The Importance of Material Flow Analysis for Commodity Transport Demand and Modelling

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Biographical notes

Jan S. Kowalski is Professor of Economics (International Economic Policy) at the Institute For Economic Policy Research at the University of Karlsruhe. His research activities focus on comparative economic systems, transformation problems in Central and Eastern Europe, regional development and policy, particularly the role of SMEs, technology and innovations, technology transfer policy, responses of the public institutions to changes in the framework for regional competition, transborder cooperations and consequences of the implementation of the EU.

After obtaining a graduate degree from the Faculty of Foreign Trade of the Warsaw School of Planning and Statistics he joined the doctoral programme of the Institute of Geography of the Polish Academy of Sciences followed by a lecturership at the Faculty of Geography and Regional Studies of the Warsaw University. 1980 he went to Germany to the Institute for Economic Policy Research of the University of Karlsruhe on a scholarship of the Humboldt-Foundation. In the fall of 1989 he was guest professor at the Universite de Montreal, 1992 he became Professor of Economics at the University of Münster, since 1995 he joined the University of Karlsruhe where he is professor of economics and the Head of the Section of International Economic Policy at the Institute for Economic Policy Research. 1999-2000: guest professor at the Economics Department, San Diego State University.

Gernot Liedtke, born in 1973, studied physics at the University of Stuttgart and industrial engineering at the École Centrale Paris. He works for the Institute of Economic Policy Research (IWW) since 2000. He defended his PhD-thesis on behaviour-oriented commodity transport simulation in 2006. For his dissertation he received the Hans-Jürgen Ewers-Price for applied infrastructure research of the free University of Berlin and the International German Science Award for Logistics of the German Logistics Association (BVL). In the current research, he combines normative tools from Logistics science with descriptive simulation methods to map de-central decision making in transport and logistics systems and thereby to study emergence of logistics-networks.
Axel Schaffer, born in 1970, studied industrial engineering at the University of Karlsruhe (TH) between 1990 and 1996. He works for the Institute of Economic Policy Research (IWW) since 1996 and defended his doctorate on ecological input-output analysis in 2002. For a presentation on the very same topic he received the “Edwin von Böventer Price” of the German speaking section of the Regional Science Association International. His current research puts an emphasis on socio-ecological input-output models that combine time use data with traditional input-output tables and material balances. The results of this research also define the core of his habilitation (completed in 2007).

Ralph Spiering, born in 1965, finished his studies of communication-sciences, politics and economics in Munich and Vienna in 1993. He is the managing partner of PACKSERVICE, a company with core activities in co-packing and logistic supports. Under his direction, PACKSERVICE now runs locations in Germany (Karlsruhe, Bühl, Pforzheim, Augsburg, Stuttgart, Unna) and Austria (Linz and Vienna). Recently he formed the PS Consulting (2005), a company for consulting services in logistic supply chain management and set up the new PS Academy in 2007 for internal and external trainings and workshops related to modern logistics.

Abstract

It can be shown that generated and attracted transport volumes, measured in tons, are closely related to direct material input (DMI). However, structural changes and new logistics concepts still lead to an increase of transportation performance. Therefore, the paper at hand aims to explain the scales of freight transport volumes (measured in tons) and performance (measured in ton-kilometers) from material flow analysis by additionally taking into account information from physical input-output tables. In so doing, effects of changing final demand on transport indicators can be identified. But while input-output tables give a good idea about technological processes, important information on the transport chain is missing. For this reason, the macroscopic approach of input-output analysis is supported by a microscopic analysis on freight transport markets and modern logistic concepts.

1 Introduction

In all post-communist countries the transportation sector composition and its performance experienced deep changes during the transition period from the centrally planned to market based economic system. On the one hand, especially in the first transition period, transport demand for goods decreased due to the rationalization processes connected with the transition. On the other hand high growth rates (as compared to their Western European counterparts) which are recorded in these countries for the last 10 years resulted in increased
demand for transport services. Simultaneously a deep evolution in the modal split towards the long distance road transport was recorded.. In this contribution we present an approach permitting the new market economies in Central and Eastern Europe to prepare for the challenges of this rash and deep structural change in a more efficient manner than the traditional approaches permit.

Material flow analysis generates highly aggregated indicators for the material flows at the scale of national economies. It can be assumed that generated and attracted transport volumes (measured in tons), measured in tones, closely relate to material flows. Thus material flow analysis can be considered a complementary tool for properly designed commodity transport models.

The paper at hand presents an approach to explain the scales of freight transport volumes from material flow analysis for the German economy. For this purpose, findings of the German system of environmental accounting are combined with traditional instruments of input-output analysis and calibrated by transport statistics.

The first part of the paper identifies interdependencies between material inputs and transport volumes. The key prediction is that transport volumes closely relate to direct material inputs, regardless the considered production branch.

In contrast, the model calculations suggest a weaker correlation between transport volumes and transport performance (measured in ton-kilometers) among production branches. This in turn, can be explained by the heterogeneity of freight markets and logistic concepts (second part).

Finally, the findings of the first and the second part allow for drawing first conclusions concerning the future development of the transport performance.

2 Direct material input and transport volumes

2.1 The relevance of direct material input for the satisfaction of final demand

By common sense reasoning, it should be expected that an increase in material input into a country’s economy (such as reflected in Direct Material Input (DMI), one of the standard indicators of material flow analysis) should boost, on the one hand, the volume of final demand and, on the other hand, freight transport within this country. DMI comprises the total volume of materials extracted from the domestic environment to enter economic processing,
plus the total volume of imports from other countries, expressed in tons per year (Eurostat and IFF, 2004).

Each ton of the DMI enters the economic cycle and will then be processed through several stages, from the extracting primary sector to manufacture, from manufacture to manufacture or commerce, from commerce to consumers, and from consumers to waste deposits. Alternately, products can be exported to another country. In this context, the German System of Environmental Accounting identifies the usage of DMI by 72 production branches (Statistisches Bundesamt, 2006). The combination of these findings with traditional input-output analysis further allows for the assignment of DMI to diverse categories of final demand (Schaffer and Stahmer, 2006a). These categories are based on the traditional input-output tables for Germany and include private and public consumption, investments and exports. A more detailed analysis further allows for separating specific categories of final demand. In this context, the presented study additionally separates final demand for food without animal feed (Schaffer, 2005; Schaffer and Schulz, 2006).

The amount of DMI necessary to satisfy the final demand for domestically produced goods $M^{\text{dom}}$ is calculated according to equation (1). In order to combine tons of DMI with monetary input-output data, DMI coefficients ($M_{\text{beom}}$) are derived from the division of physical flows with the (total) production value of the consuming branch. The index $\text{beom}$ points to the fact that DMI is further subdivided into: biomass, energy sources, ores and other minerals. Finally, the application of the classical Leontief inverse matrix allows for the allocation of directly and indirectly needed tons of DMI to the different categories of final demand (Schaffer and Stahmer, 2006b). The following relations set up the basic equations:

\[
M^{\text{dom}} = M_{\text{beom}} \cdot B^{\text{dom}} \cdot Y^{\text{dom}} 
\]

\[
M_{\text{beom}} = \begin{pmatrix}
    m_{\text{biomass}} \\
    m_{\text{energy sources}} \\
    m_{\text{ores}} \\
    m_{\text{other minerals}}
\end{pmatrix}
\]

\[
B^{\text{dom}} = (I - A^{\text{dom}})^{-1}
\]

$m_i$: Row vector (n elements) of DMI coefficients differentiated by four type. The vector results from the division of tons of DMI related to n (=71) branches’ by the corresponding production values.
$M_{\text{beom}}$: $s \times n$ matrix of DMI coefficients by $s (=4)$ categories of DMI and $n$ branches.\(^1\)

$I$: Unity matrix.

$A^{\text{dom}}$: $n \times n$ monetary matrix of input-coefficients (domestic production of the German economy in 2000).\(^2\)

$Y^{\text{dom}}$: $n \times k$ matrix of monetary final demand of domestic production (by $n$ commodity groups and $k (=5)$ categories of final demand.

$M^{\text{dom}}$: $s \times k$ matrix of DMI necessary to satisfy final demand of domestic production.

Following these equations, table 1 shows the annual DMI necessary to satisfy the different categories of final demand for domestic products. Due to the application of the Leontief inverse, DMI usage at all production stages is considered.

### Table 1

**DMI necessary to satisfy consumers’ needs for food and other categories of final demand in 1000 tons per year, Germany, 2000, (domestic production)**

<table>
<thead>
<tr>
<th>Consumption of food</th>
<th>Other private consumption</th>
<th>Public consumption</th>
<th>Investments</th>
<th>Export</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Biomass</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>117,928</td>
<td>52,027</td>
<td>9,456</td>
<td>12,166</td>
<td>56,027</td>
<td>247,604</td>
</tr>
<tr>
<td>47.6%</td>
<td>21.0%</td>
<td>3.8%</td>
<td>4.9%</td>
<td>22.6%</td>
<td>100.0%</td>
</tr>
<tr>
<td><strong>Energy sources</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18,203</td>
<td>245,872</td>
<td>35,269</td>
<td>42,268</td>
<td>148,735</td>
<td>490,348</td>
</tr>
<tr>
<td>3.7%</td>
<td>50.1%</td>
<td>7.2%</td>
<td>8.6%</td>
<td>30.3%</td>
<td>100.0%</td>
</tr>
<tr>
<td><strong>Ores</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>728</td>
<td>10,704</td>
<td>1,339</td>
<td>12,008</td>
<td>77,430</td>
<td>102,209</td>
</tr>
<tr>
<td>0.7%</td>
<td>10.5%</td>
<td>1.3%</td>
<td>11.7%</td>
<td>75.8%</td>
<td>100.0%</td>
</tr>
<tr>
<td><strong>Other minerals</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16,570</td>
<td>107,767</td>
<td>44,022</td>
<td>512,360</td>
<td>128,711</td>
<td>809,431</td>
</tr>
<tr>
<td>2.0%</td>
<td>13.3%</td>
<td>5.4%</td>
<td>63.3%</td>
<td>15.9%</td>
<td>100.0%</td>
</tr>
<tr>
<td><strong>Total DMI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>153,430</td>
<td>416,371</td>
<td>90,086</td>
<td>578,802</td>
<td>410,903</td>
<td>1,649,592</td>
</tr>
<tr>
<td>9.3%</td>
<td>25.2%</td>
<td>5.5%</td>
<td>35.1%</td>
<td>24.9%</td>
<td>100.0%</td>
</tr>
</tbody>
</table>

In order to satisfy, for example, consumers’ needs for food (without animal feed), approximately 117.9 million tons of biomass are necessary. This refers to 47.6\% of total biomass. In addition 18.2 million tons (3.7\%) of energy sources, 0.7 million tons of ores (0.7\%) and 16.6 million tons of other minerals (2.0\%) can be assigned to this category of final demand.

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\(^1\) Calculations differentiate by gender and three age groups: young persons younger than 18 years, adults aged between 18 and 65 years and seniors 65 years and older ($s = 6$ demographic groups). For the sake of clarity, figures and tables show aggregated results by gender.

\(^2\) It is assumed that each of the $n$ industries produces goods that belong to one out of $n$ commodity groups.
demand. Thus, the total DMI needed to satisfy demand for food amounts to 153.4 million tons which accounts for about 9.3% of total DMI absorbed by the economy. The physical flows include DMI assigned directly to the branch food production and to intermediated branches such as agriculture, energy supply, chemistry, transportation etc.

2.2 The relationship of direct material input and transport volumes

Supposing all material inputs into the national economy would be directly delivered to their final destination. In this case the transport volume would be equal to DMI. However, in order to satisfy final demand, direct material inputs run through a multiple stage production process. On the one hand, combustion processes that occur at all stages diminish the weight to be further processed. On the other hand, goods are loaded for transportation several times.

Thus, transport volume is a function of DMI and a re-loading factor that depends on the number of production stages and the combustion. Obviously, the re-loading factor differs significantly among the branches. A branch at the beginning of the extraction-production-consumption-disposal (EPCD) chain shall have lower factors compared to branches at the very end, despite generally higher combustion at the beginning of the chain. However, it could be assumed that the factors differ less strongly, if it comes to the satisfaction of different categories of final demand. In this case, the corresponding products went through several (partly similar) production stages and now belong to the same stage of the EPCD chain.

The use matrix of the physical input-output table (PIOT) allows for an empirical test of this assumption. This is true, since one of the PIOT sub-matrices provides a first overview on transportable physical flows used by production branches. It should be emphasized that only incoming flows are considered. Thus, double counting can be avoided.

The procedure to estimate transported flows, necessary to satisfy the different categories of final demand follows the approach outlined by equations (1) to (3). However, coefficients result from the division of incoming transport flows by the production value of the corresponding branch. Furthermore, transport volume is not subdivided anymore. Thus coefficients are given as vector and as matrix.

\[ tv_{\text{dom}}^{\text{dom}} = tv \cdot B_{\text{dom}}^{\text{dom}} \cdot Y_{\text{dom}} \]  \hspace{1cm} (4)
Row vector (n elements) of transport volume coefficients. The vector results from the division of incoming transport (measured in tones) related to n (=71) branches’ by the corresponding production values.

The application of equation (4) enables the estimation of direct and indirect transport volumes that come along with the satisfaction of final demand. Table 2 compares transport volumes with DMI and provides the corresponding re-loading factor.

**Table 2**

*Transport volumes and DMI necessary to final demand in 1000 tons per year, re-loading factors, Germany, 2000, (domestic production)*

<table>
<thead>
<tr>
<th></th>
<th>Consumption of food</th>
<th>Other private consumption</th>
<th>Public consumption</th>
<th>Investments</th>
<th>Export</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>DMI</td>
<td>153 430</td>
<td>416 371</td>
<td>90 086</td>
<td>578 802</td>
<td>410 903</td>
<td>1 649 592</td>
</tr>
<tr>
<td></td>
<td>9.3%</td>
<td>25.2%</td>
<td>5.5%</td>
<td>35.1%</td>
<td>24.9%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Transport volume</td>
<td>330 136</td>
<td>766 723</td>
<td>152 554</td>
<td>984 180</td>
<td>825 875</td>
<td>3 059 468</td>
</tr>
<tr>
<td></td>
<td>10.8%</td>
<td>25.1%</td>
<td>5.0%</td>
<td>32.2%</td>
<td>27.0%</td>
<td>100.0%</td>
</tr>
<tr>
<td>Reporting:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>re-loading factor</td>
<td>2.2</td>
<td>1.8</td>
<td>1.7</td>
<td>1.7</td>
<td>2.0</td>
<td>1.9</td>
</tr>
</tbody>
</table>

The re-loading factor, which results from the division of transport volume by DMI, ranges from 1.7 in the case of public services to 2.2 in the case of final demand for food. The re-loading factor does not necessarily equal with the separated factor of the main production branch responsible for the satisfaction of the corresponding demand. Food production, for example, shows a loading factor of about 3. Contrary, the loading factors of contributing branches, such as agriculture (1.5) or energy supply (1.2) are significantly smaller. However, due to the application of the input-output model, the re-loading factors given by table 2 account for factors of all branches that deliver inputs to food production.

It can be concluded that loading factors assigned to different categories of final demand range in a rather small corridor.
2.2 Additional impacts caused by the logistic system

Using the information of physical input-output tables, it is possible to deduce impacts of changes in the final commodity demand by segment on transportation volume measured in tons. The factor describing the relationship between final demand and transportation volume has been rather constant over time.

But while input-output tables give a good idea about technological processes, important information on the transport chain is missing. Transport stimuli, initiated by wholesale and retail trade cannot be considered in a sufficient way. In fact, only physical inputs needed for the performance of these services, e.g. building materials for warehouses etc. are taken explicitly into account. In contrast, the PIOT hardly gives any information on goods re-loaded without undergoing any physical transformation (besides being re-loaded and transported). Thus, the calculated transport volume under-estimates the real transport volume.

In order to close this gap, impacts of the logistic system are additionally taken into account. Generally, commodities are not directly delivered from their location of production to the location of consumption (which would equal to re-loading factor of 1). The division of the production process, often performed at different locations, requires the re-loading for several times. After the final production stage, goods are either delivered to their final destinations, or they are stored. In the case of storage, goods might be transported to a warehouse before being delivered to the final destination. This intermediate step, clearly adds to the above-calculated re-loading factors. The more complex modern logistics and transport systems are involved, the more the re-loading factors are determined by effects apart from the technologically driven production processes. Consequently, logistics and transportation operations lead to an additional transportation volume that is not captured in the PIOT.

In some cases, companies cannot circumvent to play an active role in the distribution of their commodities. Distribution logistics systems are used, when a large amount of articles should be delivered from a certain production to a large number of customers in space. A typical example is the replacement part logistics of car manufacturers. National and regional distribution centers assure a trade-off between storage costs and articles’ availability. The final points of delivery are reached using rather small lorries performing local distribution tours. Thus, replacement parts would be re-loaded twice after the original production process (figure 1).
Retail and wholesale systems have a close similarity to the pure distribution systems operated by the manufacturers. In these cases, a central purchasing unit of a retailing group or a retailing association orders large quantities of products from different producers re-commissions them and delivers them to shops (figure 2).

In reality, different types of logistics systems are mixed. For instance, it might happen, that a producer’s distribution system directly delivers the shops or that certain articles do bypass the central distribution centers. The highest share of consumption goods, for instance, is directed via one distribution centre to the final customers in the shops. Thus the re-loading factor...
would just increase by 1. In the case of food, however, products are often distributed by central and regional distribution centers. Liedtke (2006) gives a detailed insight into the different logistic concepts by main commodity groups. The different methods applied to get a plausible picture of inter-sectoral flows through trade networks are described by Babani et al. (2006). The results of these analyses can be presented in form of connection graphs (figure 3).

**Figure 3: The flow of „beverages“ through distribution systems in Germany (2002).**

The findings allow for a first estimation of the additional freight volume induced by the different distribution systems. This volume can be assigned to the production branches wholesale and retail trade.

An additional source of double counting should only be sketched: Parallel to distribution systems, freight transportation service companies have build up hub-and spoke systems for single pallets, parcels and containers. In cases, when companies have a too few flow of commodities, such networks are used, where the forwarder combines shipments with many other ones form other shippers.

As a consequence thereof, trade volume, assigned to the different categories of final demand can be re-calculated by following equation (4). Table 3 gives an overview on the revised findings. The total just complies with the transport volume given by the federal transport statistics (DIW, 2002).
It should be emphasized that additional re-loading is significant for final products. However, effects on intermediate flows are much smaller. Thus, the calculated effects (which account for re-loading factors of intermediate products as well) are considerably small. Strongest effects can be observed for trade volumes assigned to the consumption of food and investments. Increases related to food production are mainly driven by the above mentioned distribution system for food products. In the case of investments, waste treatment might add to the factor.³

In fact, the revised re-loading factor for the whole economy has been quite stable for the German economy in the last decade (Fischer-Kowalski et al., 2006). Thus, additional transport volumes that result from changes of final demand can indeed be estimated by the DMI necessary to satisfy final demand and a re-loading factor close to 2.5.

Considering total DMI a decreasing trend has been observed in the last decade. This is particularly true for abiotic DMI but does not hold for the consumption of biomass, which has increased (Statistisches Bundesamt, 2006). The question, whether DMI will further decrease in the future or whether this favorable trend will come to an end cannot be discussed in further detail here. However, according to several studies in the field of material flow analysis, total DMI is unlikely to increase significantly in the future (Fischer-Kowalski et al., 2006; Eurostat and IFF, 2004). Consequently, it is unlikely that transport volumes will increase significantly in the future.

³ Waste is considered input to landfills, which belong to the group of investments.
3 Direct material input and transport performance

Although transport volumes are unlikely to grow substantially in the future, transport performance measured in tkm, could indeed increase if covered distances rise. In order to discuss potential increases of distances, again the role of modern logistic concepts will be scrutinized closely.

3.1 Impacts on transport distances caused by the logistic system

To carry commodities between the nodes of the production system and the nodes of distribution and transport logistics systems, vehicles are needed.

Whilst the flow of commodities could be represented in form of directed edges (flashes) in space and time, the major share of vehicles operates in form of closed loops. Take, for example, regular round trips of airplanes or the trucks on the road, where drivers more or less regularly return to their family. A classification of tour patterns is given by Liedtke and Schepperle (2004).

**Figure 4: Clusters of typical tour patterns**

![Figure 4: Clusters of typical tour patterns](source: Liedtke and Schepperle, 2004)

These tour types can shortly described in the following way:

- Regional distribution: A rather small or medium lorry successively unloads or loads goods on a short or medium trip.
- Trucking tours: Irregular sequences of full and empty running trips.
- Shuttle tours (even, uneven).
- Consolidation: Sequences of loading and unloading sequences, long distances, large lorry.
- Tri-/quadrangle tours (e.g. company A in Region 1 - company B in Region 2 - company C in Region 2 - company D in region 1).

In some cases, a correlation between distribution systems and tour types can be found. For instance, the delivery from regional distribution centers to shops is conducted in form of distribution tours whilst cross-border transports are most likely direct transports (“Quadrangular tours”) or consolidated full load transports (“shuttle tours”) between transportation network nodes. In contrast, it could be expected that durables starting from the manufacturer be transported in form of full truckload shipments to the wholesaler’s distribution centers.

The methodological tools for setting up such a relationship based on empirical findings, additional expert inputs and entropy-maximizing algorithms is described by Liedtke and Schepperle (2003). The detailed results are presented by Babani et al. (2006) and Liedtke (2006). The results are trip length distributions for each step of supply chains. Figure 5 gives an example.

**Figure 5: Trip-length distribution of full-load trips with durables on board**

![Trip-length distribution of full-load trips with durables on board](source)

Source: Liedtke (2006)

Thereby, the findings can be combined with information on transport performance by commodity groups as given in federal transport statistics (DIW, 2002). This opens the door to analyzing the transportation performance related to the final demand.
3.2 Transport performance related to final demand

The assignment of transport performance to the diverse categories of final demand follows the approach applied for DMI and transport volume. In order to calculate transport performance coefficients, statistics on ton-kilometers by commodity groups are taken into account (DIW, 2002). These statistics allow for a separation of the following commodities: products from 1) agriculture and forestry, 2) food and animal feed, 3) products from coal mining, 4) crude petroleum and products of crude petroleum, 5) ores, 6) ferrous and steel products, 7) minerals and building materials, 8) fertilizers and 9) chemical products. Furthermore, a tenth miscellaneous category, including vehicles and machines is given. The transport performance of the first nine groups, which refers to about 75% of the total transport performance, can easily be assigned to the consuming production branches. The remaining ton-kilometers related to the tenth group have been distributed according the shares of the transport volumes.

Finally, the direct and indirect ton-kilometers necessary to satisfy consumers’ needs can be estimated according equation (5):

\[ tp_{\text{dom}} = tp \cdot B_{\text{dom}} \cdot Y_{\text{dom}} \]  

\[ (4) \]

\( tp \): Row vector (n elements) of transport volume coefficients. The vector results from the division of incoming transport (measured in ton-kilometers) related to n (=71) branches’ by the corresponding production values.

Table 4 shows the assignment of ton-kilometers to the diverse categories of final demand. Furthermore, transport distances that result from the division of transport performance by DMI are given.

<table>
<thead>
<tr>
<th>DMI (in mill. tons)</th>
<th>Consumption of food</th>
<th>Other private consumption</th>
<th>Public consumption</th>
<th>Investments</th>
<th>Export</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>153</td>
<td>9.3%</td>
<td>416</td>
<td>25.2%</td>
<td>579</td>
<td>411</td>
<td>1 650</td>
</tr>
<tr>
<td>100.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DMI (in mill. tkm)</th>
<th>Consumption of food</th>
<th>Other private consumption</th>
<th>Public consumption</th>
<th>Investments</th>
<th>Export</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 523</td>
<td>12.4%</td>
<td>104 907</td>
<td>21.5%</td>
<td>157 634</td>
<td>143 673</td>
<td>488 600</td>
</tr>
<tr>
<td>100.0%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Reporting: distances in km | 394 | 252 | 243 | 272 | 350 | 296 |

**Table 4**

Transport performance and DMI necessary to satisfy final demand in million tkm and million tons per year, transport distances in km, Germany, 2000, (domestic production)
Transport performance does not account for sea shipping but refers to road, rail and inland waterway transport in Germany (no matter if the haulier is German or not). Furthermore, imports are only considered, if they enter the production process but not if they are delivered directly to the consumers.

The covered distances give an idea about the average distance covered by one ton of material input to satisfy consumers’ needs on its way alongside the EPCD chain. Distance is particularly high in the case of (direct and indirect) inputs to food production and to exports. However, the high re-loading factor related to food production points to a higher number of trips necessary to satisfy demand for food. Thus, the average trip distance is probably higher in the case of exports.4

Due to decreasing or at least constant DMI, transport performance will only grow, if re-loading factors or average distances rise. With regard to the loading factors some changes might occur in the future. However, expected changes hardly justify to expect significant growth rates for a longer period (section 2.3). Thus, it all depends on average distances. Since the study at hand does not account for kilometers driven abroad (in order to satisfy demand for domestic products), the question cannot fully be answered here. However, considering logistic concepts might give a first insight into future trends.

4 Conclusions

The main points made in this paper fall into two parts: The first part is devoted to the development of a model that links DMI and freight volumes by combining material flow with input-output analysis. Concerning the production process, it can be shown that transport volumes are a fairly constant multiple (re-loading factor) of DMI depending, on the one hand, on the number of production stages and, on the other hand, the combustion of energy sources. The application of input-output analysis allows for a good estimation of transport volumes that come along with the production of goods. However, volumes related to the distribution of these goods can hardly be projected from physical or monetary input-output tables.

The presented study overcomes this shortcoming by additionally taking into account detailed information on freight markets and logistic concepts. In so doing, revised re-loading factors can be identified. Although the revised calculations result in higher factors, they still seem to be rather constant over time. Since DMI is expected to continue the decreasing trend in the

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4 Note that the re-loading factor is also determined by the combustion of energy sources. Thus it does not reflect the average but rather the minimum number of trips necessary to satisfy demand for the corresponding category.
near future (for the German economy), transport volumes can be considered to stagnate in the near future. Thus, it can be concluded, that significant growth rates of transport performance must derive from rising distances. Indeed, international transport might continue to gain in importance. However, first empirical findings suggest that the introduction of the HGV toll in Germany clearly slows down this process. As a consequence thereof, limits to growth might soon be experienced in the case of road freight transport in Germany.

References


