Comparison of environmental multipliers of monetary and physical Leontief inverse

Ilmo Mäenpää

Thule Institute, University of Oulu
P.O. Box 7300, FIN-90014 University of Oulu, Finland
Phone +358 8 553 3555, Fax +358 8 553 3564, E-mail: ilmo.maenpaa@oulu.fi

Abstract

The question to be analysed in this study is as follows: would Leontief inverse of a physical input-output table (PIOT) give more reliable estimates especially for total environmental loads of products – or for environmental multipliers – than that of monetary table (MIOT). It is shown that the two approaches give different results and that both of them have inherent problems. As a solution to these problems a method is suggested that integrates the first round PIOT to the MIOT.

This study belongs to the methodological part of the ongoing research project *Environmental impacts of material flows caused by the Finnish economy* (ENVIMAT) financed by the Ministry of the Environment of Finland. For more information on the project, see: http://www.ymparisto.fi/default.asp?contentid=195528&lan=fi&clan=en

Keywords: input-output tables, MIOT, PIOT, environmentally extended input-output model, TMR, green house gas emissions

1. Input-output models used

The analysis is based on the 151 industry MIOT and PIOT for Finland for the year 2002, both with the same products and industry classifications.

The basic compilation level supply and use tables of Statistics Finland were used as a basis for the MIOT tables. The basic supply and use tables are rather detailed: 178 industries (mainly 3-digit NACE classification) and 918 products (applied CPA classification). Several service industries were aggregated because of the lack of physical data such that the number of industries reduced to 151.

For the PIOT the physical supply and use tables were compiled with the same industry and product classifications as in the monetary supply and use tables. The commodity deliveries and acquisitions database of the Finnish Industry Statistics, Foreign Trade Statistics and Energy Statistics were the main data sources for filling the supply and use tables with mass flows in kg units. Several other special statistics and databases such as agricultural, forest and mining statistics were also used for additional information. The monetary use tables were applied for allocating the product use to service industries and domestic final use categories. Here the detailed product classification of 918 products enabled a rather accurate allocation. The methodology of compilation of the Finnish PIOT has been developed in an earlier work (Mäenpää 2005).

The pure PIOT consists only of mass flows measured in kilograms. The first problem in applying PIOT to multiplier estimation is the lack of immaterial input links, which is why the pure PIOT was extended to include these. Some important immaterial input links can be measured in physical terms, too. The use of electricity and district heat was measured in energy units, kWhs. For services the monetary values from the MIOT were adopted. Thus the basic PIOT was extended into a hybrid table where all the product flows of the economy, whether material or immaterial, are included.

In the comparison of the results of the Leontief inverse calculations of MIOT and PIOT, two environmental load categories are used: total material requirement (TMR) and Greenhouse Gas emissions (GHG). TMR includes both the domestic and imported direct inputs and hidden flows. The GHGs include here only domestic emissions.

The total environmental loads of final products were calculated by the Leontief model $e'(I-A)^{-1}diag(f)$, where e is the vector of direct environmental loads per unit output of industries, A is the intermediate input coefficient matrix and f the vector of the final use of the products. All the calculations are done with the 151 industry breakdown. For demonstration, the results are aggregated into 15 industries and divided by aggregated monetary final use vector to reach the comparable environmental load intensities of the final products.

In both PIOT and MIOT models the direct TMR and GHG of each industry are the same. Thus the differences in the results are due to the differences in the allocation properties of the Leontief inverse of the two approaches.

2. Total material intensities

Total material intensities of products by MIOT and PIOT are presented in Figure 1. Large differences between intensities can be found especially in forest industries and metal industry.

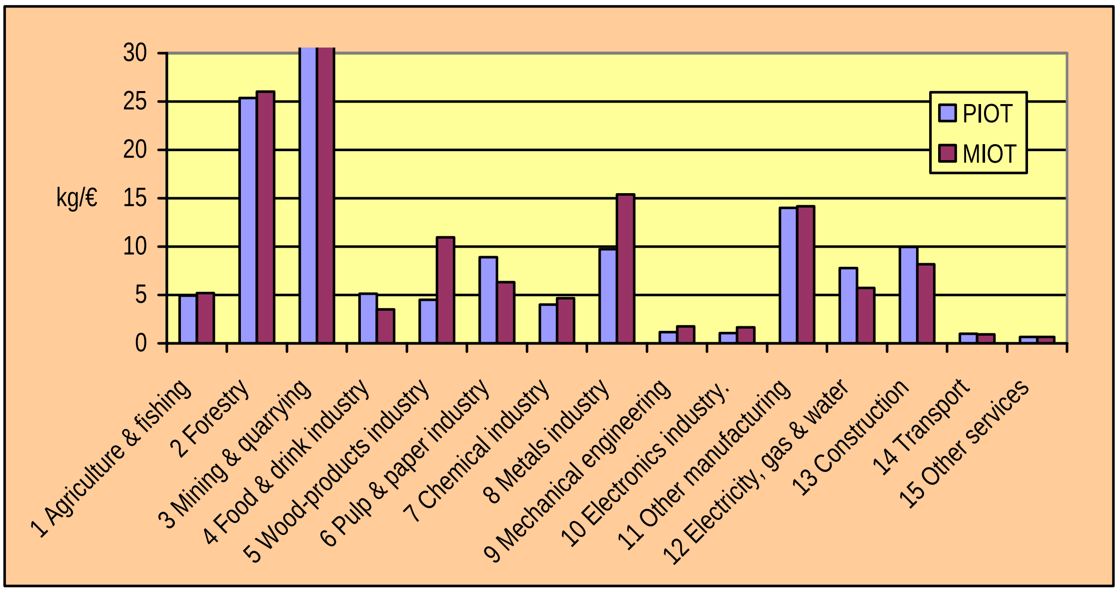

Figure 1. Material intensity of final products by industry in Finland 2002 (Intensities of mining & quarrying: 93 kg/€ by MIOT, 124 kg/€ by PIOT)

One reason behind the forest industry differences is the price deviation between saw logs and pulpwood. The price per kg of saw logs is almost twice the price of pulpwood. Therefore the use of forestry output is distributed between sawmills and pulp and paper mills as follows:

	MIOT	PIOT
Sawmills	60%	45%
Pulp & paper	40%	55%
	100%	100%

It is clear that with the MIOT method, too much of the TMR content of forestry output is allocated for wood products and too little for paper products.

Similarly, price differences of mining ores make the allocation of the material content of mining products for the chemical, metal and mineral industries different from true material inputs. The MIOT seems to allocate too much of the mining TMR to metal industry.

In the MIOT model, the problem of the inaccurate allocation of the environmental loads of primary raw materials can be corrected as follows. By means of the use table of the PIOT we move the load contents of the primary raw material producers to the users of those materials in the load vector e. Thus we have replaced the first order effects of MIOT by PIOT. Then we apply the corrected load vector in the MIOT Leontief model. For the direct final use of primary raw material products, the direct TMR content have to be added, however, to the Leontief inverse solution.

In Figure 2 the results of the original MIOT and corrected MIOTc are compared. The material intensities of wood and metal products have been reduced as expected, but in pulp and paper industry the higher raw wood intensity has been compensated for by other changes.

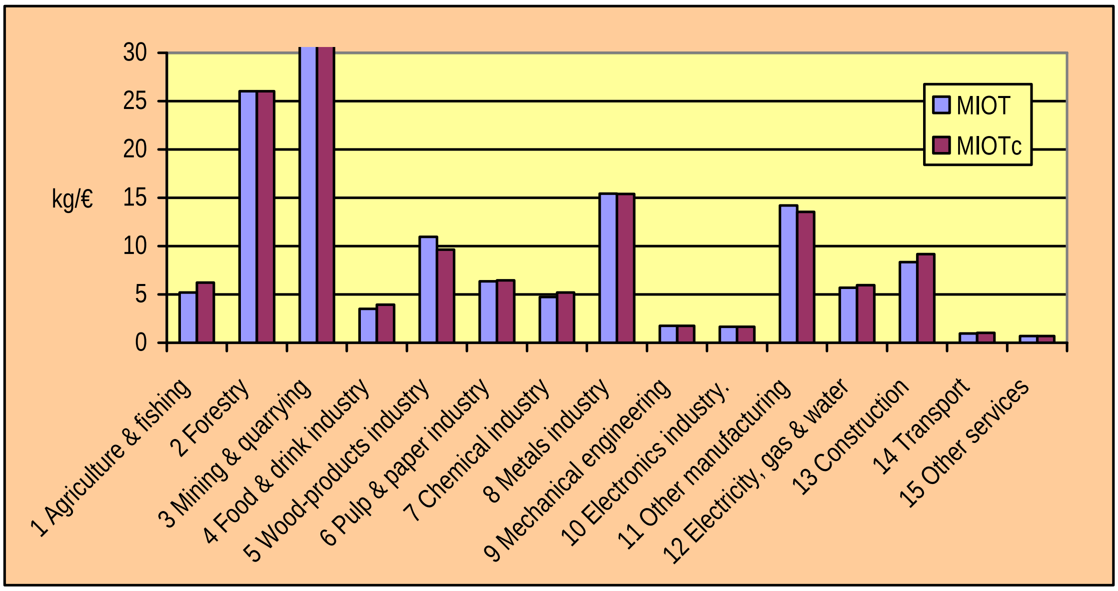

Figure 2. Total material intensities of final products by original MIOT and with raw material corrected MIOTc

The large deviations between MIOT and PIOT remain after the correction of primary raw materials in MIOT as seen in Figure 3.

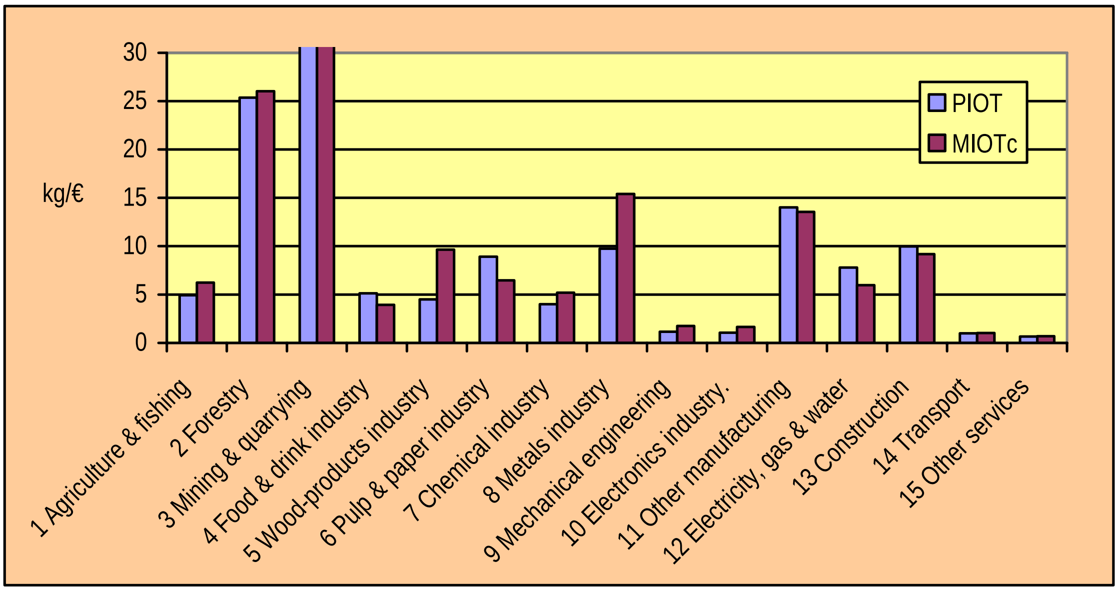

Figure 2. Total material intensities of final products by PIOT and with raw material corrected MIOTc

The main reason for the deviations seems to be in by-products. The by-product problem can clearly be seen in saw mills. The output of the sawing industry consists of three products which are divided as follows in MIOT and PIOT:

	MIOT	PIOT
Sawn goods	85 %	43 %
Sawmill chips	12 %	26 %
Other wood residues	3 %	31 %

Sawn goods are the main product of the industry. Sawmill chips are used in the pulp and paper industry as substitutes for virgin pulpwood. Other wood residues are used mainly as fuels for own use and in district heat and CHP plants. The MIOT allocates 85% of the sawmill TMR to the users of sawn goods and only a minor part to the users of by-products, whereas the PIOT allocates less than a half of the TMR to main product users and more than a half to by-product users.

A similar by-product problem is found in the steel and iron industry. In the mass units of PIOT about 22% of products consist of slag, and thus in the PIOT Leontief inverse that share of the TMR of the iron and steel industry output is allocated to the users of slag, or mineral industry and construction. In value terms of MIOT, only a negligible share of TMR is allocated to slag users.

	MIOT	PIOT
Steel products	99.6%	78%
Slag	0.4%	22%

The by-product flows with large masses but low monetary values are widespread in industrial intermediate product flows. This is a serious problem in the PIOT model and difficult to correct.

3. Green house gas intensities

The GHG intensities of products calculated by MIOT and PIOT are compared in Figure 3. The intensity differences between the methods are mostly in the same direction as in the TMR intensity comparison, even though the intensity levels between industries differ considerably.

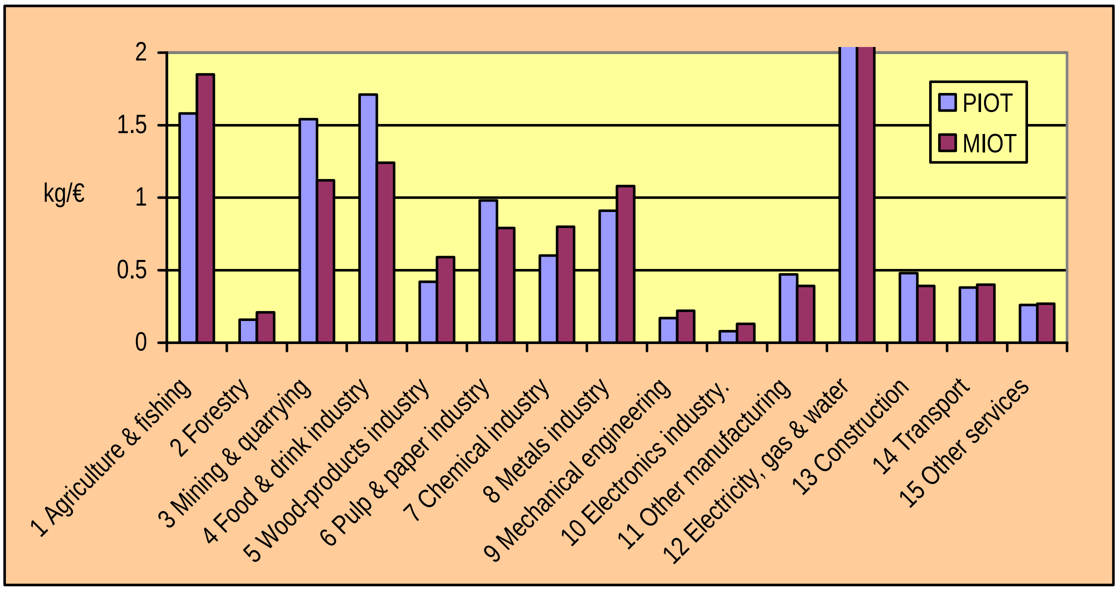

Figure 3. GHG intensities of products by MIOT and PIOT (Electricity, gas & water: MIOT 5.7 kg/€, PIOT 5.6 kg/€)

4. Conclusions

The environmental loads of final products calculated by Leontief inverse of MIOT and PIOT differ clearly. The reason for this that the assumption of homogeneity of products inside each industry do not hold. Especially the price differences between the main products and by-products are large and because they most often go to uses of different industries the Leontief inverse effects are large. Because the by-products are outputs of the same production processes as the main products, the more disaggregation of input-output tables do not provide solution to this problem.

Both MIOT and PIOT methods have problems. The main problem of MIOT seems to be often biased allocation of the loads of primary raw materials. The problem with PIOT is in the allocation of upward loads of secondary materials to the users.

The MIOT model can be corrected for the primary raw material bias problem by applying the first order primary material flows of the PIOT to the environmental load vector before the MIOT Leontief inverse method is applied.

Acknowledgements

The ENVIMAT research project titled "Environmental impacts of material flows caused by the Finnish economy (ENVIMAT)" (2006-2008) was funded by Environmental Cluster Programme organized by the Ministry of the Environment.

References

Mäenpää, I. 2005. Physical flow accounts, Calculation methods and concepts, Material balances of Finland 1999. Statistics Finland, Thule Institute, Helsinki, p. 171

Weisz, H. & Duchin, F. 2006. Physical and monetary input-output analysis: What makes the difference? In: Ecological Economics, vol. 57(3), pp. 534-541