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Isn't small beautiful?

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Abstract

Main goal of this paper is to present an ecological input-output model that on the one hand adopts the traditional monetary flows and that on the other hand transfers ecological relevant physical flows into the monetary scheme. Therefore the provision of natural resources and the absorption of emissions are evaluated in monetary terms. The model suggests, based on a detailed literature review, separate price corridors for each category of resources and emissions.

The model considers 'Nature' as intermediate sector that provides resources and absorption services as (monetarized) inputs for the conventional intermediate sectors, which in turn affects the calculation of the Leontief output multipliers significantly. In this context the relevance of large multipliers are scrutinized closely. With regard to the concept of a sustainable development, the often positive assessment of high output multipliers is questioned in this paper. In contrast, if two sectors show similar income multipliers (based on the Leontief inverse matrix and the income coefficients) and different output multipliers, the sector with the smaller output multiplier may fulfill the idea of a sustainable development in a more efficient way.

1 Introduction

At the end of the sixties studies by AYRES and KNEES (1969), LEONTIEF (1970) and ISARD (1972) opened the field of input-output analysis for environmental studies. While AYRES and KNEES started to investigate material flows in further detail, LEONTIEF included disposal services into the input-output framework and ISARD combined monetary and physical flows into a regional input-output model. These studies have been followed by various ecological input-output approaches that combine natural usage with economic activities. PERMAN et al. (1999) present a detailed overview of these studies.

Nowadays the data availability allows the generation of physical input-output tables (PIOT) that give a detailed overview of the anthropogenic and environmental flows of modern economies. Thus, material flow analysis is not limited to the quantities behind the monetary flows anymore, but includes various kinds of natural resources and emissions. Since the PIOT is structured in an equivalent manner to the monetary input-output tables (MIOT), a Leontief inverse matrix, based solely on physical flows, can be calculated. However, in contrast to the conventional interpretation, relatively high row and column sums of the physical Leontief inverse cannot be interpreted as positive stimulus for the considered economy only, but rather point to a low material-productivity. In fact more than 80% of the physical flows in 'The German Throughput Economy' (STRASSERT, 1998) consist of natural resources on the input, and anthropogenic pollution on the output side. Specifically the role of recycling activities is still minor.

Obvious (man-made) climate changes have indeed led to a growing ecological sensibility in society and policy in the last decade. However, the awareness does not cause behavioral changes immediately and increasing pollution can still be observed for many industrial branches. On the other hand the trend towards a service oriented economy, accompanied by a trend of dematerialization for the industrial processes and almost immaterial services, cannot be denied. Therefore physical and monetary flows should be considered simultaneously - either within a parallel accounting or within the frame of one input-output model where natural services are priced in an appropriate way (HANNON, 2001). This study suggests to transfer the crucial monetary and physical flows into a single monetary table. But despite the implementation of evaluated ecological flows into the input-output analysis, a prior aim is to preserve the comparability with traditional SNA framework. For that purpose the **ecol**ogical **i**nput-**o**utput model **'ecolio'** is designed. On the one hand, it adopts the traditional monetary flows and, on the other hand, it transfers the ecological flows into the monetary scheme by pricing natural usage.

Based on a detailed literature research, **'ecolio'** offers separate price corridors for 4 kinds of resources and 11 kinds of pollutants to the user. Both, the provision of resources and the absorption of emissions are considered as natural services. After the monetary evaluation, the natural services are aggregated to one sector 'Nature'. Subsequently the model considers 'Nature' as intermediate sector, which provides inputs for the conventional sectors. Furthermore it is assumed that, within the frame of the market system, the behavior of the entrepreneurs is not of an altruistic nature. Their companies will only contribute to ecological protection if they are either forced by law or if the market requires nature friendly decisions (e.g. 'green image'). Consequently the traditional MIOT already enclose all operational environmental costs. Hence the industries will not provide any monetary goods (but only 'bads') to the production of the newly introduced sector 'Nature'. This assumption yields zeros in the intermediate part of the corresponding column of 'Nature'.

Finally **'ecolio'** enables the user to calculate an ecologically extended Leontief inverse matrix and to produce (more) sustainable multipliers. In particular the popular backward output- and income- multipliers will differ significantly from the traditional multipliers.

The ecological model can be applied in two alternative ways:

i. Since the usage of the natural capital stock, which can be defined as the stock of natural resources and the level of natural absorbability, is 'free of charge' for the industries, the first approach 'eco1' considers the evaluated services of sector 'Nature' as natural subsidies. Since IOTs generally present subsidies as negative inputs and since this study considers the sector ‘Nature’ as intermediate sector, negative input-coefficients occur in the A-matrix. Consequently backward output multipliers become the smaller the more natural capital is used and the higher the usage is evaluated.

ii. The second alternative, which is labeled ‘eco2’, criticizes the multiplier concept in a more general way. In particular for highly developed regions the significance of high output multipliers is doubted. To illustrate the critique, real costs for the usage of natural capital are supposed (e.g. the purchase of emission certificates). Thus industries that most intensively absorb natural services show the highest increases of the output multipliers. If, in line with the traditional multiplier concept, only high multipliers would be considered as ‘good’ multipliers, regional policies would automatically prefer the resource intensive sectors over the less material intensive counterparts, which generally show relatively small output multipliers. However, the promotion of nature intensive branches would contradict the idea of a sustainable development. Further on it could be assumed that the additional intermediate costs are equalized by a declining net value added. If not only company profits but also incomes of employees diminish in the long run, nature intensive sectors do not only show rising output multipliers but also decreasing income multipliers. A trend that certainly cannot be considered to be in line with the general idea of growing welfare.

The structure of the traditional and the applied ecological tables is given below.

Table 1: Structure of conventional IOT (monetary terms)

Sector	1	2	Nature	Sum 1	Final Demand	Total Output
1	x	x	n.a.	x	x	x
2	x	x	n.a.	x	x	x
Nature	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Sum 2	x	x	n.a.	x	x	x
Net Value Added	x	x	n.a.	x		
Depreciation	x	x	n.a.	x		
Ecomarge	n.a.	n.a.	n.a.	n.a.		
Total Input	x	x	n.a.	x		

n.a. = not available

Table 2: Structure of ecological IOT applied within 'ecolio', 'eco1' (monetary terms)

Sector	1	2	Nature	Sum 1	Final Demand	Total Output
1	x	x	0	x	x	x
2	x	x	0	x	x	x
Nature	-10	-20	0	-30	0	-30
Sum 2	x	x	0	x	x	x
Net Value Added	x	x	0	x		
Depreciation	x	x	0	x		
Ecomarge	10	20	-30	0		
Total Input	x	x	-30	x		

Table 3: Structure of ecological IOT applied within 'ecolio', 'eco2' (monetary terms)

Sector	1	2	Nature	Sum 1	Final Demand	Total Output
1	x	x	0	x	x	x
2	x	x	0	x	x	x
Nature	10	20	0	30	0	30
Sum 2	x	x	0	x	x	x
Net Value Added	x	x	0	x		
Depreciation	x	x	0	x		
Ecomarge	-10	-20	30	0		
Total Input	x	x	30	x		

If instead of the conventional approach one of the suggested ecological approaches is applied, the tradeoff between additional sectoral output and more intensive usage of natural capital becomes more transparent. The obvious occurrence of the opportunity costs for natural usage, generated by **'ecolio'**, could particularly support a sensitivity analysis.

2 Conceptual design of the ecological approach

According to LEWIS (1955) economic growth is a desirable goal for society, because it provides a bigger variety of options. Clearly, though, there is an intertemporal dimension to this. Enhanced scope for action today may be available only by reducing such scope for the future. Since mankind has indeed control over its environment, mankind must also take responsibility for it. Simultaneously current living standards can hardly be restricted. Consequently policy, economy and society face the problem to take the ecological responsibility seriously, while parallel satisfying further needs. Obviously it cannot be the goal of this study to find a solution for this problem. Aim of this study is rather to provide one small piece for the overall mosaic. This piece (and this paper) deals with the incorporation of natural usage into an ecological input-output model.

From physical to monetary flows

If the analysis aims to include qualitative aspects of material flows, the problem of the appropiate valuation occurs. *"Poisonous and innocuous materials are 'valued' only by their weights, but not according to their impacts. Such analysis has to be made in a second step, using suitable weighting schemes"* (STAHMER, 2001, p. 127). The monetary evaluation of the material flows can be considered as one appropriate weighting scheme. However, the monetarization of nature is discussed vividly. Neither monetarization nor the strict physical analysis should be considered as the superior way to follow the path of sustainability. Sometimes it can be dangerous to monetarize external (environmental) effects, while in other cases differentiated toxicity factors may not be sufficient to cause a reversal in political and economic acting. Before practically evaluating one ton of carbon or sulfur dioxide (etc.), some principal problems, that occur when physical flows are transferred into monetary ones, should be analyzed in further detail.

STRASSERT (1997) and DALY (1994) emphasize the analogy of the consumption of natural resources and the production of pollutants with the principle of imports and exports and the recently established PIOT of the German Office of Statistics, places the usage of resources as primary input on the incoming side of the SNA, while the emissions are located as category of the final demand on the expenditure side.

COSTANZA et al. point out that *"the services of the ecological systems"* (1997, p. 253) clearly contribute to the overall welfare. The consideration of ecological systems as services shows the close linkage to already monetarized disposal services and, concerning natural resources, to the supplier of raw materials. Thus, with regard to the transformation of physical into monetary terms, ‘Nature’ can alternatively be considered as intermediate sector. All the more, since one characteristic of intermediate, in contrast to primary inputs, can be seen in the fact, that these are used only once in the production process. The consideration of natural services within the intermediate quadrant clearly distinguishes this approach from other approaches.

Table 4: Structure of the physical part within the frame of ‘ecolio’ (flows in t)

PIOT	Agriculture, manu-facturing, services	Nature	Final Demand	Total Output
Agriculture, manu-facturing, services	Goods (<5% of total physical flows)	Goods, emissions, non-recyclable waste	Goods	
Nature	Resources	No flows	Resources	
‘Primary Input’	No flows	Emissions, non-recyclable waste		
Total input				

While natural resources are obviously inputs for the industrial production, emissions are physical industrial output. But with the transformation into monetary terms, the absorption of pollution becomes an input for the industrial production. This procedure is oriented at already internalized pollutants as ‘waste for disposal’, which are considered within the sector ‘external environmental protection’ in the official physical and monetary framework.

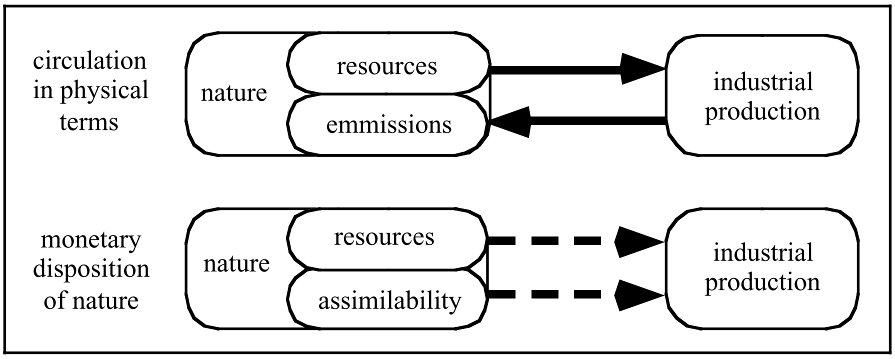


Figure 1: Monetary disposition of sector ‘Nature’

While Figure 1 shows the direction of the circulation in physical terms and the monetary disposition of nature, Table 5 considers the already included disposal services.

Table 5: Structure of intermediate quadrant of official PIOT and MIOT respectively

PIOT	Agriculture, manufacturing, services	External environmental services	Units
Agriculture, manufacturing, services	Goods	Goods / Sewage for treatment, waste for disposal	t
External environmental services	Goods	Goods / Sewage for treatment, waste for disposal	t
MIOT	Agriculture, manufacturing, services	External environmental services	Units
Agriculture, manufacturing, services	Goods and services	Goods and services	€
External environmental services	Disposal services	Disposal services	€

Considering the physical flows 'sewage for treatment' and 'waste for disposal' are classified as output of the production process. However, the monetary output delivered from agriculture, manufacturing or services towards the external environmental services, is limited to the valuable output such as capital goods and transport or banking services. The physical units of the polluted output vanish. Only the costs for the disposal are included. These costs are regarded as intermediate inputs.

The 'ecolio-methodology' for not yet internalized natural usage is similar. Emissions produced by the industry and absorbed by the nature are considered as absorption or disposal services (output of sector nature), and therefore as intermediate input for the production process. Hence resources as well as emissions are listed in the row 'Nature' of the monetary part of the IOT applied by **'ecolio'** (see Table 6).

Table 6: Structure of monetary part within the frame of 'ecolio' (flows in €)

Flows in €	Agriculture, manufacturing, services	Nature	Final Demand	Total Output
Agriculture, manufacturing, services	Goods, services	Goods, services	Goods, services	
Nature	Resources, disposal services	No flows	Resources, disposal services	
'Primary Input'	No flows	No flows		
Total input				

The column of sector 'Nature' shows monetarized industrial output that is used by 'Nature' to produce its output. Due to the transfer of physical into monetary units, only the 'goods' but not the so-called 'bads' (e.g. emissions) appear in the column.

However, as mentioned already, the behavior of the economic actors is not assumed to be of an altruistic nature. Efforts to install environmental protection measures are either driven by legislation or by the market. Since the traditional MIOT already encloses all operational environmental costs for the enforced measures, the industries are not expected to provide any monetary goods to the production of the newly introduced sector 'Nature', e.g. old steel products, that are recycled are part of the market process and cannot be considered again. With the exception of 6500 t (0.001% of total flows), this assumption is consistent with the PIOT provided by the German office of statistics. Consequently the assumption leads to zeros in the intermediate part of the corresponding column 'Nature' for the monetary table.

The efforts to generate ecologically more suitable multipliers include the (at least) partial internalization of the environmental costs. But since market prices do not exist for these inputs, the evaluation of natural services becomes inescapable for the transfer from physical to monetary flows. The task of the following chapter is not to generate the 'one and only' value of the considered resources and emissions, but to scrutinize closely the relevant literature and to provide an appropriate price corridor for each category of resources and emissions.

Evaluation of natural services

Out of various sophisticated approaches that have been elaborated in recent years, the 'willingness to pay' (WTP) concept crystallized as most popular alternative. The following studies, partly based on direct and partly on indirect variants of the WTP concept, have been taken into account for the monetary evaluation of resources and emissions:

- *UIC Report 2000:* The UIC (International Union of Railways) report on external effects, elaborated by INFRAS / IWW (2000). [Used abbreviation in table 7: **UIC**]

- *The marginal costs of climate changing emissions, 2000:* Following EYRE et al. (1997), TOL and DOWNING evaluate greenhouse and region-specific gases. [**TOL**]
- *Externalities of Energy 1995:* The ExternE study encloses the impacts of 13 emissions on the quality of air, water and soil. [**ExternE**]
- *The social costs of traffic, 1994:* BLEIJENBERG et al. perform a literature review on environmental costs and provide price ranges for CO_2, SO_2, NO_x and VOC. [**BLEIJ.**]
- Complementary data are taken from HOHMEYER / GÄRTNER [**HOH**] (1994), Jilek et al. (1998) and from the German 'Bundesverkehrswegeplan 1992' [**BVWP**].

Though the prices vary, the studies provide quite reliable results for a low and a high evaluation of most pollutants. The same holds for 'Solid energy resources'. However, most studies on external costs of energy resources focus on the effects caused by the combustion. Consequently the valuation of external effects rather serves as data source for the pricing of emissions than as baseline for the valuation of the scarcity of resources. Therefore, to avoid double counting, the pricing for scarce resources should forego external effects of the combustion processes and should solely be based on the scarcity of these resources.

According to NORDHAUS (1973) scarcity vanishes, if a technology can be found that allows the replacement of exhaustible energy resources by quasi-unlimited resources in the future. This kind of technology is named 'backstop technology'. NORDHAUS expected the nuclear era to introduce such a backstop technology. However, due to the imponderabilities of nuclear energy, subsequent studies rather consider solar energy as more appropriate 'backstop technology'. Though the production of solar energy is currently more expensive than the traditional energy supply, the tightening scarcity of exhaustible resources, the technological development in the field of traditional and regenerative energy supply and the intensifying ecological awareness will eventually cause equal prices for the energy supply by the backstop and the conventional technology. Neglecting transaction costs, the market will be dominated by the new technology at this point - even if other energy sources would still be available. The procedure to identify high prices reflecting the scarcity of coal, crude oil and gas is based on a backstop technology-approach suggested by HOHMEYER (1992). In Table 7 results that have been produced by following this approach are labeled [BST].

The approach to measure scarcity of natural water is oriented on a similar methodology. The 'backstop technology' is defined by the desalinization of seawater. According to de VILLIERS (2000, p. 419) the price difference of desalinated water and fresh water was around 0.56 €/t in 1991. Since additional distribution costs might occur a high price of 0.6 €/t is fixed. Any improvement of desalinization technique would reduce this price.

The external effects of water pollution are limited to the effects caused by directly derived sewage. KAISER (1990, p. 294) calculates external costs of 0.09 €/t of sewage water.

Table 7 gives an overview of the resources and pollutants considered by **'ecolio'**. The price ranges are based on the estimations provided by the studies mentioned above.

Table 7: Price corridors for resources and pollutants in €/t

Resources and pollutants	Low	Reference	Suggested	Reference	High	Reference
Coal	0	OWN	5	OWN	32	BST
Crude oil, Gas	0	OWN	4	OWN	27	BST
Stones, clay, sand	0	OWN	0	OWN	0.5	BST
Natural water	0.02	OWN	0.25	OWN	0.60	VILLIERS
Cooling water	0	OWN	0	OWN	0.03	OWN
Directly derived sewage	0	OWN	0.09	KAISER	0.12	OWN
Carbon monoxide (CO)	0.50	OWN	6	BVWP	15	BLEIJ
Carbon dioxide (CO_2)	4	UIC	20	UIC	50	UIC
Di-Nitrogen Oxide (N_2O)	440	TOL	750	TOL	1250	TOL
Nitrogen oxides (NO_x)	750	BLEIJ	1200	BVWP	4200	BLEIJ
Methane (CH_4)	30	TOL	45	TOL	70	TOL
Sulfur dioxide (SO_2)	510	BVWP	3000	ZEW	3300	BLEIJ
Volatile Organic Compounds	500	BLEIJ	4000	BLEIJ	6000	BLEIJ

OWN = own estimations

3 Ecological correction of traditional multipliers, 'eco1'

Prior aim of the approach 'eco1' is the consideration of the hypothetical costs of the absorbed natural services. Assumed that the natural services have a monetary value, industries with relatively high natural usage have a significant (hypothetical) cash benefit compared to less resource intensive sectors. Since public financial supports show similar characteristics, the natural inputs can be considered as natural subsidies. While public subsidies occur as negatives in the primary input quadrant, the consideration of natural subsidies yields negative intermediate input coefficients. The application of natural subsidies leads to decreasing sectoral outputs, which could be interpreted as a current overestimation of the gross production value. It can be argued that so far consumed, but not paid, natural contribution must be subtracted from the industrial production, as well as it is done with governmental transfers.

On the other hand the careful incorporation of the ecological approach into the traditional SNA is considered to be an important criteria, and (hypothetical) decreasing outputs would hardly fulfill this target. Additionally declining outputs x_j would significantly change the input coefficients a_{ij}. Therefore, to ensure the comparability with the traditional approach, the supposed natural subsidies are equalized via a row 'Ecomarge'.

To illustrate the ecological modification an exemplary economy is given by Matrix 1 below. For the sake of simplicity sector 'Nature' produces only one homogeneous good. This could either be a specific resource, e.g. natural water, or the absorption of one particular emission, e.g. SO_2. The matrix follows the structure outlined by Table 2 in section 1.

Matrix 1	j = 1	j = 2	j = 3	j = 4	Nature	Sum	FD	Output
i = 1	20	15	12	17	0	64	46	110
i = 2	18	25	17	15	0	75	60	135
i = 3	16	13	22	18	0	69	51	120
i = 4	14	16	20	28	0	78	62	140
Nature	-20	-5	-10	-5	0	-40	0	-40
Sum	88	74	81	83	0	326	229	465
Income	35	56	37	53	0	181		
Other PI	7	10	12	9	0	38		
Ecomarge	20	5	10	5	-40	0		
Input	110	135	120	140	-40	465		

Though the main purpose of the 'Ecomarge' is of technical nature, it could be interpreted as kind of supposed ecological depreciation. The sectoral natural depreciation corresponds to the inputs delivered by sector 'Nature' in the intermediate quadrant. The total natural depreciation corresponds to the total exhaustion of the natural capital stock, which is listed in the cell 'Ecomarge (row) / Nature (column)'. The negative sign reflects the loss of natural capital or of natural quality.

Backward output multipliers

From the economic point of view the existence of natural subsidies and the assignment within the intermediate quadrant is one alternative among various possibilities. However, mathematically the negative x_{ij} and especially the negative coefficients a_{ij} (i=n+1, j=1..n) have to be scrutinized closely when the Leontief inverse matrix is calculated. With regard to the appearance of negative a_{ij} the Leontief inverse cannot be calculated reasonably without the following assumptions (the analytical proof is given in the annex):

- A1 $a_{ij} \geq 0$, i,j = 1...n (former intermediate sectors)
- A2 $a_{ij} \leq 0$, i = n+1 (Nature), j = 1...n
- A3 $a_{ij} = 0$, i = 1...n, j = n+1 (Nature)

The first assumption describes the condition for the ordinary intermediate relationships, which do not include the sector 'Nature'.

The output of sector 'Nature', which is considered as natural subsidy, is given with a negative sign or it is zero, i.e. the production value of sector j is decreased by the estimated value of natural services absorbed by sector j (assumption A2).

Assumption A3 shows that sector 'Nature' does not absorb any industrial intermediate goods and / or services.

The ecological multipliers are elaborated analog the traditional approach. First the input coefficients a_{ij} are formulated:

$$a_{ij} = \frac{x_{ij}}{x_j};\ i, j = 1, ..., n+1$$

The comparison of the A-matrices without (Matrix 2a) and including 'Nature' (Matrix 2) proves the strong orientation of the ecological extension to the traditional approach:

Matrix 2	j = 1	j = 2	j = 3	j = 4	Nature
i = 1	0.18	0.11	0.10	0.12	0
i = 2	0.16	0.19	0.14	0.11	0
i = 3	0.15	0.10	0.18	0.13	0
i = 4	0.13	0.12	0.17	0.20	0
Nature	–0.18	–0.04	–0.08	–0.04	0

Matrix 2a	j = 1	j = 2	j = 3	j = 4
i = 1	0.18	0.11	0.10	0.12
i = 2	0.16	0.19	0.14	0.11
i = 3	0.15	0.10	0.18	0.13
i = 4	0.13	0.12	0.17	0.20

Based on the interpretation of natural services as natural subsidies, the negative input coefficients within the intermediate quadrant will eventually cause negative coefficients within the Leontief inverse $(I-A)^{-1}$ as well. But due to the assumptions A1, A2 and A3 the matrix calculation does not interfere with the (conventional) interindustrial part. The comparison of the extended matrix with the Leontief inverse without 'Nature' (3 and 3a) shows significant changes for the output multipliers, represented by the last row 'sum'.

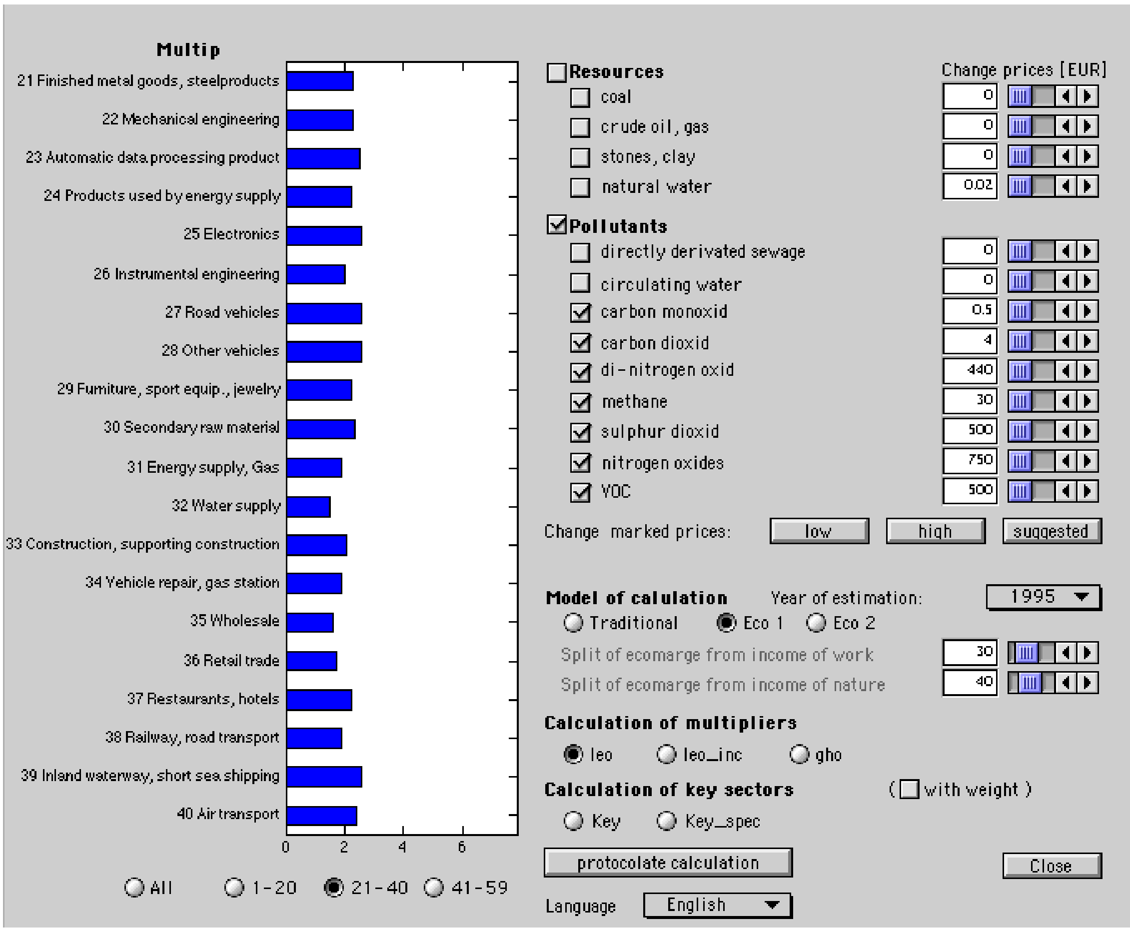
Matrix 3	j = 1	j = 2	j = 3	j = 4	Nature
i = 1	1.37	0.26	0.27	0.29	0
i = 2	0.38	1.36	0.34	0.30	0
i = 3	0.34	0.25	1.37	0.31	0
i = 4	0.35	0.30	0.38	1.40	0
Nature	–0.30	–0.13	–0.19	–0.14	1
Sum	2.13	2.04	2.18	2.15	1

Matrix 3a	j = 1	j = 2	j = 3	j = 4
i = 1	1.37	0.26	0.27	0.29
i = 2	0.38	1.36	0.34	0.30
i = 3	0.34	0.25	1.37	0.31
i = 4	0.35	0.30	0.38	1.40
Sum	2.43	2.17	2.37	2.29

Including sector 'Nature' one € additional final demand for sector 1, which is supposed to use natural capital intensively, results in a total effect of 2.13 € (including initial €). In contrast the output multiplier of the conventional approach equals 2.43 €.

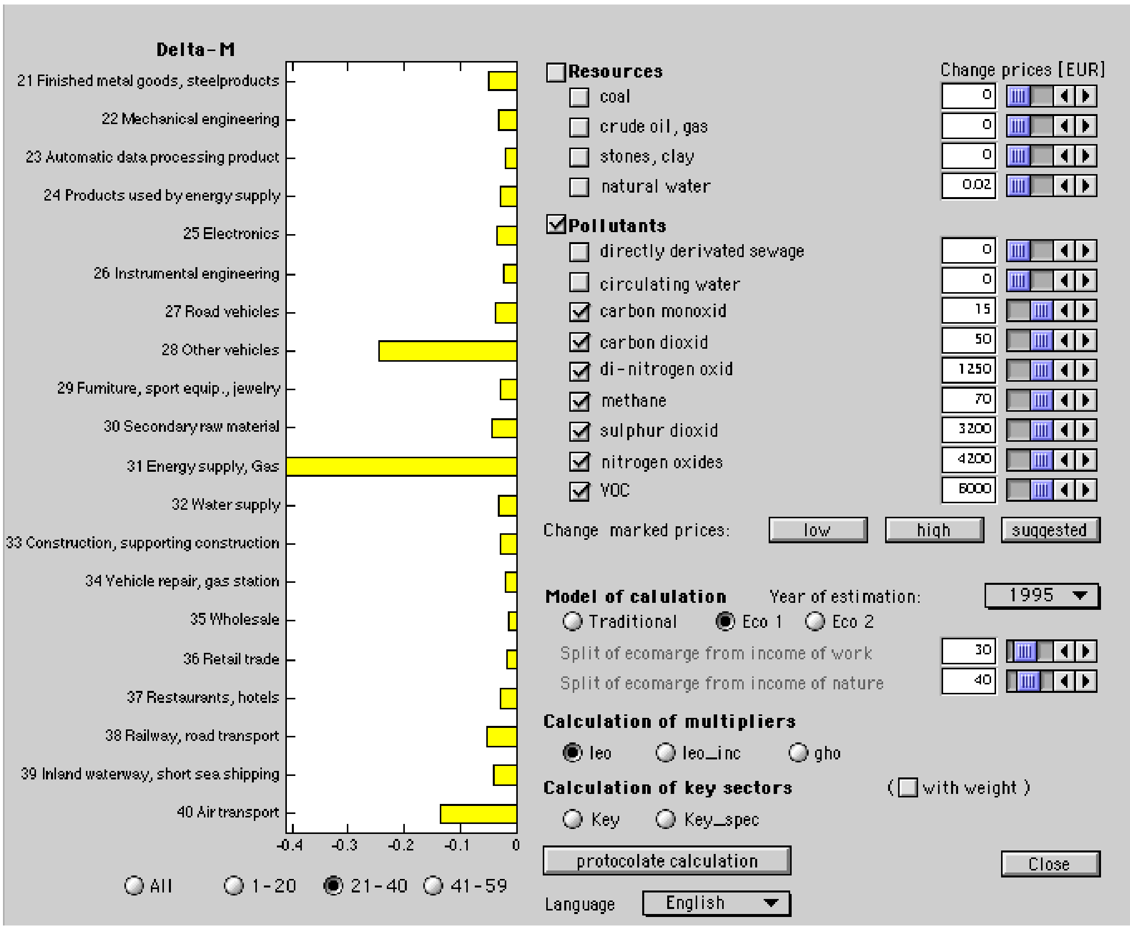
Since all sectors are supposed to use natural capital, the first general effect of the applied methodology is the generation of decreasing output multipliers for any sector. However, the magnitude, which depends on the intensity of natural usage and the chosen evaluation, differs significantly for the considered sectors. Hence the second more specific effect is a reassignment of the sectoral ordering, based on output multipliers. According to the traditional approach sector 1 shows the highest output multiplier, followed by sector 3, sector 4 and finally sector 2. Including sector 'Nature' sector 3 takes the lead, followed by sector 4, sector 1 and sector 2.

When 'eco1' is applied for the German economy, the official MIOT and PIOT respectively of 1995 are taken into account. The screenshots one and two show the ecologically modified Leontief multipliers for (due to clarity, only) twenty sectors.



Screenshot 1: Leontief multipliers including minimal priced emissions

While Screenshot 1 provides the multipliers including the emissions, evaluated with low prices, Screenshot 2 illustrates the changes of the multipliers that result from an increase of the natural evaluation to the highest level. Major changes occur for the sectors 'Energy supply', 'Other vehicles' and 'Air transport'. Sectors, which are not included in this group of twenty sectors, but which show over-average declines of their output multipliers as well are ‚Agriculture', ‚Mining', ‚Products of crude petroleum', ‚Chemistry', ‚Paper and pulp', ‚Glas and minerals' and ‚Ferrous metals'.



Screenshot 2: Changes of Leontief multipliers, caused by high evaluation of emissions

4 The significance of small output multipliers, 'eco2'

'Small is beautiful' is the title of a famous book written by SCHUMACHER in 1973. In the middle of the post-war upswing, when many economic and political decision-makers internalized the 'more is better' philosophy, SCHUMACHER tried to bear down this trend. 'Small is beautiful' countered politicians, who proudly presented new statistics that showed constantly increasing gross regional products, with the simple question, whether these statistics truly reflect an improved living standard for the concerned people. Besides constantly rising unemployment, SCHUMACHER argued in line e.g. with MEADOWS et al. (1972, 1992), that constantly growing output has been accompanied by a continuously increasing exploitation of the natural capital stock. But since welfare indicators should indeed include the environmental quality of a region, improved living standards can rather be achieved by qualitative instead of quantitative growth. Hence smaller growth rates are more likely to identify an ecological and economic sustainable development.

Nowadays the ‘green message’ is not revolutionary anymore, but though legislation and sometimes even market incentives support nature friendly technology, DALY has obviously been right when he doubted already in the seventies that technological development solely will overcome the discrepancies of ‘iron’ economic laws and ecological targets: *“But we can be fairly certain that no technology will abolish absolute scarcity because the laws of thermodynamics apply to all possible technologies. No one can be absolutely certain that we will not some day discover perpetual motion and how to create and destroy matter and energy. But the reasonable assumption for economists is that this is an unlikely prospect and that while technology will continue to pull rabbits out of hats, it will not pull an elephant out of a hat – much less an infinite series of ever-larger elephants!”* (DALY, 1974, p. 19)

This section discusses whether, from the sustainable point of view, smaller output multipliers should be preferred to bigger ones, while simultaneously the maximization of household incomes (high income multipliers) is still considered one main goal of regional policy. However, sustainability does by no means require growth rates near zero. In line with PECCEI (1977), the founder of the ‘Club of Rome’, economic growth is considered to be necessary and appropriate for a lively and dynamic society in this study. Admittedly future growth of GDP and especially of welfare should not arise from further extension of industrial production at the cost of natural capital but from the decoupling of economic growth and environmental impacts. Therefore the postulation of restricted growth can be interpreted as pleading versus extensive material throughput and unlimited consumption of natural resources rather than versus economic growth per se.

One of the main political challenges can be seen in defining appropriate limits of growth and in designing tools that cause adequate behavioral changes. In this study limitation is defined via setting appropriate prices for the natural usage, which eventually shall limit the ecological services absorbed by the anthropogenic system. With regard to the efficiency of absorbed resources the physical throughput is of specific interest. Therefore the main focus in this section is again on the intermediate flows, on the generation and in particular on the interpretation of output multipliers.

Although the strength of the input-output technique is exactly to draw a detailed picture of the economy including intermediate flows, the main aim of the regional policy is to increase the welfare of the region and not necessarily the industrial outputs. Since welfare is generally not measured by industrial output level, but rather by the status of e.g. private consumption and/or household incomes, the interpretation of high output multiplier as 'good' multiplier is questionable.

Considering two sectors i=1 and i=2 of the analyzed economy, the application of the traditional methodology would consider the sector with the higher output multiplier as more important for the regional development. This may be true for under-developing regions, where the prior goal of the regional policy is to settle a strong and interindustrial base as core for further development. But while high output multipliers could be seen as important stimulus for developing regions to stabilize their still fragile economic base, the focus in highly developed regions is different. In this case high output multipliers serve merely as indicator for relatively material and/or nature intensive production without any guarantee of growing welfare. In contrast if high output multipliers result from the absorption of materialintensive intermediate inputs, they can be interpreted as indicator for low material productivity rather than as characteristic for favorable regional development. Thus the dependence of modern economies on material intensive but not material productive sectors can, with regard to the idea of a sustainable development, be doubted convincingly. Sectors with high shares of primary inputs, in particular of high wages and salaries should be regarded at least as important - though these sectors often show relatively low output multipliers. Contrary a strategy that leads to less production and equal household incomes saves natural resources and should rather be preferred over strategies favoring sectors with high output multipliers.

Again the methodology is illustrated by the exemplary economy of section 3. But if industrial sectors chose to consume natural water or to produce SO_2-emissions, they have indeed to buy water- or SO_2-certificates from sector 'Nature' represented e.g. by public corporations. Thus the industries do not purchase water but the right to use it, i.e. the sector 'Nature' changes from a material to an almost immaterial sector. The prices for the certificates equal the estimated values. The matrix follows the structure of Table 3 in section 1.

In contrast to the first ecological approach 'eco1' natural services are not considered as subsidies. The right to use natural capital causes real costs. Hence the intermediate outputs of 'Nature', i.e. the distribution of certificates that right the usage of nature, are positive. Since the total output (= total input) is assumed to remain constant a row 'Ecomarge' is introduced to equalize additional intermediate costs in the primary input quadrant.

Matrix 4	j = 1	j = 2	j = 3	j = 4	Nature	Sum	FD	Outputs
i = 1	20	15	12	17	0	64	46	110
i = 2	18	25	17	15	0	75	60	135
i = 3	16	13	22	18	0	69	51	120
i = 4	14	16	20	28	0	78	62	140
Nature	20	5	10	5	0	40	0	40
Sum	88	74	81	83	0	326	229	545
Income	35	56	37	53	0	181		
Other PI	7	10	12	9	0	38		
Ecomarge	–20	–5	–10	–5	40	0		
Inputs	110	135	120	140	40	545		

The zeros in column ‘Nature’ are not stringent for the here discussed ‘eco2’ approach (they are for ‘eco1’). In fact the occurrence of real costs for natural usage will likely be accompanied by intermediate inputs. But while the intermediate outputs may be significant, the intermediate inputs of this almost perfectly immaterial sector ‘Nature’ are negligible. (Any assignment of intermediate inputs would additionally increase the multipliers.)

Backward output and income multiplier

As usual the direct input coefficients a_{ij} form the baseline for further analysis. The next step is the calculation of the modified Leontief inverse $(I\text{-}A)^{-1}$. Below, the extended inverse is compared to the inverse when sector ‘Nature’ is not considered at all.

Matrix 5	j = 1	j = 2	j = 3	j = 4	Nature
i = 1	1.37	0.26	0.27	0.29	0
i = 2	0.38	1.36	0.34	0.30	0
i = 3	0.34	0.25	1.37	0.31	0
i = 4	0.35	0.30	0.38	1.40	0
Nature	0.30	0.13	0.19	0.14	1
Sum	2.74	2.30	2.56	2.43	1

Matrix 5a	j = 1	j = 2	j = 3	j = 4
i = 1	1.37	0.26	0.27	0.29
i = 2	0.38	1.36	0.34	0.30
i = 3	0.34	0.25	1.37	0.31
i = 4	0.35	0.30	0.38	1.40
Sum	2.43	2.17	2.37	2.29

Sector 1 clearly shows the highest multiplier without considering natural services and even enlarges the distance to the other sectors including ‘Nature’. On the other hand sectors 2 and 3 show, due to their less intensive usage of nature capital, relatively small increases of their multipliers, i.e. if regional policy strategies would focus on sectors showing high multiplier, direct and indirect nature intensive production would be preferred over nature friendly sectors. When the incentive of the natural pricing has been to protect nature, the preference of sectors with rapidly, at the cost of natural capital, increasing multipliers would be paradox.

Since sectors with high output multipliers often deal with intensive material and energy consumption, the preference of these sectors could convincingly be doubted for modern economies even without explicit consideration of natural services. Though the example focuses on the ecological consideration the discussion can also be seen as general critique of the common preference of high output multipliers. Obviously the theoretical work of SCHUMACHER or MEADOWS has, despite wide spread scientific support in literature, hardly transferred into practice yet. Think different: 'Isn't small beautiful?'.

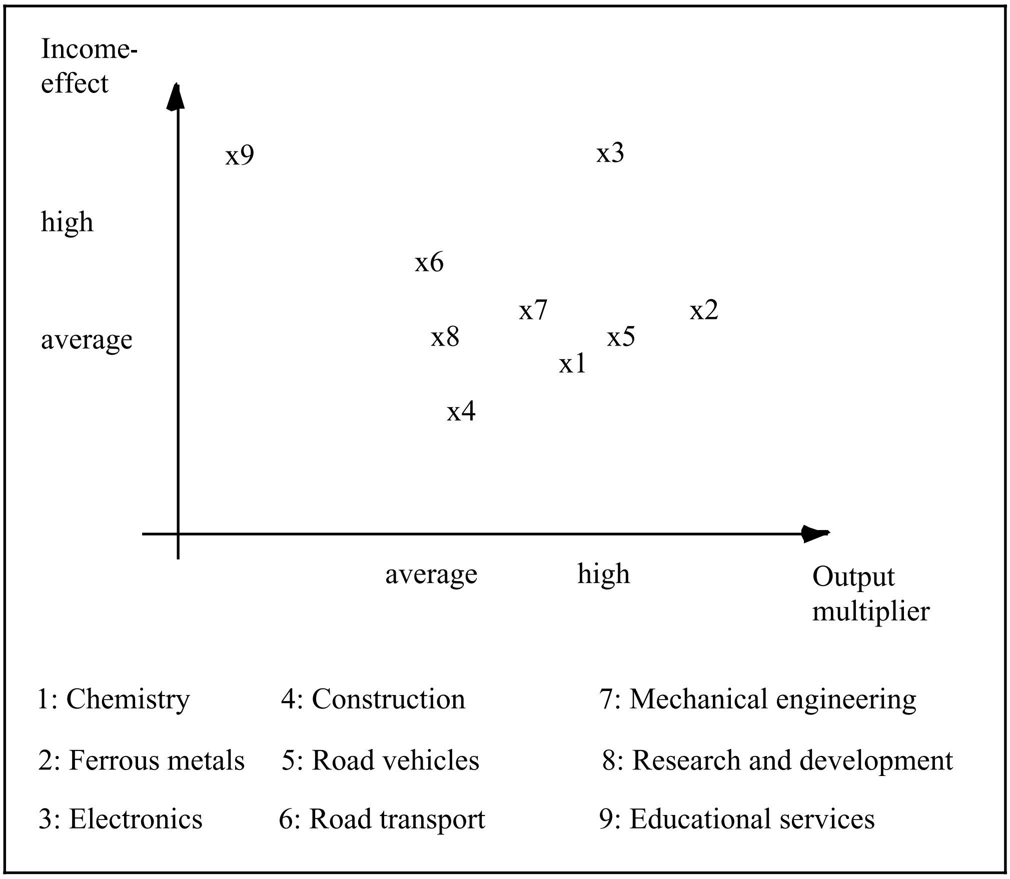
With regard to household income effects the 'more is better' philosophy meets the goals of regional policy in a better way than pure output increases. While high output multipliers may stand for close interindustrial dependency, probably accompanied by additional transport volumes, and for the general extension of the gross production value, high income multipliers can be regarded as welfare raising effects.

However, if two sectors generate similar income effects, the sector with higher output multiplier will cause additional output without additional welfare effects. Therefore the sector with the smaller output multiplier fulfills the principles of a sustainable development in the considered region in a more satisfying way.

The question arises, whether the integration of sector 'Nature' will cause changes for the income effects as well, when real additional intermediate costs occur for the usage of nature capital. Assuming that within a competitive market the companies cannot pass these additional costs to the consumers easily (e.g. foreign competitors) the costs must be transferred to the primary inputs. Company profits (and therefore taxes) will diminish as well as wages and salaries may decrease. On the other hand natural usage also implies additional indirect income effects. If incomes are paid for the distribution of the natural certificates, additional natural usage leads to the purchase of additional certificates, which in turn will increase the household incomes gained within sector 'Nature'.

But even without the integration of natural services a simultaneous consideration of income effects and output multipliers is worthwhile. Figure 2 provides first results of a parallel analysis for selected sectors.

Figure 2: Income and output multipliers for selected sectors



While the sector 'Ferrous metals' shows a very large output multiplier, its income multiplier is at average level. Contrary 'Educational services' are accompanied by high income effects and rather small output multipliers. 'Electronics' confirms its important role for the German economy by high income and large output multipliers.

5 Conclusions and outlook

The presented ecological input-output model considers 'Nature' explicitly as an intermediate sector. The consideration of natural flows leads to an enlargement of the A-matrix in the form of additional negative (variant: natural subsidies, 'eco1') or positive (variant: small is beautiful, 'eco2') input coefficients. The ecological approach, which is embedded into the conventional methodology, considers natural resources and the absorption of emissions as monetary outputs provided by sector 'Nature'.

Due to the assumption that no industrial 'goods', which are not integrated in the traditional monetary tables already, but only 'bads' (e.g. emissions) form the physical inputs for sector 'Nature', the relevant monetary input is equal to zero.

The example and the results for the German economy show that the implementation of natural services can lead to significantly different results. One of the main parameters of these differences is the evaluation of natural flows in monetary terms. It is impossible to calculate the 'true' value of any resource. Intrinsic qualities will be, if at all, evaluated differently. Furthermore monetarizations are always context-specific and monetary terms therefore depend upon the social-economic conditions of the society in question.

'ecolio' offers a price corridor for each kind of resources and emissions. Any specific price constellation, which is set by the user, yields different results for the output multipliers and their ordering. Hence, without discussing the elaboration of natural values in further depth, the model can be recommended for a sensitivity analysis.

The ecological approach 'eco2' suggests a reversion of the traditional way of thinking. Assuming that two sectors show similar income multipliers for the considered (and highly developed) region, the sector with a smaller output multiplier fulfills, according to 'eco2', the requirements of sustainability in a better way than the sector with a relatively high output multiplier.

The idea to generate ecologically more suitable output multiplier with an ecological input-output model by pricing natural usage is appropriate for a short-term analysis. However, once the prices become operational costs, the companies will try to maximize their profits by modifying their production function. The newly established market incentives will not only cause a more consequent utilization of energy saving potentials natural pricing could also initiate a complex substitution process. Exemplary the distribution of SO_2-certificates could provoke a substitution of sulfur-rich by sulfur-poor energy inputs and eventually may even initiate the general replacement of (energy) intermediate inputs by primary inputs. Therefore the internalization of environmental costs will release or at least accelerate structural changes, which have to be taken into account when input-output multiplier are applied for medium and long term projections.

It can be shown that, at least for the above-mentioned example, a favorable macroeconomic development is not interfered or slowed down by the introduction of natural pricing – if Gross Value Added and production values are considered (SCHAFFER, 2002). Since additionally nature friendly production processes are stimulated by the internalization of external costs, natural pricing or ecological taxation can be regarded as one appropriate measure to realize the idea of an economic and ecological sustainable regional development.

However, the sectoral development differs significantly. While some sectors, in particular 'Gas', 'Capital goods' and 'Market services' gain in importance, the output of sector 'Coal' is constantly decreasing. Since the labor-productivity of the 'winners' is higher than for the 'losers' in this case the substitution process is unlikely to reduce the pressure on the labor market.

Analytical proof of the existence of the ecologically extended Leontief inverse matrix

Assumptions:

- The Neumann's series (Neumannsche Reihe) without the ecological extension does converge, i.e. :

  $\sum_{k=0}^{\infty} A^k = (I - A)^{-1}$ (Conventional Leontief inverse matrix of n x n A-matrix)

- The output of sector nature is considered as natural subsidy and therefore shows a negative sign:

  $-1 < a_{i,j} \leq 0$ (i=n+1, j=1...n)

- The production process does not provide additional inputs for the production of natural resources, i.e. all potential industrial inputs are already included within the ordinary monetary tables.

  $a_{i,j} = 0$ for i=1...n, j=n+1

- $\tilde{A} = \begin{pmatrix} A & \vec{0} \\ v' & 0 \end{pmatrix}$ where v' is the transposed vector v and $\vec{0}$ is the zero vector.

Hypothesis:

$\tilde{A}$ does converge.

Analytical proof:

$$\tilde{A}^2 = \begin{pmatrix} A & \vec{0} \\ v' & 0 \end{pmatrix}\begin{pmatrix} A & \vec{0} \\ v' & 0 \end{pmatrix} = \begin{pmatrix} A^2 & \vec{0} \\ v'A & 0 \end{pmatrix}$$

$$\Rightarrow \quad \tilde{A}^k = \begin{pmatrix} A^k & \vec{0} \\ v'A^{k-1} & 0 \end{pmatrix}$$

$$\Rightarrow \quad \sum_{k=0}^{\infty} \tilde{A}^k = \begin{pmatrix} \sum_{k=0}^{\infty} A^k & \vec{0} \\ v' \sum_{k=1}^{\infty} A^{k-1} & 0 \end{pmatrix}$$

Since the Neumann's series without ecological extension converges, the modified series with extended matrix $\tilde{A}$ will converge as well, which in turn means $(I - \tilde{A})^{-1}$ does exist.

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