioural mechanisms.[3] Most studies have focused on a local or a national scale. International links are usually ignored or assumed as exogenous. By extending the MPC with international dimensions, the economic and environmental causes and effects of globalisation can be better understood.

An international MPC consists of two or more regions that are individually linked through various types of material and product flows. These flows originate from one of the economic activities in the MPC. The following categories of flows are identified.

- *Primary commodities* or *virgin materials*: raw materials that have been extracted from natural resources; examples are iron ore and wood pulp.
- *Secondary commodities* or *recyclable waste materials*: raw materials that have been recovered after production or consumption; examples are iron scrap and wastepaper.
- *Final commodities* or *intermediates*: intermediary products suitable to directly convert into consumer goods; examples are crude steel and printing paper. It is assumed that final commodities can be produced from both primary and secondary commodities.
- *Consumer products*: final goods manufactured in the final production stage and used in the consumption stage; examples are cars and books.
- *Waste materials*: residue materials that no longer can be converted in useful materials or products in an economically feasible manner; an example is municipal solid waste.

Figure 1 shows an international MPC consisting of two countries A and B. Country A is well endowed with high-tech capital and skilled labour. Given its high level of welfare, the levels of consumption of consumer products and production of secondary commodities are large. Country B is poorly endowed with capital and know-how and well endowed with unskilled labour and primary raw materials. The production of secondary commodities is

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[2] A related term for the material-product chain in this study is the lifecycle. This interpretation of the lifecycle should not be confused with the product cycle by Vernon (1966), describing the invention, small scale production, imitation and mass production of new products, or the plant lifecycle (Dumias et al. 1997) following the birth, expansion, and closures of plants.

[3] Examples include Ayres and Kneese (1969), Ayres (1978), Leontief (1970), Perrings (1987), Ruth (1993), Van den Bergh and Nijkamp (1994), Kandelaars and van den Bergh (1996), Kandelaars (1999), Bouman et al. (1999).

small. The arrows between countries A and B represent international trade flows of materials and products. Under conditions of open borders and different factor endowment various trade patterns may result.

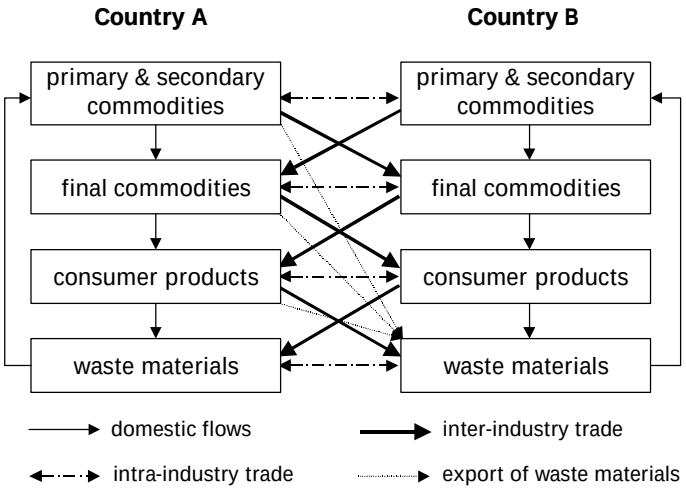

Figure 1 Materials flows in the international materials- product chain

The most common trade pattern is *inter-industry trade* in which upstream transactions in dissimilar commodities and products take place between different segments in the MPC in country A and B. The difference in factor endowments between countries is the main cause of inter-industry trade between the subsequent stages in the international MPC. In the first stage of the MPC raw commodities consisting of primary and secondary commodities are traded to the manufacturing industry in both countries. Country A exports secondary commodities to country B that in turn converts these into useful final commodities by utilising cheap unskilled labour. Country B exports primary commodities to country A that transforms these into final commodities using skilled labour and sophisticated technologies. In the second stage of the MPC, country A converts the final commodities into high-tech products some of which are exported to country B. Country B exports (mass-consumer) products whose production is labour intensive. In the final stage of the MPC, country A consumes and disposes the consumer products and export low quality residues to country B requiring labour-intensive treatment. Waste materials requiring capital intensive treatment are exported from country B to country A.

Another type of international relationship is *intra-industry trade*. Such trade is especially observed for commodities and products with seemingly identical characteristics, and between countries with seemingly identical factor endowments. Common explanations offered by the new trade theories include economies of scale, product differentiation, technology differences, and network effects. Intra-industry trade facilitates specialisation within the individual stages of the MPC. An example is the trade in the waste management stage between countries A and B. This may imply that country A is specialised in incinerating solid waste with a high energetic value and therefore imports this ‘commodity’ from country B. Country B, on the other hand, may have an abundance of composting and landfill facilities so that it imports organic waste from country A. Economies of scale are an important factor that drive this type of trade.

Finally, *waste materials* arising from various segments of the MPC are internationally traded. In the example of Figure 1, waste residues are traded from country A to country B. Various factors such as differences in labour costs, lack of space, and differences in the level and enforcement of environmental standards can cause these trade flows. Although this flows is often characterised as environmental dumping, waste residues can very well be traded due to a comparative advantage of the importing country in processing waste materials into useful secondary commodities.

These three types of trade flows evolved in a chronological order. Traditionally, immobility of labour and capital has caused relative differences in factor and natural resource endowment to be the main driving factors in inter-industry trade. Materials and products flow vertically from one segment to another within the international MPC. With the mobilisation of capital, production centres became less dependent on the local availability of material resources. Technological knowledge, scale effects and vicinity to consumer markets became decisive factors, causing intra-industry trade. Materials and products were traded horizontally between segments in the international MPC. In due course, the environment has gained importance as a production factor. For example, the growing scarcity of landfill space in developed countries has caused waste materials to flow from the North to the South.

Empirical studies confirm these changes in the international MPC. For example, van Beukering and Bouman (2000) show that primary, secondary and final commodities have increased significantly over the last three decades. Moreover, a specific pattern along the international MPC, linking developed and developing countries, has developed. More specifically, as Table 1 shows, the importance of North-North trade has decreased. Compared with the North-North flows in the early seventies, the shares of primary, secondary and final commodities in the total trade volume, have declined in the last three decades by 22, 36 and 15 percent, respectively. With increases of 207 and 203 percent, developing countries have become more important as importers of primary and secondary commodities. The trade volume of primary, secondary and final commodities between developing countries has also grown significantly. Particularly the importance of secondary commodities in the south-south trade has increased significantly (569 percent).

Table 1 Trade flows in the international MPC

Trade flow		Share in total trade (1995-97 average)			Change in share (relative to 1970-74 average)		
From	To	Primary commodity	Secondary commodity	Final commodity	Primary commodity	Secondary commodity	Final commodity
North	North	45%	55%	54%	-22%	-36%	-15%
North	South	18%	28%	17%	207%	230%	15%
South	North	19%	6%	12%	-33%	106%	-33%
South	South	18%	11%	17%	120%	569%	299%

Note: The unweighted average share of commodities consists of aluminium, copper, lead, nickel, paper, iron, tin, and zinc.
Source: Compiled from Van Beukering and Bouman (2000).

Four factors seem to be relevant in explaining the allocation of the different stages of the international MPC and the resulting material and product flows across countries. Table 2 summarises these factors for primary, secondary and final commodities. First, the labour and capital intensity of the commodities in the MPC can determine the location of its production. Secondary commodities generally embody a relatively high labour intensity and require relatively little capital per unit of product. This can explain the large flow of secondary materials from developed to developing countries where labour is cheap and capital is scarce. Second, the technology requirement for the commodities varies. Recycling is known to use simpler techniques than most primary processes. Third, economies of scale are larger in the primary industry. Especially in developing countries, recycling is often performed by small firms. Finally, the environment-intensity of each commodity varies. Therefore, dirty commodities are likely to be produced in countries with the least strict environmental policies. In the following sections, various trade theories, emphasising the importance of these subsequent factors are discussed.

Table 2 Factor requirements in the MPC

	Labour/capital ratio	Technology requirement	Economies of scale	Environment-intensity
Primary commodities	High	High-tech	Large	High impact
Secondary commodities	Low	Low tech	Small	Medium impact
Final commodities	High	Standard-tech	Large	Low impact

Source: Di Vita (1997), Mani and Wheeler (1998), van Beukering and Curlee (1998)

3. Traditional trade theories

Since Ricardo's *Principles of Political Economy* in 1817, there is a general consensus among economist that comparative cost differences across countries stimulate international trade. Less agreement exists, however, on the actual cause of these cost differences. Traditional trade theories can be distinguished according to their explanation of the cause of the comparative cost difference. Due to the immobility of capital and labour, the driving factor in international trade was traditionally assumed to be the productivity of labour. This varies between countries due to technological knowledge and natural conditions, such as climate, natural resources, soil conditions, and the geographical position of a country. In the Ricardian theory much weight is given to these natural conditions as a determinant of comparative cost differences.

In the 20th century the economists Heckscher (1919) and Ohlin (1933) introduced a more realistic assumption by including, next to labour, capital as a essential factor of production. Since then, the Heckscher-Ohlin (HO) theorem has been the dominant theory in explaining trade patterns (Hakura 1999). The HO theorem explains international trade by relative differences in factor endowments of labour and capital. It is based on identical technology across countries on the production side and identical and homothetic preferences on the consumption side. In addition, it assumes perfect competition in markets for goods and factors, perfectly mobile production factors across sectors within countries, and completely

immobile factors across countries (Keuschnigg 1999).[4] Vanek (1968) developed a generalisation of the HO theorem (HOV theory) by extending it to a 'multi good-factor-country' framework. Instead of trying to rank many goods with respect to inputs of many factors, this approach orders factors with respect to a single criterion: their factor content in net-trade flows. Other extensions of the HO theorem include the Stolper-Samuelson and the Rybczynski theorem.[5]

Numerous empirical economists have tested the HO theorem, starting with Leontief (1953) who developed the well-known Leontief paradox. Roughly two types of tests can be distinguished. One attempted to explain the patterns of trade and another tested the hypothesis of factor price equalisation. Most studies, such as Bowen et al. (1987) and Brecher and Choudhri (1988), conclude that factor-endowment has a strong but certainly not unique impact on commodity trade patterns.

The traditional trade theory of comparative advantage is a static equilibrium theory. The supporters of dynamic or endogenous comparative advantages start from the idea that comparative advantages not only reflect the static endowment of given national resources, but also are constantly changing in response to the creation of local knowledge and skills. Specialisation according to current comparative advantage under free trade may therefore be welfare reducing in the long run because the changes in technological knowledge are ignored (Redding 1999). For developing economies this implies that they should not necessarily specialise in low-technology goods but rather should develop sectors that allow acquiring a comparative advantage in the future, such as high-technology goods.

Can the traditional trade theories of comparative advantage provide an explanation for an international MPC? For differences in factor endowment to be relevant, each step in the product chain should embody different factor intensities. If the production of primary and secondary commodities maintains similar factor requirements, no incentive for specialisation exists. Mani and Wheeler (1998) depict the primary commodity industry to be pollution and capital-intensive, requiring a great amount of energy and land. The manufacturing industry is considered as a relatively clean and labour-intensive industry, although with more variation across industries than in the primary commodity industry. Van Beukering and Curlee (1998) and Di Vita (1997) characterise the secondary commodity industry as labour intensive, and energy and material extensive. In this segment of the MPC, however, variations in the factor requirements are large.[6] Finally, the theory of dynamic comparative advantage implies that developing countries are better off if they move from

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[4] One of the first empirical test of the HO-theorem resulted in the well-known Leontief paradox (1953) stating that the United States was a net-exporter of labour-intensive products.

[5] The Stolper-Samuelson theorem states that an increase in the price of imported goods leads to an increase in the return to the scarce factor and a reduction in the return to the abundant factor, holding fixed factor supplies. The Rybczynski theorem states that at constant output prices, an increase in the supply of a factor will lead to an increase in the output of the commodity that uses that factor intensively, and to an output reduction in the other commodity (see, e.g., Leamer 1984).

[6] For example, the lead recycling industry in the Philippines consists of two types of firms. A large number of small-scale, highly polluting and labour intensive backyard smelters operate in this sector that use mainly domestic lead scrap. The other type consists of large-scale, clean and capital intensive factories that rely on foreign supplies (Hoffmann 1999).

secondary industries to more advanced economic activities. Recycling as a low-tech process is not economically attractive in the long run. On the other hand, recycling technologies are likely to improve. As a result the recycling sector may be transformed from a low-tech into a high-tech industry. This development has already begun in particularly developed countries.

4. Theories of trade and location

The central question in theories on trade and location is why and where different types of production and consumption clusters develop across the globe? Fujita et al. (1999) state that the international allocation of commodities, products and services is caused by a combination of centripetal and centrifugal forces. Centripetal forces such as market-size effects (i.e. backward and forward linkages), thick labour markets (i.e. availability of specialised skills) and external economies (i.e. information spillovers) promote the formation of economic clusters. Centrifugal forces prevent the evolution of one production centre rather the current formation of numerous economic clusters. These forces include immobility of production factors (i.e. land/natural), high land rents in concentrated areas, and external dis-economies (e.g. traffic congestion).

Theories on the location of economic activities include new trade theory, new growth theory and new economic geography. An important source of inspiration for these theories has been the growing trade of products that are close substitutes, the so-called intra-industry trade. Aturupane et al. (1997) distinguish between horizontal and vertical intra-industry trade. The latter consists of exchange of similar goods of different quality and the former comprises exchange of similar goods that are differentiated by characteristics or attributes rather than quality. This distinction is important as the determinants of each type differ. Various explanations have been given for intra-industry trade, such as product differentiation, and border and seasonal trade (Keuschnigg 1999), economies of scale (Krugman 1991), imperfect competition (Grubel and Lloyd 1975), market segmentation (Amati 1998), labour market pooling (Diamond and Simon 1991, Krugman 1991), lock-in effects (Dumais et al. 1997, Venables 1998), market-size effects and immobile factors (Krugman 1999). Factors, particularly relevant for explaining the international MPC, are elaborated below.

Venables (1998) examines what determines the spatial allocation of industries between countries, taking into account comparative advantages. A multi-industry model is developed of industries with large cross-country differences in productivity and small efficiency differences, which will locate in a specific country according to comparative advantages. Once industries have chosen a location, clustering effects cause them to remain locked-in at this location. In some cases the clustering effect caused by backward and forward linkages between firms is so large that industries locate in countries with comparative disadvantages. Clustering effects increase with the reduction of trade barriers.

Krugman (1991) has proposed a new economic geography as a style of economic analysis that explains the spatial structure of the economy by the opposite effects of market-size in generating linkages that foster geographical concentration and the force of immobile factors working against such concentration. New economic geography models have a general equilibrium structure. Distribution of population, demand and supply are endogenous.

Spatial concentrations emerge when individuals are choosing locations to maximise their welfare given what other individuals are doing. The location of the individual agent depends on access to supply and demand, which in turn improves the market access or supply of other producers in that location.

Falvey (1981) showed that vertical intra-industry trade occurs in markets were a large number of firms produce similar goods with varying qualities without increasing returns to scale. In these models, the relatively abundant country exports higher quality goods and the relatively labour-abundant country exports lower quality goods. Aturunpane et al. (1997) find that 80 to 90 percent of the total intra-industry trade between Eastern Europe and the European Union is vertical. Determinants are found to be product differentiation, labour intensity of production, economies of scale and FDI.

Finally, the vicinity to supplier and consumer markets is also a powerful determinant of intra-industry trade. Simply knowing how far a country is from other countries provides considerable information about the amount that it trades (Frankel and Romer 1999).

These four factors in location theories contribute to an explanation of international MPCs. First, backward and forward linkages evidently form the production sequence of an MPC: the output of one segment forms the input to the other segment in the MPC. Second, the economies of scale resulting from concentration also play an important role in different stages of the MPC. International trade in secondary materials has allowed recycling industries in particular industries to enjoy economies of scale (Elmer 1996). Third, product differentiation explains the intra-industry trade occurring in secondary commodity markets. For instance, the Netherlands belongs to the largest exporters of wastepaper while also importing significant quantities of wastepaper. Product differentiation is occurring in the paper recycling industry, which requires specific types and qualities of wastepaper (van Beukering and Sharma 1998). Finally, vicinity to supplier and consumer markets has an impact on the allocation of the international MPC. A significant share of trade in secondary materials occurs between neighbouring countries. The low value of recyclable materials constrains the maximum distance of transportation. Interesting examples are the trade in recyclables within Europe, the significant wastepaper trade between the US and Canada (Ince 1995), and the trade of waste plastics between China and Hong Kong (van Beukering 1999).

5. Trade theories involving technical change and capabilities

Factor endowments, economies of scale, and product differentiation can explain international trade of products and materials requiring simple technologies with low learning costs. These factors, however, do not fully account for changes in international specialisation with regard to more advanced products and materials. One explanation is that theories focusing at factor endowments, economies of scale and product differentiation treat the dynamic learning process occurring at the microeconomic level as a black box. Costly and slow learning is assumed away. Several theories have been developed that specifically focus on technical change and technical capabilities as explanatory factors of international trade.

Neo-technology theories (Posner 1961, Vernon 1966, Hirsch 1967) attribute comparative advantages to the ability of the economic agents to absorb mature and novel technologies.

The main focus is on the impact of learning costs and market failures on the comparative cost differences across countries. The most well-known neo-technology trade models are the product cycle by Vernon (1966) and the first-mover advantage (Porter 1990). The 'product cycle' model states that, due to the presence of technical skills and a large consumer market, new products are first produced in the most advanced economies. As the production process becomes standardised, importing countries adopt the production method. As the product goes through its natural cycle, from being research and skill intensive to intensive in unskilled labour, world production moves to the less advanced countries. The theory on 'first-mover-advantage', also known as the Porter Hypothesis, claims that innovative technologies and consumer goods that develop due to strict environmental policies create a competitive advantage in the global market for developed countries. In other words, this theory suggests that in the long term, strict environmental policies are beneficial to the international competitive position of an economy.

Second, theories on technological capabilities are considered. Technological capabilities are defined as "the complex array of skills, technological knowledge, organisational structures, required to operate a technology efficiently and accomplish any process of technological change" (Lall 1992). The main property of these theories is that due to the presence of transaction costs technological know-how does not flow effortlessly from one agent to the other (Pietrobelli 1997). The capability to incorporate advanced technologies or information may differ between companies and countries. Harrigan (1999) shows through a cross-section analysis of countries how differences in access to technology cause large variations in the total factor productivity. Although technological capability is clearly a firm-level concept, it has macro-economic consequences. For example, divergent technological capabilities contribute to explain differences in economic performance of countries.

Related to the theory on technological capabilities is the notion that developed countries are better able to take advantage of the scale economies than the developing countries (Benarroch 1998). Therefore, in a world of increasing returns to scale, the North specialises in goods with the highest economies of scale and the South in the remaining goods. Navaretti et al (1998) shows that especially developing countries import used equipment and demonstrate that this is not for reasons of the low labour costs but because of the technological and skill constraints and capabilities of industries in the South.

The theories on technical change and technical ability can explain several aspects of the international MPC. At present, the main technological innovations occur in the intermediate and manufacturing sectors in developed economies. Recycling production technologies have matured during the last decades, and have largely been adopted by the developing countries. This explains the relatively large trade flow of secondary materials from developed to developing countries. The theory of technological capabilities emphasises the importance of micro-level skills in explaining the development of trade and specialisation patterns. Especially in the market for secondary commodities, in which materials of a rather heterogeneous quality are traded, a reliable network of suppliers is of crucial for maintaining a constant flow of inputs of a high quality. The notion that developed countries are better able to utilise economies of scale explains why particularly industries with constant return to scale, such as the recycling industry, are moving to developing countries.

Several other technology-oriented theories that have not been specifically labelled as technical change or capability concepts are relevant in the context of the international MPC.

Dosi and Soete (1989) demonstrate that the current pattern of trade and specialisation is primarily the outcome of a process combining learning, innovation, imitation, and organisational change. This confirms the shift of innovative recycling centres from the North to the imitating recycling industry in the South. Yin-Chyi (1998) claims that developing countries should promote trade with technologically advanced countries because this results in increased learning. He argues that both exports and imports are equally important in the learning process. This can explain why recyclers in developing countries depending on imports for their inputs generally operate more efficiently than recyclers depending on domestic resources. Gustavsson *et al*. (1999) find that R&D activity at the firm level is particularly advantageous in large and growing economies where local positive externalities and spillovers magnify the benefits. R&D is especially of vital interest to high and medium technology sectors. Indeed, most of the recycling techniques originate from large economies such as the United States and Germany. Gereffi (1999) introduces the process of 'industrial upgrading' denoting organisational learning to improve the position of firms or nations in international trade networks. Participation in global commodity chains is a necessary step for industrial upgrading because it situates firms and economies on learning curves. Reppelin-Hill (1999) shows how new environmentally friendly technologies diffuse faster in open economies.

6. Demand-oriented trade theories

Instead of focusing on supply factors Linder (1961) emphasises variations in demand as the driving force of international trade. He defines the structure of demand, which is strongly influenced by income levels, in terms of qualities of demanded products. Countries with high real income levels would not just tend to consume *more* products but also *better* products. As recycled products and materials are generally of a lower quality than primary goods and materials, this implies that the demand for recycled products is relatively large in developing countries. Linder argues that each country confines its production to goods within the range of product qualities consumed domestically. This implies that developing countries would tend to focus relatively more on secondary production and trading than on primary production. Only after several constraints on the expansion of the industry are overcome, such as limited market information and transportation costs, domestic production may extend its focus to the export market. The firms supplying secondary commodities nowadays have access to a wide international network through, for example, the Chicago Board of Commodities (CBOT 1999).

7. Environment-oriented trade theories

Environmental cost is a factor that is increasingly recognised to have an impact on the comparative cost difference between countries. There are clear differences in environmental costs across countries, especially between developed and developing countries. This difference can cause trade between both regions. In this context, theories of trade and environment have been developed during the late 1970s and the 1990s. Much attention has been given to the 'pollution haven' or 'ecological dumping' hypothesis. This hypothesis states that if free trade occurs between countries with different environmental standards, countries with lower standards will develop a comparative advantage in relatively 'dirty' industries (Dean 1992, Rauscher 1994). Stringent domestic environmental regulations will

thus reduce the international competitiveness of national pollutive and resource intensive industries. A number of studies, however, have shown that ecological dumping is unlikely to occur. Reasons vary from the inability of governments to set a particular level of environmental tax or standard (Ulph 1999) to the limited importance of environmental costs in the overall costs of industries (Bouman 1998).

Another view on the relation between environmental policies and trade is given by the 'Porter hypothesis' (Porter 1991). This hypothesis claims that strategically operating governments should set stringent environmental policies as a way to increase the incentives for firms to invest in R&D and innovate new 'green technologies' ahead of their rivals. This would lead to a long-term competitive advantage for industries with though environmental regulations. Ulph (1991) shows, however, that because tougher environmental policies reduce profits, the incentive for firms to invest in R&D may actually reduce.

In addition, the literature has studied the net-effect of trade liberalisation on the environment. From a theoretical perspective, the impact of trade liberalisation on the environment is not clear. Siebert (1987) and van Beers and van den Bergh (1996) incorporate environmental elements in the HO model by interpreting the availability of scarce environmental assimilative capacity as a factor of production that influences the comparative advantage of a country. If a country has a relatively abundant factor 'environment', then removing trade barriers leads to increased specialisation in environment-intensive goods. However, the environmental version of the Stolper-Samuelson theorem states that the price of environment relative to other inputs will increase, causing all industries to switch to less pollution intensive techniques. Copeland and Taylor (1994) show that a decrease in income in a country can produce a comparative advantage in environment-intensive goods, even when externalities are optimally internalised into production costs.

Empirical evidence on the relation between the production factor 'environment' and trade is limited. Tobey (1990) examines the impact of environmental regulations on trade flows using the HOV model. Environment is treated in a similar manner as the production factors labour and capital. No relation is found between environmental stringency and trade. By focusing directly on the toxic intensity of output, Lucas *et al.* (1992) find that countries with higher growth rates maintain lower rates of increase in toxic intensity. Openness in the trade regime contributes to cleaner growth, namely by changing the composition of output towards cleaner sectors. This evidence of the 'technique effect' implies that developing countries have no comparative advantage in environment-intensive goods. Xinpeng (1996) examined whether stringent environmental standards reduce international competitiveness of such industries. He finds that the export performance of dirty industries in 34 countries remained unchanged between the 1960s and 1990s, despite the introduction of stringent environmental standards in most importing countries. Van Beers and van den Bergh (1997) is one of the few empirical studies finding a negative impact of environmental regulation on imports and exports, for total trade and for "dirty footloose" industries.

Theories of trade and environment can provide useful information for analysis of the international MPC. Developing countries might have a comparative advantage in environment-intensive products and thus would increase exports of environment-intensive goods and imports of environment-intensive inputs under free trade. Current international MPCs reveal a relatively large share of secondary commodities from developed to

developing countries. It is not possible, however, to say in general whether secondary commodities are more environment-intensive than primary commodities. Due to the cleaner production characteristics of wastepaper compared to conventional paper production, Van Beukering and Duraiappah (1998) find that strict environmental regulations encourage the import of wastepaper in India. Michael (1998) finds a similar impact of environmental regulations in the US. Hoffmann (1999) and Van Beukering and Bouman (2000), on the other hand, find that due to stricter national and international environmental standards the trade of lead scrap has been reduced.

8. Conclusions

Globalisation leads to an increased physical interdependency of economic activities in different regions. The theoretical and empirical causes and consequences of this development are hard to decipher. The international material-product chain (MPC) approach has been applied as conceptual framework to understand the international trade of secondary materials. Rather than viewing trade as a homogeneous flow of materials and products, the international MPC classifies trade flows according to the origin in the MPC. Taking into account the variations in the factor requirement of the different segments in the MPC and the local availability of these factors, the MPC illustrates how and why vertical and horizontal integration between segments of the MPC occurs at national and international levels. As a result, observed developments in international trade can be explained more accurately.

Several trade theories have been evaluated to determine their explanatory value of the current patterns in the international MPC. None of the trade theories provide an all-encompassing explanation of the increase of vertical and horizontal dependencies between the various segments in the MPC. Each theory explains a different aspect of the international MPC:

- The HO theorem forms an appropriate basis for application to recyclable waste trade as a result of existing comparative advantages. Developed countries export the abundance factor ‘secondary materials’ while developing countries use the required cheap labour to convert secondary materials into products.
- The demand theory reason that because consumers demand lower quality materials and products in developing countries, secondary commodities flow to these countries. As technological innovations in the recycling industry gradually eliminate the quality difference between recycled and primary products, the explanatory value of this theory on international trade of primary and secondary materials may reduce.
- According to neo-technology theories, new (recycling) technologies originate and mature in developed countries after which they gradually diffuse to developing countries. Indeed, the last decades have shown significant increases in recycling in developed countries. The growing trade flows of secondary materials can be explained as embodying the recycling technologies that exported from Europe, the United States and Japan.
- Theories on location point at the importance of the positive externalities of clustering of economic activities. Being strongly dependent on up- and downstream agents, concentration is especially important for the recycling industry. Only when strategically

located, economies of scale in the recycling industry can be achieved. International trade is a supplementary source of inputs.

- Trade theories incorporating environmental elements reason that developing countries might have an advantage in environment-intensive products and materials and thus import relatively much low-grade commodities and waste materials.

There is a parallel between the sequence of subsequent stages in the MPC and the emergence of the discussed theories on trade. Ricardian theories focus mainly on primary commodities. The neo-classical HO theorem concentrates predominantly on final commodities. Location and technology-oriented theories tend to focus on consumer goods. Environment-oriented trade theories are particularly relevant in explaining trade flows of waste materials and secondary commodities. The most plausible explanation for this phenomenon is that, not surprisingly, trade theories are influenced by changes in the real world. Extrapolating this trend, one could expect that soon trade theories emerge that address specific features of e-commerce. This could have significant impacts on perspectives on the relation between traded services, goods and materials.

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