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292/2007

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WIFO Working Papers, No. 292
May 2007

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2007/120/W/0

FROM ECOLOGICAL FOOTPRINT TO ECOLOGICAL RENT: AN ECONOMIC INDICATOR FOR RESOURCE CONSTRAINTS

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Abstract:
This paper takes as a starting point a combination of an (monetary) input-output model with a national Ecological Footprint account for Germany in the spirit of Wiedmann, et.al. (2006). Footprint as well as Biocapacity are dealt with at the industry level. Gross output of each industry and final demand for each industry can then be split up into a share that is reconcilable with Biocapacity and another share that corresponds to Biocapacity overshooting. The Ecological Footprint concept is extended in this study by introducing the additional biophysically productive land necessary for sustaining the given level of economic activity. It is assumed that each industry had to rent the corresponding areas and to apply a given technology in order to make this additional land biophysically productive. That results in a new technology for each industry leading to an increase in costs and prices. The new price level is directly linked to the share of output that corresponds to Biocapacity overshooting. Economic indicators can be derived by measuring the income difference brought about by the price increase. This difference corresponds to a Ricardian rent which is due to resource constraints on output growth.

Key words: input-output models, Ecological Footprint, Ricardian rent

1. Introduction

The carrying capacity concept has been the main foundation for the 'Ecological Footprint indicator' first proposed by Wackernagel, Rees (1996). This approach attempts to quantify the ecosystem resources in terms of biologically productive space that would be necessary to supply all resources a nation's population consumes and to absorb all the wastes that are generated. The Ecological Footprint concept should therefore be seen as an indicator or biophysical measure of natural capital. As Wackernagel,et.al. (2005) have recently pointed out, there is a link between the discussion about 'weak' vs. 'strong' sustainability (see: Neumayer (2002)) and the Ecological Footprint concept. Starting point of the paradigm of 'strong' sustainability is the observation of absolute scarcity of certain natural resources that leads to binding resource constraints (Daly, 1990). This binding resource constraint represents a limit for the exploitation of non-renewable natural resources or for the carrying capacity of ecosystems to absorb emissions. The potential of substitutability between natural and man-made capital, which is the core of the 'weak' sustainability paradigm is therefore limited with binding resource constraints. The Ecological Footprint can be seen as a measure of this resource constraint. Although the literature has deeply engaged in analysing the economic consequences of different versions of 'weak' sustainability the economic impact of 'strong' sustainability is less well researched (Neumayer (2002)).

The main idea of this paper is to extend the biophysical measure in the Ecological Footprint concept to an economic measure of a binding resource constraint. The Footprint concept is therefore used for deriving indicators of overuse of natural capital by economic activity and not as an environmental policy advice. The framework applied in this paper is an extended input-output framework including Ecological Footprint and Biocapacity as additional accounts.. Starting with Bicknell et al., (1998) a strain of literature emerged on combining the Ecological Footprint concept with input-output analysis (among others: Ferng (2001, 2002), Lenzen, Murray (2001, 2002, 2003), McDonald, Patterson (2004)). Most of these papers have interpreted the Ecological Footprint concept as an indicator concept and not as a tool for environmental policy analysis itself. Ferng (2002)) has incorporated this indicator concept in a general equilibrium model for environmental policy analysis in order to quantify the impacts of policies that reduce the Energy (Carbon) Footprint. Wiedmann, et.al.(2006) give an exhausting literature overview and also propose a methodology of linking Ecological Footprint accounts to input-output tables. This line is followed here and further developed, so that Ecological Footprint as well as Biocapacity can be allocated to industries.

The further development towards an economic measure based on the Ecological Footprint is carried out in the spirit of an adaptation of the well known 'pollution model' of Leontief (1970). The crucial issue in order to arrive at an economic measure is to construct a link between the overuse of natural capital and the costs of production. Leontief's pollution model offers one option for this link by introducing an emission absorption sector. A different link is lined out in Duchin (2004) between resource components within primary factors and value added components within a physical input-output model. This link results in rent components for the use of natural resources within value added.

Leontief's pollution model has often been critized for being too restrictive and only applicable to pollutants with a well defined economic activity of pollution absorption (see for example: Lager (1998)). This critizism can be seen as legitimate, if Leontief's pollution model is used as a tool for environmental policy advice. An alternative interpretation is to view absorption activities as 'hypothetical' activities measuring the costs of overuse of natural capital. An application with natural absorption of the ecosystem as the specific absorption activity in a Leontief pollution model can be found in Kratena (2004).

This interpretation of Leontief's pollution model coincides with the indicator-perspective of the Ecological Footprint. In both cases the indicator shows *ex post* the consequences of a certain level and structure of economic activity (produced with a given technology) in terms of loss of natural capital. If Leontief's pollution model is applied the costs of this loss of natural capital can be approximated by the 'hypothetical' cost of (*ex post*) absorption. As Lager (1998) has pointed out in Leontief's pollution model prices depend on the level of emission absorption and therefore on quantities. This can be seen as an important analogy to a Ricardian model of rent. Kratena (1990) has shown how Ricardian rent can be integrated into the price model of this type and Lager (1998) has developed a Ricardian rent model of this type for the case of emission trading. Instead of dealing with a separate emission absorption sector in this paper the absorption technology is formulated as part of the production process in each industry.

The synthesis derived in this paper therefore consists of:

(i) incorporating Ecological Footprint, Biocapacity and Ecological Deficit at the industry level into an input-output model

(ii) introducing an additional technology at the industry level describing the cultivation of land necessary for eliminating the Ecological Deficit

(iii) formulating the extended input-output quantity and price model and deriving a Ricardian rent from the model solution as an economic indicator of resource constraints

Section 2 of the paper describes the methodolgy. Results of the empirical application for Germany are presented in section 3. Tentative conclusions and important issues for future research are discussed in section 4.

2. An input-output model with Ecological Footprint accounts

The Ecological Footprint accounts can be integrated in the input-output model by disaggregating them to the single industry level. This includes the Biocapacity accounts, where the assignement to industries is based on certain assumptions. The next step of model extension consists of calculating output levels reconcilable with industry Biocapacity. From that follows the introduction of additional Biocapacity that would be necessary to eliminate the Ecological Deficit. This is done at the industry level and implies an additional technology for each industry. An alternative solution would be to use the Leontief pollution model and introduce additional Biocapacity as a quadrant in an extended input-output framework as in Kratena (2004). The approach chosen here bears the advantage of revealing the consequences of overshooting Biocapacity more clearly at the industry level. Therefore the full economic consequences of the extension can be shown for each industry in the solution of the quantity as well as the price input-output model.

2.1. The input-output quantity model

If the Ecological Footprint is allocated to the industries one can in the line of Wiedmann,et.al. (2006) calculate the column vector of this footprint **EF** and describe it as the product of the final demand (column) vector **F** with the Leontief inverse $\mathbf{[I - A]^{-1}}$ and the diagonal matrix of direct 'Footprint coefficients' ef_i, $\mathbf{EF^{dir}}$:

$$EF = EF^{dir}\left[I - A\right]^{-1} F = EF^{dir} X \qquad (1)$$

In (1) **X** represents the (original) column vector of gross output.

The next main assumption is that Biocapacity as measured in the National Footprint accounts can also be assigned to each single industry. This is straightforward for some parts of the Biocapacity (e.g.: cropland) or for the built-up land (if the statistics contain the disaggregation). For other parts of the national Biocapacity this can only be done by basing on assumptions. The industry weights in those parts of the Footprint refering to forest could be used for example for distributing the forest Biocapacity (the detailed methodology is described in section 3 below). It must be noted that this distribution of Biocapacity across industries is an important assumption and results by industry are highly sensitive to this assumption. If we accept this disaggregation of Biocapacity by industry, we could see it as the sector-specific endowment of natural capital and it can together with the matrix of direct Footprint coefficients be used to calculate the vector of gross output $\overline{X}$ reconcilable with Biocapacity.

$$\overline{X} = \left[EF^{dir}\right]^{-1} BC = \left[I - A\right]^{-1} \overline{F} \qquad (2)$$

In (2) the matrix $\left[EF^{dir}\right]^{-1}$ is the diagonal matrix of elements (1/ef_i). From the demand side this 'Biocapacity output' must also equal the product of the Leontief inverse with the vector of 'Biocapacity final demand', $\overline{F}$. This vector can be found for given Biocapacity and given direct footprint coefficients by:

$$\overline{F} = \left[I - A\right]\left[EF^{dir}\right]^{-1} BC \qquad (3)$$

This procedure therefore enables to split up final demand into one part that is reconcilable with Biocapacity ($\overline{F}$) and another part that corrsponds to the overshooting Ecological Footprint (the Ecological Deficit), **F***, so that $F^* = F - \overline{F}$ holds.

For the extension of the model it is further assumed that a new and additional activity exists that would be necessary in each industry to expand the Biocapacity so that it equals to the Ecological Footprint of actual economic activity. This additional activity consists of renting the land area corresponding to the 'Ecological Deficit' and cultivating it in order to make it biophysically productive. Therefore the new output vector of the extended model with an effective resource constraint is given by a new matrix of technical coefficients, **A***:

$$X = \overline{X} + [I - A^*]^{-1} F^* \tag{4}$$

The elements a_{ij}* of this new matrix are given by:

$$a_{ij}^* = a_{ij} + a_{iF}\left(ef_i - BC_j / X_j\right) \tag{5}$$

In (5) the coefficient a_{iF} represents the specific input from industry *i* measured in monetary units into an activity *F* per unit of land area in order to make this area biophysically productive. It is assumed that this technology is the same for all *j* industries. The coefficients ef_j and BC_j/X_j are measured in land area per unit of monetary output; i.e. the whole term $\left(ef_i - BC_j / X_j\right)$ corresponds to the Ecological Deficit of an industry per unit of output.

Expression (5) states that the technology itself depends on the output level via BC_j/X_j, so that the non-substitution theorem is not valid in this case. This result is similar to the result Lager (1998) derives for Leontief's pollution model. It can be further shown, that $\frac{\partial a_{ij}^*}{\partial X_i} = \frac{BC}{X_i^2} > 0$ and that the relationship in (5) therefore decribes a concave function between the increase in inputs (as compared to the original technology described by a_{ij}) and the output level. This functional relationship can be seen as an equivalent to the explanation of decreasing returns in Ricardo's work. The introduction of a binding resource constraint in this framework leads to increasing inputs in order to generate the necessary additional Biocapacity for absorption.

The solution of the system comprising equation (4) and (5) is done in an iterative procedure: a matrix **A*** is inserted into (4) and the elements of vector **X** are then inserted into (5), until the solution converges to equilibrium values of the elements of **A*** and **X**.

The part of output in each industry corresponding to Biocapacity overshooting can then be defined by coefficients ε that are elements of a diagonal matrix, $\hat{E}$:

$$\hat{E}X = [I - A^*]^{-1} F^* \qquad (6)$$

2.1. The input-output price model

As has been noted above one important property of the model outlined here is that the non-substitution theorem is not valid so that prices are not independent of quantitities. The consequences can be shown by the solution of the price model. Starting point is the formulation of the unit cost $\bar{c}$ for the part of output reconcilable with Biocapacity ($\overline{X}$):

$$\bar{c} = \bar{v}[I - A]^{-1} \qquad (7)$$

In (7) $\bar{v}$ is the value added coefficient for this part of the output comprising labour inputs and different capital input components (depreciation, gross operating surplus) per unit of output.

In the extended model it is not this unit cost that determines the price level of gross output, but the marginal cost of producing output with a technology that avoids the emergence of Ecological Deficit:

$$p^* = v^*[I - A^*]^{-1} \qquad (8)$$

In (8) the extended matrix of inputs **A*** as well as a new vector of value added coefficients **v*** are taken into account. This is based on the assumption that a technology for making additional land biophysically productive also implies additional inputs of labour, capital as well as land rent. Again the analogy to Ricardo's model becomes obvious, as the price level is determined by the cost of the last unit that has to be produced in order to accomodate demand.

This price level can now be written as comprising the unit costs for $\bar{X}$, the unit costs for the overshooting output part $\hat{E}X$ as well as a residual, ρ:

$$p^* = \bar{v}\left[I - \hat{E}\right][I - A]^{-1} + v^*\hat{E}[I - A^*]^{-1} + \rho \qquad (10)$$

In (9) the unit costs are each weighted with their shares in total gross output, given by the diagonal matrix, $\hat{E}$. Expression (10) makes the invalidity of the non-substitution theorem in this extended model explicit. Output prices are directly dependent on the part of output that corresponds to overshooting Biocapacity, measured by the coefficients in matrix $\hat{E}$. Output growth is accompanied by a shift in the weights from the technology determined by $\bar{v}$ and **A** to the more input-intensive technology determined by **v*** and **A***.

The residual component ρ can be seen as a Ricardian rent per unit of output that arises from an increase in prices as output growth becomes more input-intensive due to a binding resource constraint.

$$\rho = p^* - \bar{v}\left[I - \hat{E}\right][I - A]^{-1} - v^*\hat{E}[I - A^*]^{-1} \qquad (11)$$

Total Ricardian rent, R is then given as the scalar that equals the product of the vector of rent coefficients ρ with the gross output vector **X** from the solution of the quantity model.

$$R = \left[p^* - \bar{v}\left[I - \hat{E}\right][I - A]^{-1} - v^*\hat{E}[I - A^*]^{-1}\right]X \qquad (12)$$

3. Empirical results for Germany

Starting point for the empirical application of the model framework outlined above are the Ecological Footprint accounts and the quadratic input-output table (domestic production) for Germany. Using only the direct Footprint of domestic production excludes the impact of imports on the Ecological Footprint and is a simplifying assumption for a first numerical analysis of the concept. The data used also imply some mix of different base years, as the latest (2006) edition of Ecological Footprint accounts from GFN contains data for the year 2003 whereas the input-output table stems from 2000. As a first step the Footprint data have been converted to units of total level of area (mill. ha) by using the GFN population data.

The published Ecological Footprint data as shown in Table 1 exhibit some degree of disaggregation. This is a first indication for assigning the single parts of total Footprint to the industries in the input-output table. The original input-output table 2000 for Germany has been published by the German Statistical Office at the level of NACE 2 digit industries (about 60 industries). It must be further noted here that the direct Footprint of private household activities that results from the disaggregation is not taken into account. This is especially relevant for the Carbon Footprint. The assignation of the single Footprint categories to the industries has been carried out in the following way:

- Cropland Footprint, grazing land Footprint: these categories have been directly allocated to agriculture

- Forest, timber, pulp and paper Footprint, forest fuelwood Footprint: these categories have been directly allocated to forestry

- Fishing ground Footprint: this category has been directly allocated to fishery

- Carbon Footprint: Starting point was the data set of CO_2 emissions by industry from German NAMEA accounts. Total CO_2 emissions for 2003 have then be related to the total Carbon Footprint for the same year. That resulted in an ’absorption factor’ in the dimension of land (in ha) per ton of CO_2 emission that has been used for calculating the Footprint by industry.

- Nuclear Footprint: this category has been directly allocated to Electricity, gas and water supply.

- Built-up land Footprint: Starting point was the data set of land use by industry from German NAMEA accounts. Total land use data of NAMEA have then be adjusted to the total Built-up land Footprint from GFN accounts for 2003 which resulted in a considerable upward adjustment. Built-up land Footprint by industry has then be calculated by applying this adjustment factor to the NAMEA land use data.

>>>>>>>>>>*Table 1: Ecological Footprint Accounts, Germany (in ha/person), 2003*

For the distribution of Biocapacity data by industry the following methodology has been used:

- Cropland Biocapacity, grazing land Biocapacity, fishing ground Biocapacity, built-up land Biocapacity: these categories have been distributed in the same way as the corresponding Footprint categories.

- Forest Biocapacity: It was assumed that all the other Footprint categories use total national Forest Biocapacity for resource supply and emission absorption and that total Forest Biocapacity can therefore be distributed in the same proportion as these Footprint categories across industries.

>>>>>*Table 2: Ecological Footprint (in mill. ha), actual and 'Biocapacity'-output (in mill. €)*

The results of these calculations yield Footprint and Biocapacity data by industry fully consistent with Footprint accounts from GFN. From these Footprint data by industry the Footprint coefficients can be derived by dividing through the gross output level. That yields in a next step Biocapacity output by using these Footprint coefficients together with Biocapacity data according to (2). Table 2 shows the results for these variables (industries have been aggregated to a 28 industry-classification used for the application in this paper). Biocapacity output is in general by about 67% lower than actual output. This relationship is considerably lower for the personal services sector and considerably higher for emission-intensive industries (e.g. Electricity, gas and water supply).

Table 3 shows the results for splitting up of final demand into the Biocapacity (consistent) part and the overshooting part. These calculations have been carried out by applying (3) to the Footprint and input-output data. The main result is that the differences across industries increase compared to the gross output data due to the sectoral interrelations from the input-output table. The total result is the same as for gross output, namely an actual demand level of about 67% above the Biocapacity level. It is worth noting that in the domestic input-output table used here the Biocapacity level of final demand might become even negative. As the actual final demand vector comprises total imports the interpretation is that imports of goods from this industry must exceed final demand in order to achieve a level reconcilable with Biocapacity.

For extending the input – output framework as laid down in section 2 the coefficients of the 'additional technology' in (5) and (8) have to be determined. The coefficients a_{iF} have been taken from the column of the forestry sector in the input-output table. The inputs of this sector have been divided by the Biocapacity of the forestry sector and the result is interpreted as the specific input structure of providing one hectare of a biophysically productive area. As far as the value added coefficients in the vector **v*** are concerned the original value added coefficients have been augmented by the specific labour and depreciation inputs (per hectare) of the forestry industry plus the price of land rent in agriculture and forestry in Germany.

>>>>>>>*Table 3: Actual and 'Biocapacity'-final demand (in mill. €)*

Table 4 contains the main results from the solution of the extended quantity model. Total output has increased slightly (about 1%) due to additional intermediate demand given by the additional technology. The largest output increase can be found in the agriculture, forestry and fishing sector, as this is the most important input in the a_{iF} coefficients. The elements of matrix $\hat{E}$ measuring the overshooting part of output range from 50 to 80% as in Table 2. The main difference that arises in the extended model is a much higher activity in the forestry sector in order to provide the biophysically productive land. The model solution guarantees that enough additional biocapacity is provided to eliminate the Ecological Deficit in each industry.

>>>>>>>>>>*Table 4: Solution of the extended quantity model: total and 'overshooting' gross output (in mill. €), coefficients (ε), and additional Biocapacity (in mill. ha)*

The new matrix of technical coefficients from the solution of the quantity model can then be used to solve the price model. That yields the results shown in Table 5. The overall increase in output prices induced by introducing the additional Biocapacity in the economy is only 5.3% although the overshooting part of gross output is about 60% across industries. This result is closely linked and highly sensitive to the assumptions about the additional technology for Biocapacity. These assumptions all reflect linear average input coefficients, especially for rent prices of land. It is probable that this assumption might not hold in the case of a large increase in demand for biophysically productive land. Land prices and as a consequence land rent prices might rise considerably in such a scenario.

On the other hand the results in Table 5 reveal that for some industries important price increases are the consequence of eliminating the Ecological Deficit. That is in first instance the case for the sector that provides the additional Biocapacity, namely agriculture, forestry and fishing. Emission intensive industries like 'Electricity, gas and water supply' are also characterized by significant price increases. The consequence of the price increase is the emergence of a rent component in value added which amounts to 0.3 of gross output in agriculture, forestry and fishing and to 0.2 in Electricity, gas and water supply. Overall the rent component amounts to 0.02 of gross output. The last column in Table 5 contains the Ricardian rent as a percentage of value added of each industry. For those industries with high price increases the rent constitutes a large part of the original value added. For the total economy the rent represents about 4% of this original value added.

The general purpose of these calculations is to show how the concept of economic production or demand that overshoots Biocapacity can be translated into an economic measure of cost. The numerical results are highly sensitive to the assumptions about the 'additional technology' introduced in the input-output framework in order to supply the necessary Biocapacity. It is to suspect that the large increase for biophysically productive land that results from these calculations would have as a consequence a considerable increase in land rent prices. This aspect has not been quantified here and actual land rent prices of the base year (2000) have been taken instead. From the soultion of the extended quantity model it can be derived that final demand is about 67% above the level that is reconcilable with Biocapacity. Using that as a measure of the economic cost of resource constraints one could conclude that a 67% reduction of final demand represents one possible way of eliminating the Ecological Deficit. From the solution of the price model one derives different measures of the economic costs of resource constraints. The total additional value added due to the introduction of additional Biocapacity in the system amounts to 4.6 %. This can be seen as an economic measure of cost of complying with the resource constraint of given Biocapacity. A large part of this additional value added, namely 3.9% of value added accrues to the rent component.

>>>>>>>>>*Table 5: Solution of the extended price model: price increase (in %), unit rent (ρ) and rent per value added*

>>>>>>>>>*Table 6: Economic indicators (mill. €) of resource constraints*

4. Conclusions

The main result of this paper is the derivation of an economic indicator from an extended input-output model with Ecological Footprints, Biocapacity and a technology for additional Biocapacity cultivation by industry. From the solution of this extended input-output model different measures of cost of eliminating the Ecological Deficit can be derived. One measure coincides with a Ricardian rent that emerges due to an output price increase linked to the elimination of the Ecological Deficit.

The numerical results in section 3 can only be interpreted by taking into account the strong assumptions about costs of additional inputs for Biocapacity. Therefore these results should rather be seen as a first example how the new concept presented in this paper could be applied empirically. That holds also for the assignation of Footprints and Biocapacity to the industry level. The sensitivity of results to these assumptions should be checked in further development of the methodology. One sensitivity analysis could consist of a different (equal) assignation of the non-specific Biocaopacity to industries. The model could also be formulated as a 'Leontief pollution model' having the cultivation of Biocapacity as one single activity instead of distributing it to the industries.

Following the methodology outlined here extensions of this approach should comprise the inclusion of imports and the import-induced Footprint, the application of a make-use system as in Wiedmann, et.al. (2006) as well as the inclusion of direct Footprints of household activity. Empirical research in the technology of Biocapacity cultivation should also allow developing this part of the model further and ending up with more or less accepted factors like in the case of the methodological basis of Footprint accounts.

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Table 1: Ecological Footprint Accounts, Germany (in ha/person), 2003

Population (millions)	82.476
Total Ecological Footprint	4.549
Cropland Footprint	0.731
Grazing land Footprint	0.179
Forest: timber, pulp and paper Footprint	0.481
Forest: fuelwood Footprint	0.014
Fishing ground Footprint	0.116
Carbon Footprint	2.450
Nuclear Footprint	0.407
Built-up land Footprint	0.170
Total Biocapacity	1.741
Cropland	0.659
Grazing land	0.058
Forest	0.830
Fishing grounds	0.028
Ecological deficit (-)	-2.807

Source: GFN, Ecological Footprint and Biocapacity (2006 edition)

Table 2: Ecological Footprint (in mill. ha), actual and 'Biocapacity'-output (in mill. €)

	Ecological Footprint	Biocapacity	Ecological Deficit	Actual Output	Biocapacity Output	difference in %
Agriculture, forestry and fishing	128.72	73.11	-55.60	50128	28474	-43.2
Mining of energy producing materials	0.46	0.14	-0.32	6565	2009	-69.4
Other mining and quarrying	1.49	0.37	-1.11	8084	2037	-74.8
Food, beverages and tobacco	2.26	0.65	-1.61	131372	37572	-71.4
Textiles, leather and footwear	0.27	0.09	-0.18	30023	10075	-66.4
Wood and of wood and cork	0.29	0.10	-0.19	22081	7381	-66.6
Pulp, paper, printing and publishing	1.88	0.52	-1.36	86529	23999	-72.3
Coke, refined petroleum, nuclear	5.31	1.26	-4.04	37362	8898	-76.2
Chemicals and pharmaceuticals	4.84	1.21	-3.63	151230	37800	-75.0
Rubber and plastics	0.42	0.15	-0.26	50387	18303	-63.7
Other non-metallic mineral	7.93	1.91	-6.02	38527	9292	-75.9
Basic metals and fabricated metal	15.06	3.71	-11.35	176962	43571	-75.4
Machinery nec	0.80	0.31	-0.49	155015	59627	-61.5
Electrical and optical equipment	0.75	0.26	-0.49	132277	45932	-65.3
Transport equipment	1.55	0.46	-1.08	238891	71589	-70.0
Manufacturing nec and recycling	0.63	0.23	-0.40	71987	26109	-63.7
Electricity, gas and water supply	113.80	27.00	-86.80	62094	14730	-76.3
Construction	2.39	0.98	-1.41	226619	92539	-59.2
Wholesale and trade	5.07	1.79	-3.28	369276	130110	-64.8
Hotels and restaurants	0.91	0.35	-0.56	65606	25203	-61.6
Transport and storage, communication	9.25	3.11	-6.14	229180	77080	-66.4
Financial intermediation	0.50	0.15	-0.35	178500	52921	-70.4
Real estate, business services	4.34	1.22	-3.12	661315	186421	-71.8
Public Administration/Defence	2.38	0.72	-1.66	166280	50521	-69.6
Education	1.72	0.66	-1.06	101786	39106	-61.6
Health and social work	1.92	0.60	-1.33	182650	56737	-68.9
Social & personal services	2.98	1.34	-1.64	149304	67211	-55.0
Private Households	0.00	0.00	0.00	6220	6220	0.0
TOTAL	317.89	122.40	-195.49	3786250	1231469	-67.5

Table 3: Actual and 'Biocapacity'-final demand (in mill. €)

	Biocapacity Final Demand $\overline{F}$	Total Final Demand F	difference in %
Agriculture, forestry and fishing	17826	17701	0.7
Mining of energy producing materials	844	1963	-57.0
Other mining and quarrying	-35	949	-103.7
Food, beverages and tobacco	26226	98145	-73.3
Textiles, leather and footwear	8045	24045	-66.5
Wood and of wood and cork	1921	7232	-73.4
Pulp, paper, printing and publishing	9651	39452	-75.5
Coke, refined petroleum, nuclear	2742	17409	-84.3
Chemicals and pharmaceuticals	16183	75029	-78.4
Rubber and plastics	8023	20944	-61.7
Other non-metallic mineral	-1027	10265	-110.0
Basic metals and fabricated metal	9415	63354	-85.1
Machinery nec	47789	120728	-60.4
Electrical and optical equipment	26549	76489	-65.3
Transport equipment	50678	169837	-70.2
Manufacturing nec and recycling	22402	60501	-63.0
Electricity, gas and water supply	3324	25032	-86.7
Construction	77316	179035	-56.8
Wholesale and trade	90504	251089	-64.0
Hotels and restaurants	23400	60207	-61.1
Transport and storage, communication	29057	85040	-65.8
Financial intermediation	19138	69729	-72.6
Real estate, business services	61721	273564	-77.4
Public Administration/Defence	46274	152343	-69.6
Education	35147	89932	-60.9
Health and social work	55000	177688	-69.0
Social & personal services	45196	87022	-48.1
Private Households	6220	6220	0.0
TOTAL	739529	2260944	-67.3

Table 4: Solution of the extended quantity model: total and 'overshooting' gross output (in mill. €), coefficients (ε), and additional Biocapacity (in mill. ha)

	Total Output	Overshooting Output	Coefficients ε	Additional Biocapacity
Agriculture, forestry and fishing	62334	33860	0.54	86.9
Mining of energy producing materials	6615	4606	0.70	0.3
Other mining and quarrying	8154	6116	0.75	1.1
Food, beverages and tobacco	132308	94736	0.72	1.6
Textiles, leather and footwear	30080	20004	0.67	0.2
Wood and of wood and cork	22219	14838	0.67	0.2
Pulp, paper, printing and publishing	87042	63042	0.72	1.4
Coke, refined petroleum, nuclear	38207	29309	0.77	4.2
Chemicals and pharmaceuticals	152270	114470	0.75	3.7
Rubber and plastics	50586	32283	0.64	0.3
Other non-metallic mineral	39100	29808	0.76	6.1
Basic metals and fabricated metal	177879	134308	0.76	11.4
Machinery nec	155784	96157	0.62	0.5
Electrical and optical equipment	132499	86567	0.65	0.5
Transport equipment	239089	167499	0.70	1.1
Manufacturing nec and recycling	72015	45907	0.64	0.4
Electricity, gas and water supply	62607	47876	0.76	87.7
Construction	227483	134944	0.59	1.4
Wholesale and trade	371910	241800	0.65	3.3
Hotels and restaurants	65670	40467	0.62	0.6
Transport and storage, communication	230740	153661	0.67	6.2
Financial intermediation	180503	127582	0.71	0.4
Real estate, business services	667713	481292	0.72	3.2
Public Administration/Defence	166778	116256	0.70	1.7
Education	101926	62820	0.62	1.1
Health and social work	182823	126086	0.69	1.3
Social & personal services	150006	82795	0.55	1.7
Private Households	6220	0	0.00	0.0
TOTAL	3820559	2589090	0.68	0.0

Table 5: Solution of the extended price model: price increase (in %), unit rent (ρ) and rent per value added

	Δ price (%)	ρ	Rent/ Value Added (%)
Agriculture, forestry and fishing	76.3	0.32	89.3
Mining of energy producing materials	10.9	0.03	13.7
Other mining and quarrying	12.0	0.04	8.5
Food, beverages and tobacco	18.8	0.08	30.3
Textiles, leather and footwear	2.8	0.01	2.9
Wood and of wood and cork	8.1	0.03	8.7
Pulp, paper, printing and publishing	3.8	0.01	3.2
Coke, refined petroleum, nuclear	6.8	0.02	22.3
Chemicals and pharmaceuticals	4.6	0.01	6.4
Rubber and plastics	2.9	0.01	2.4
Other non-metallic mineral	12.7	0.04	9.6
Basic metals and fabricated metal	7.4	0.02	7.1
Machinery nec	2.1	0.01	1.7
Electrical and optical equipment	1.7	0.01	1.5
Transport equipment	2.5	0.01	4.0
Manufacturing nec and recycling	2.1	0.01	1.6
Electricity, gas and water supply	72.9	0.21	43.0
Construction	2.6	0.01	1.9
Wholesale and trade	1.7	0.01	0.9
Hotels and restaurants	4.9	0.02	3.9
Transport and storage, communication	3.1	0.01	2.4
Financial intermediation	0.8	0.00	0.6
Real estate, business services	0.8	0.00	0.4
Public Administration/Defence	1.7	0.01	0.8
Education	1.6	0.01	0.7
Health and social work	1.9	0.01	0.9
Social & personal services	1.6	0.01	0.9
Private Households	0.0	0.00	0.0
TOTAL	5.3	0.02	3.9

Table 6: Economic indicators (mill. €) of resource constraints

Final Demand	2260944
Biocapacity Final Demand	739529
difference in %	-67.3
Value Added, Y	1856200
Value Added, Y*	1940837
difference in %	4.6
Rent	72060
Rent, as % of Y	3.9

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