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Methodology of the Input-Output Analysis

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Abstract

In the near future consequences of the anthropogenic climate change will be more and more perceptible all over the world. But the regional distribution will differ substantially even between regions within the same country. Thus, local authorities need to adapt their regions individually to the risks resulting from the new climatic conditions. By implementing climate change in specific regional models the small scale economic impacts of climate change and the economic usefulness of adaptation measures can be evaluated. The input-output method presented in this paper delivers insight into the impact chain through which endogenous shocks affect the economy. The methodology is relatively uncomplex compared to other model types. Thus, the results are quite easy to understand and to communicate to the public. On the other hand the results underlie several restrictive assumptions. In the empirical environmental literature the input-output method is common for the assessment of economic damages after disasters. But models, which implement economic effects of adaptation measures, are very scarce.

Keywords: input-output model; sectoral interdependencies; impact analysis

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1 Introduction

At the end of the year 2008 the German government signed the so called "German adaptation strategy to climate change" (Bundesregierung 2008). Its long term aim is to lower the vulnerability and to increase the adaptability of natural, social and economic systems to changing climatic conditions. In the past the political and scientific focus was primarily on mitigation strategies, i.e. measures to reduce greenhouse gas emissions. But the increasing risks arising from not preventable consequences of the anthropogenic climate change impose enormous pressure on politicians and government authorities. They have to take measures in order to adapt their economies to the new climatic conditions. However, the current debate and scientific research also include adaptation strategies. The benefits of adaptation measures such as coastal defence or restructuring the agricultural sector occur at the local level. Thus, local authorities might prefer the investment in these measures to the implementation of mitigation strategies because benefits from mitigation occur globally.

In order to offer the authorities a basis for decision-making, economic effects as well as costs and benefits of adaptation measures have to be analysed, especially on the local level. Thus, the objective of this paper is to elaborate the methodology of a specific regional model which interlinks climate change and economic developments. In environmental economics literature three methodical approaches are predominant for quantifying the effects of climate change. These are computable general equilibrium models[1], growth models and input-output models.

The following explanations concern the methodology of the input-output framework. The input-output analysis captures the interactions of local sectors with each other, with sectors outside the region, and with final demand sectors on a highly disaggregated level. This enables the scientist to quan-

[1] A survey of CGE models in this context is given by Döll (2009).

tify the impact on specific sectors which result from changes in economic variables. Possible feedback effects to the initiating sector are included and, furthermore, links to impacts on income and employment can be provided.

In the following section an overview of the general input-output method will be given. Here the input-output table, which is the basis for every input-output model, and the general model itself will be described. Afterwards the advantages and disadvantages of this method will be discussed. The fourth section deals with the applications of input-output models in the empirical environmental literature. The paper closes with a short conclusion.

2 The input-output method

2.1 The input-output table

The starting point for input-output analysis is an input-output table. It presents the statistical information system and records the quantitative transactions between the economic sectors of the considered region, the sales to the final demand sector and the value added of each sector. In an open economy the final demand sector is assumed to be represented by the following economic subjects (Ardent et al. 2009):

- Household sector that demands private consumer goods,
- government sector that demands public consumer goods,
- foreign trade sector that demands export and supplies imports.

Table 1 shows a reduced extract of the input-output table of Germany in 2005. The high sectoral disaggregation allows a specific exploration of the dependencies of the economic sectors. For example the manufacturing of machinery depends directly on the metal production industry because it needed goods worth 13 318 million Euro for its production in 2005. In other words: For producing machinery worth 1 million Euro the value of input from the metal production was 73 816 Euro.[2]. In turn metal production needed goods worth 33 000 Euro[3] from the business related services for the production of 1 million Euro of its output. Thus, the manufacturing of machinery indirectly needed inputs from the business related services worth 2 441 Euro[4] to produce goods worth 1 million Euro. Since the sector of business related services also needed inputs from other sectors, other products are indirectly incorporated in the production of machinery. The technique of matrix multiplication makes it possible to add the flows of goods related to the production of a good. Given an exogenous specification of the demand (for example investment or consumption demand) the direct and indirect economic effects of changes in final demand (on the level of sectors or of the economy as a whole) can be recorded.

[2] 13 318 mill. (metal products to manufacturing of machinery)/180 421 mill. (production value in the manufacturing of machinery)*1 mill. = 73 816.

[3] 3 193 mill. (company related services to metal production)/96 533 mill. (production value in the metal production)*1 mill. = 33 076.

[4] (33 076/1 000 000) * 73 816 = 2 441.

Table 1: Extract from the input-output table of Germany 2005 (ex factory prices in million Euro)

Sector i purchases to sector j	Manufacture of metal products	Manufacture of machinery	Real estate activities	Research and development	Business related services	…	Total	Domestic consumer spending of private households	Exports	Total	Whole supply of goods
Metal products	16.583	13.318	106	36	76		71.635	3.968	27.975	42.622	114.257
Machinery	2.310	33.631	629	29	25		60.555	7.118	110.916	167.180	227.735
Real estate activities	1.474	2.364	11.610	390	9.569		110.292	215.816	979	220.920	331.212
Research and development	10	93	0	1.278	0		8.967	0	6.110	16.000	24.967
Business related services	3.193	12.785	10.022	1.833	58.136		267.887	9.703	22.050	42.054	309.941
…											
Total intermediate inputs	56.082	111.773	68.266	10.867	104.379		2.109.731	1.121.484	900.470	2.826.274	4.936.005
Income from employment	27.726	49.335	11.581	6.968	92.485		1.131.060	0	0	0	0
Value added	39.966	68.000	253.392	8.720	190.136		2.024.890	0	0	0	0
Production value	96.533	180.421	324.394	20.259	295.838		4.187.395	0	0	0	0
Imports	17.724	47.314	6.818	4.708	14.103		748.610	0	0	0	0

Source: German Statistical Office (2009).

The input-output table can be presented in a formal scheme as shown in figure 1. The figure reveals a break down into three quadrants. The first quadrant (I) displays the transaction matrix or intermediate matrix, which is the core of the input-output table. It depicts the goods and services flowing in the production sphere combined to produce outputs for sale to other industries and to final consumers, i.e. it shows the intersectoral interdependencies of the n sectors in the region (Holub and Schabl 1994). Each column contains the intermediate goods, which are part of the output. The sum of each column

$$U_j = \sum_{i=1}^{n} x_{ij} \tag{1}$$

reflects the whole use of intermediates of a sector; it is called intermediate input. The rows contain the part of the production which is delivered as

Figure 1: Scheme of an input-output table

(I) x_{ij}	S_i	(II) Y_{ik}	Y_i	X_i
U_j		Y_k	Y	X
(III) P_{Ij}	P_I			
P_j	P			
X_j	X			

Source: Hujer and Cremer (1978), p. 148.

intermediates to other sectors. The sum of each row

$$S_i = \sum_{j=1}^{n} x_{ij} \tag{2}$$

is called intermediate output or intermediate demand.

The second quadrant (II) represents the final demand matrix, i.e. the delivery of the individual production sectors to final demand sectors. The final demand (Y_i) is, in contrast to the intermediate demand, an autonomous quantity in the open model. The sum across the i^{th} row, adding the sales to other industries and to the various categories of final demand, shows the total gross output for that sector (X_i) (Holub and Schabl 1994; Hujer and Cremer 1978).

The third quadrant (III) is the matrix of primary expenses. It contains the purchases made outside the square matrix of the first quadrant. The category known as value added contains three important elements: the returns to capital (profits, dividends), the returns to labour (wages, salaries) and depreciation and amortisation of fixed assets. The third quadrant also contains two import row vectors and finally the vector of total gross inputs (Hewings 1985; Hujer and Cremer 1978). As Leontief contributed, the framework depends on a "double-entry" accounting. That means that each revenue item of an industry must reappear as an outlay item in the account of some other industry (Leontief 1941). Thus the vectors of total gross output and input are equal (Hewings 1985).

The construction of input-output tables involves inherent uncertainty and imprecision especially at the sub-national level. While the national tables agree with the system of national accounts, the resources to develop regional tables are scarce (Beynon and Munday 2007). This means that regional tables are often derived by an adjustment of the national table in Germany (e.g. Gabriel 2001; Koschel et al. 2006) as well as in other countries like the USA (e.g. Rosenberg 1993). These so called non-survey methods are based on the assumption that the local technology is the same as the technology of the national average (Rosenberg 1993; Strassert 1968). The location quotient method is one of the established approaches in this field. The location quotient (LQ) measures the share of the regional output (or provisionally employment) of a sector in the whole output (employment) of the region in comparison to the according share in the whole economy. Thus, it is a measure for regional specialisation. If $LQ < 1$ the regional industry has less output (employment) than its national average. To meet the demand requirements of the region it needs to import from other regions. Thus, the national input coefficient a_{ij}, which specifies the share of intermediates in the whole output of each branch j, is multiplied with the location quotient. This procedure reduces the share of intermediate inputs purchased from local sectors and, hence, the demand for intermediates has to be met by additional imports. If $LQ \geq 1$ the regional coefficient stays equal to the national coefficient. The assumption is that the regional sector is more specialised than its national counter part and therefore self-sufficient. Extensions of this method

account not only for the size of the selling industry but also for the purchasing industry as well as for the size of the region (Swaminathan 2008).
In order to reduce uncertainty in regional tables, especially about the imports and exports of the regional sectors, partial survey techniques can be used. With this method key local industries are surveyed for financial transactions information. This hybrid approach has inter alia been adopted by Stäglin (2001) for the region of Hamburg, by Oberhofer and Haupt (2001) for the region of Regensburg and by Koschel et al. (2006) for Hesse. But imprecision and uncertainty still persist even when there are high-quality survey returns available. This is because the survey information from firms has to be aggregated into defined sectors suitable for the national classification or even for an aggregation of the national sectors into regional sectors. The attribution of firms to a specific sector may be obtained by a direct question within the survey. But the aggregation as well as the, to a certain extent, arbitrary attribution imply that the data in the table is necessarily an average from a series of returns and could poorly represent a typical firm in the industry concerned (Beynon and Munday 2007).

2.2 The static open input-output model

For the analysis of the input-output table it is necessary to formulate a model which interprets the data recorded in the table and asseses the economic consequences of external shocks to the system, e.g. resulting from extreme weather. The final input-output account will then capture the extensive regional purchasing and supply relationships as well as the displays of the primary inputs (capital and labour).

The model considered here is a static and open model. It is called static because a time dimension is not explicitly taken into account. All quantities in the table are related to the same period, thus they are flows with the dimension quantity per period. Temporal shifts and, thus, progresses of economic processes are not subject of investigation. Therefore, static input-output-models are not capable of capturing changes in factor stocks over time by positive or negative net investment; the capital stocks have to be interpreted as exogenous variables. The investigation of an open input-output model implies that not all variables are interdependent. More precisely the model contains a total (or partial) exogenous final demand (Holub and Schabl 1994; Hujer and Cremer 1978; Krengel 1973). Starting point for the model is a linear system of equations, which captures the interdependencies of intermediate goods and final demand in an input-output table:

$$\begin{array}{llllllll} x_{11} & +\ldots & +x_{1j} & +\ldots & +x_{1n} & +Y_1 & =X_1 \\ \vdots & & \vdots & & \vdots & \vdots & \vdots \\ x_{i1} & +\ldots & +x_{ij} & +\ldots & +x_{in} & +Y_i & =X_i \\ \vdots & & \vdots & & \vdots & \vdots & \vdots \\ x_{n1} & +\ldots & +x_{nj} & +\ldots & +x_{nn} & +Y_n & =X_n \end{array} \tag{3}$$

Each row contains the whole output (gross production value) X_i of an economic sector as the sum of the intermediate outputs of the other sectors x_{ij} (from sector i to sector j) and the output supplied to the final demand Y_i. The static open model assumes constant input coefficients. Thus, the current inputs and the purchased intermediates are proportional to the output of the respective sector. This results in Leontiefs' production function of the type, which is linear homogeneous and limitational. The input coefficients a_{ij} specify the proportional relationship between the whole input X_j of branch j and the intermediate outputs x_{ij}. In matrix notation the below system of equations follows:

$$\underline{x} - \underline{A} \cdot \underline{x} = \underline{y} \tag{4}$$

where $\underline{x}$ and $\underline{y}$ are the vectors of the technology dependent output as a whole (gross production) and the final demand independent of the system, $\underline{A}$ is the matrix of the input coefficients. In order to solve the model, the gross production values (production volumes) have to be determined at a given autonomous final demand and constant input coefficients. Therefore the equation system has to be solved for the vector of gross production:

$$\underline{x} = (\underline{I} - \underline{A})^{-1} \cdot y \qquad (5)$$

where $\underline{I}$ is the $n \times n$ identity matrix $(i, j = 1, 2, \ldots, n)$. Thus, for a given final demand y it is solvable if the inverse matrix $(\underline{I} - \underline{A})^{-1}$exists (Holub and Schabl 1994; Mertens 1973; Koschel et al. 2006), i.e.

$$det\,(\underline{I} - \underline{A})^{-1} \neq 0 \quad .$$

The matrix $\underline{L} = (\underline{I} - \underline{A})^{-1}$ is known as Leontief Inverse. Their elements l_{ij} show by how many units the production of sector i has to change, if the demand for goods of sector j varies by one unit. In other words, l_{ij} shows how many units of intermediate production of sector i are needed to produce one unit of final demand of sector j directly or indirectly. Thus, the production is displayed as a function of final demand. The sum of each column represents the sectoral production multiplier. The sums constitute how many production units all production sectors together have to provide for the production of one unit of final demand for goods of sector j, i.e. they determine the directly and indirectly required gross production. With this implicit attention to input requirements, the model is often described as focussing on "backward linkages" (Pischner and Stäglin 1976; Mertens 1973; Rosenberg 1993; Koschel et al. 2006).

An approximation of the calculation of the inverse matrix by determining the following power series separates each required production step due to a change in final demand:

$$\triangle\underline{x} = \underline{I} \cdot \triangle\underline{y} + \underline{A} \cdot \triangle\underline{y} + \underline{A}^2 \cdot \triangle\underline{y} + \underline{A}^3 \cdot \triangle\underline{y} + \ldots + \underline{A}^n \cdot \triangle\underline{y} \qquad (6)$$

The direct effects are the sum of the initial effect $\left(\underline{I} \cdot \triangle\underline{y}\right)$ and the first round effects $\left(\underline{A} \cdot \triangle\underline{y}\right)$, i.e. the direct impacts on the input components of the sector affected by the demand changes. The further evolving indirect effects are captured by the expression $\left[\left(\underline{A}^2 + \underline{A}^3 + \ldots + \underline{A}^n\right) \cdot \triangle\underline{y}\right]$, while the impact of a (one-time) change in demand decreases in every production step (Mertens 1973; Moosmüller 2004).[5]

2.3 Income and employment effects

Firms need workforce for the production of goods. Private households provide their workforce and in turn they receive wages or salaries. To obtain the employment and income effects resulting from changes in final demand, the indirect production effects need to be calculated (Pfähler et al. 1997). Hence, the sectoral changes in final demand are captured in the column vector $\triangle\underline{y}$ and this vector is multiplied by the Leontief-Inverse. The resultant vector $\triangle\underline{x}$ contains the direct and indirect production necessary to satisfy the demand impulse.

The production effect can be derived as follows:

$$\triangle\underline{x} = \left(\underline{I} - \underline{A}\right)^{-1} \cdot \triangle\underline{y} \quad . \tag{7}$$

It includes the initial, the first round and the indirect effects. In the empirical literature this equation commonly constitutes the indirect effect. The approach for an impact analysis of an external shock to a regional economy is to incorporate the first round effect in the vector $\triangle\underline{y}$. Concerning for example an adaptation strategy in an economy, then the vector already captures the calculated sum of contracts resulting for each sector. The following multiplier process, where additional intermediates are produced, has to be attributed to the indirect impacts of the initial final demand change. Hence, it would not be necessary to subtract the initial effect from the above equation to obtain the indirect effects[6] (e.g. Hujer and Kokot 2001; Koschel et al.

[5] This corresponds to the prevalent economic theory, e.g. to the basic Keynesian income multiplier.

[6] The proper direct effect of a one Euro increase in output of sector 1 calls for first

2006).

In order to assess employment effects the vector of additional production is pre-multiplied by the diagonal matrix of labor coefficients. If data about employment is available, the sectoral labor coefficient (LC_i) can be calculated by dividing the employment (E_i) by the value added (X_i) (Hewings 1985; Koschel et al. 2006):

$$LC_i = \begin{pmatrix} \frac{E_w}{X_1} & \cdots & 0 \\ \vdots & & \vdots \\ 0 & & \frac{E_n}{X_n} \end{pmatrix} \quad . \tag{8}$$

Income effects can be evaluated by pre-multiplying $\triangle \underline{x}$ with the diagonal matrix $\underline{B}$. This matrix contains the sectoral income coefficients as diagonal elements. The income coefficients for the income generated in each industry are typically derived by $b_j = \frac{W_j}{X_j}$, with W_j being the income distributed to private households (wages and salaries) and X_j the gross output of sector j (Hujer and Kokot 2001).

Thus, the employment $\triangle \underline{E}$ and income effects $\triangle \underline{W}$ can be derived as:

$$\triangle \underline{E} = \left\{ \underline{LC} \cdot (\underline{I} - \underline{A})^{-1} \right\} \cdot \triangle \underline{y} \quad , \tag{9}$$

$$\triangle \underline{W} = \left\{ \underline{B} \cdot (\underline{I} - \underline{A})^{-1} \right\} \cdot \triangle \underline{y} \quad . \tag{10}$$

However, the assumption of proportional relationship still holds here (Holub and Schabl 1994; Hujer and Kokot 2001).

For a complete picture of the effects resulting from a shift in final demand one has to take into account the fact that wages and salaries received by the local employees may be spent on local goods and services, thereby generating additional output and, hence, additional income (Hewings 1985). Therefore the primary input-output model has to be extended in order to capture the

round effects in output of a_{11} in sector 1, of a_{21} in sector 2 and so on. The total first round effect from sector 1 is $\sum_{i=1}^{n} a_{i1}$(West and Jensen 1980).

additional increase in gross production by treating the consumption expenditures as endogenous (Hujer and Kokot 2001). To properly assess these feedback effects between production, additional income and consumption the marginal propensity to consume needs to be derived from the consumption function. Provided the marginal propensity to consume is known, the whole effect can be described as:

$$\triangle \underline{x} = \left\{ (\underline{I} - \underline{A})^{-1} \cdot (\underline{I} - \underline{V})^{-1} \right\} \cdot \triangle \underline{y} \quad . \tag{11}$$

The elements of the matrix $(\underline{I} - \underline{V})^{-1}$ represent sectoral consumption multipliers, which emanate from the initial effect $\triangle \underline{y}$ and the resulting repercussions. They give the whole amount of the increase in final demand in sector i due to an increase of final demand in sector j. The elements in the matrix cover both, the adjusted production interdependence of the sectors as well as the feedback effects due to the additional income generation and the resulting consumer demand. The matrix is specified as follows:

$$\underline{V} = \begin{pmatrix} \sum_{i=1}^{n} l_{i1} \cdot b_i \cdot c_i & \dots & \sum_{i=1}^{n} l_{in} \cdot b_i \cdot c_i \\ \vdots & & \vdots \\ \sum_{i=1}^{n} l_{i1} \cdot b_i \cdot c_i & \dots & \sum_{i=1}^{n} l_{in} \cdot b_i \cdot c_i \end{pmatrix} \tag{12}$$

with
l_{ij} = coefficients of the Leontief-Inverse ,
b_i = input coefficients for wages and salaries,
c_i = marginal propensity to consume.

$\underline{V}$ represents the first round impact of the additional final demand by $\triangle \underline{y}$ on the demand for consumer goods, i.e.

$$\triangle \underline{c_0} = \underline{V} \cdot \triangle \underline{y_0} \tag{13}$$

The elements of the extended Leontief-Inverse $(\underline{I} - \underline{Z})^{-1} = (\underline{I} - \underline{A})^{-1} \cdot (\underline{I} - \underline{V})^{-1}$

correspond to the total production multipliers (i.e. addressing the sectoral intermediate linkages), which emanate from the initial effect $\triangle \underline{y}$ and the resulting repercussion. The coefficient matrix Z can be represented as follows:

$$\underline{Z} = \begin{pmatrix} a_{11} + b_1 \cdot c_1 & \dots & a_{1n} + b_1 \cdot c_n \\ \vdots & & \vdots \\ a_{n1} + b_n \cdot c_1 & & a_{nn} + b_n \cdot c_n \end{pmatrix} \tag{14}$$

with
a_{ij}= input coefficients of the matrix of intermediate linkages,
b_i= input coefficients for wages and salaries,
c_i= marginal propensity to consume.

In order to derive the induced impact effects due to the repercussion of income and consumption, the direct and indirect effects have to be subtracted from the overall impact:

$$\triangle \underline{x}_{induced} = \left\{ (\underline{I} - \underline{A})^{-1} \cdot \left[(\underline{I} - \underline{V})^{-1} - \underline{I} \right] \right\} \cdot \triangle \underline{y} \quad . \tag{15}$$

Subsequently the inverse of the employment and the inverse of income can be derived as:

$$\underline{EI}_{augmented} = \underline{LC} \cdot (\underline{I} - \underline{A})^{-1} \cdot (\underline{I} - \underline{V})^{-1} = \underline{LC}\,(\underline{I} - \underline{Z})^{-1} \quad , \tag{16}$$

$$\underline{WI}_{augmented} = \underline{B} \cdot (\underline{I} - \underline{A})^{-1} \cdot (\underline{I} - \underline{V})^{-1} = \underline{B} \cdot (\underline{I} - \underline{Z})^{-1} \quad . \tag{17}$$

Thus, the induced employment and income effects can be calculated:

$$\triangle \underline{E}_{induced} = \left[\underline{LC} \cdot (\underline{I} - \underline{Z})^{-1} - \underline{LC} \cdot (\underline{I} - \underline{A})^{-1} \right] \triangle \underline{y} \quad , \tag{18}$$

$$\triangle \underline{W}_{induced} = \left[\underline{B} \cdot (\underline{I} - \underline{Z})^{-1} - \underline{B} \cdot (\underline{I} - \underline{A})^{-1} \right] \triangle \underline{y} \tag{19}$$

(Hujer and Kokot 2001; Koschel et al. 2006).

3 Pros and Cons

The input-output method is relatively easy to manage and its empirical implementation is less time consuming than general computable equilibrium models. But unfortunately the model is not based on a microeconomic, consistent and closed framework. This implicates that income cycles as well as price and substitution effects can not be displayed endogenously in the model. Impact analysis with the input-output method therefore involves numerous limitations. Allocation effects of policy measures or climatic extreme events on the basis of plausible behaviour of economic agents are not considered. Furthermore, the cyclical connection between income and expenditure as well as the economic links between the markets of the region are neglected. Hence, the interpretation of the quantitative results always have to account for the weaknesses and limits of the input-output model. However, nevertheless they can be considered as giving an idea of the dimension of economic impacts of certain events.

Some assumptions, to which the input-output model is restricted, might be obscure at least in the short run. A conventional demand-driven input-output model assumes an entirely elastic supply-side in the economy. Thus, the availability of inputs does not constrain an expansion in output. Furthermore, inputs can be immediately drawn into the economy during expansions or must simply become unemployed during contractions, i.e. resources are efficiently employed.

An input-output model is further restricted by the assumption of constant returns to scale and no technological progress. This implies that the technical coefficients are constant and the production function is linear. Hence, the amount of inputs purchased by a sector is solely based on the level of output desired, i.e. the model is reduced to impacts of effective demand. This means that the input requirements of an industry will change in a proportional way when its output level changes. Thus, the matrix detailing the rates of input use in production does not change over time, even if the overall production levels do. This assumption limits the practicability of an input-output model as a predictive tool and it can not reflect any of the process adjustments and technological changes that might occur in response to climate changes (Ardent et al. 2009; Rosenberg 1993; Turner et al. 2003).

Input-output analysis on a national level is less demanding in data collection and availability than other models applicable to depict impact mechanisms like CGE-analysis. Its source are the input-output tables published regularly by the statistical offices. A critical point is the timeliness of input-output data, because there is a long time lag between the collection and the availability of data (Ardent et al. 2009; Pfähler et al. 1997). Furthermore, limitations come up when regional input-output tables are required. The construction might be expensive and time consuming, because the required data are not published by the statistical office. The derivation of the regional input-output table from the national tables, which is the common approach, implies the assumption that the local technology is the same as the national average and it always entails a certain degree of imprecision and uncertainty (Beynon and Munday 2007; Rosenberg 1993; Strassert 1968).

An advantage of the input-output analysis is that it is one subset of the social accounting systems. Thus, the input-output analysis has the interesting feature that, on the one hand, it is strongly linked with standard macroeconomic accounting principles, and, on the other hand, it can be linked with many of the more traditional avenues of inquiry in the geographic and regional sciences fields. The high sectoral disaggregation enables to trace climate change impacts all along the value added chain of the economy. Thus, it becomes apparent which sectors are strongly affected by disasters or adaptation measures and how the repercussions are for the other sectors.

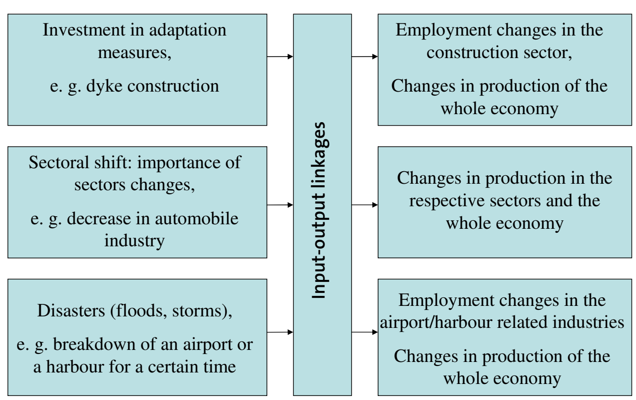
A further advantage of the input-output analysis is that it is less time consuming than other statistical methods because of its low complexity. Therefore, the input-output analysis is relatively cost and time saving. Furthermore, the results of this method are quite simple to understand and to communicate to the public (Pfähler 2001).

4 Applications for Quantifying the Effects of Climate Change

4.1 A short overview

Through input-output linkages changes in only one sector can provoke enormous repercussions in the whole local economy. Specific sectors located at the waterside might suffer damages from floods, which might entail temporary employment and production losses. On the other hand dyke constructions for prevention of flood damage, for example, can provide new jobs in the construction sector and related branches. Thus, for quantifying the effects of climate change an impact assessment over all sectors of the economy is required. Figure 2 exemplifies the impacts through input-output linkages.

Figure 2: Input-Output linkages



Source: HWWI.

Previous works predominantly dealt with the evaluation of environmental economic impacts through CO_2 emissions per sector (e.g. Ardent et al. 2009) or the evaluation of different mitigation policies concerning reduction of CO_2 emissions on a national level (e.g. Leontief 1970; Folmer and Thijssen 1996). On the sub-national level, investigations by using input-output analysis are relatively scarce, when long-term and more successive impacts are considered. Prevalent in the literature is the assessment of the regional total costs after disasters, like earthquakes (e.g. Cho et al. 2001), hurricanes (e.g. West and Lenze 1994) or floods (Tierney 1995, who investigated the impacts on businesses).

Impact analysis of different mitigation policies on a regional level has been conducted by Koschel et al. (2006), while Rosenberg (1993) used the input-output framework to analyse the impact of different climate change scenarios on specific sectors and the repercussion for the whole local economy. The last two investigations will be presented in the following sub-sections. An investigation on the city scale was e.g. introduced by Park (1998), who analysed the effects of different mitigation scenarios for the Seoul Metropolitan Area.

4.2 INKLIM

INKLIM stands for Integriertes Klimaschutzprogamm Hessen. Within this project Koschel et al. (2006) evaluate different CO_2-mitigation scenarios for Hesse. The evaluations depend on a regional input-output table for Hesse, that has been compiled on the basis of the input-output table of the Federal Republic of Germany of the year 2000 by using the location quotient method. Furthermore the input-output table of Baden-Württemberg provided an indication for the extent of imports and exports in Hesse.

Different scenarios of policy activities for a decrease of CO_2-production are evaluated and the effects on the local economy are measured by the use of an input-output model. The standard of comparison for the environmental protection measures is a reference scenario in which there is no political interference. A specific model (TIMES-model) calculates sectoral costs for each measure scenario. The study took into account the following effects of mitigation activities on production and employment over the entire intermediate chain: investment and other demand effects, budget and financing effects, energy consumption effects and income effects.

The vector of sectoral investment demand associated with each measure as well as other sectoral demand generated by additional expenditures like operating costs or expenditures of the households affects the input-output model as an exogenous demand impetus. In a second step the positive demand impetus is confronted with a negative financing effect, while the underlying assumption is that the resulting costs will be borne by the households in the form of a decline in private consumption. This is an ad hoc assumption because of the absence of a circle of flows of income. Thus changing demand structures due to climate protection measures are exogenously determined. This can be seen as one of the weaknesses of the model. The production and employment effects are calculated in a comparative static way against the reference years 2010, 2015, 2020 and 2050. The induced effects in this model are the effects induced by consumer spending from the employees at the companies, who have received contracts to implement climate policies.

Koschel et al. (2006) acknowledge that the introduced input-output model has some further methodical weaknesses. For example feedback effects from rising gross production are only captured by an income multiplier. Furthermore, when interpreting the results one has to remember that the employment effects depend on employment and intermediate coefficients that depend on average values.

The quantitative analysis shows small positive effects of the package of measures on the gross production and employment in Hesse. However, the results show great differences between sectors. Engineering, construction as well as agriculture and forestry did benefit from the demand impetus in all scenarios, while the effect in the service sectors is vague and the sector energy and mineral oil is outstanding negatively affected. Taking the counter financing into consideration reveals that especially the sectors with a high consumption ratio (like buildings, trade, food and traffic) did benefit due to the induced effects. They profited by the increase of income of the employees through additional production in respective sectors and, hence, the additional demand and by savings in the energy sector evoked by the different measures (Koschel et al. 2006).

4.3 The MINK study

The regions under investigation of the MINK study are the central U. S. states Missouri, Iowa, Nebraska and Kansas. Rosenberg (1993) analyse the regional economic impacts of developments in the sectors agriculture, forestry, energy, and, to a limited extent, water resources induced by climate change. The underlying assumption is, that these are the resource sectors most likely to be affected by climate change. The climate change actually affects the productivity of the natural resources in the investigated sectors. But due to the fact that input-output models are demand driven, the impact on the economic system results from changes in final demand for outputs of the respective sector.

Rosenberg (1993)take advantage of an already created model (IMPLAN) and implement a data file with conditions of the year 1982 for total production, value added and employment in 528 industries, along with estimates of regional final demand for produced commodities and services. The impact multipliers derived from the input-output table can be computed to show the direct and indirect impacts of a change in industry sales to final demand on the value of regional production, employment, or value added (a comprehensive measure of regional income). Thus, the model becomes a predictive tool. For example '... the increase in costs of feedgrain production caused by the climate-induced losses of yield results in a reduction in export demand for the crops equal to the simulated decline in crop production. In this case, the supply of feedgrain available to animal production in MINK is unchanged, so animal production and meatpacking in the region are not affected by the decline in grain output (Rosenberg 1993, p. 143).' Another set of estimates is subject to the assumption that the locally available supply of feedgrain declines by the full amount of the production decline, while the exports are unaffected. The most considerable linkage is found between the agricultural sector and the rest of the MINK economy. The effects of the analog climate scenarios (considering direct effects on production and in one case adaptation activities) on each sector have been evaluated in earlier analysis, thus, the expected development of yields, costs of production and the resulting changes out of it like changing production quantities and behaviour of economic actors (like farmers) are known under the different scenarios. Rosenberg (1993) estimate the effects on the economy in 1980 and analogue in a scenario of the economy of 2030, while they took advantage of population and economic projections, however, assumed the same inter-industry multipliers as in 1980 (Rosenberg 1993).

5 Conclusion

The application of an input-output model is a useful tool in order to analyse regional economic interdependencies. It is especially suited to display the interdependence of the regional sectors as well as their connection to final consumers and the rest of the world. The construction of a regional input-output table poses one of the biggest challenges, since the Federal Statistical Office of Germany only provides nationwide tables.

Climate change impacts can be implemented in the input-output framework through exogenous shocks to the regional value-added chain in the form of changes in final demand structures. The resulting economic changes can be evaluated from direct to indirect and income induced effects. Knowledge about the repercussion of exogenous shocks to a region is especially important for policy measures. The results from input-output models can to a limited extent indicate the impact of different measures on production, income and employment in the investigated region. The most serious problem might be the constant production multipliers that do not allow for any kind of adjustment processes, like e.g. substitutions. But as noted in the above sections, the input-output framework is shaped by further disadvantages, which makes it inferior compared to other models like CGE or growth models especially when it comes to long-run analysis. An input-output model shows a static picture of the economy and does not take into account price or substitution effects nor does it include technological progress and economies of scale. Nevertheless the input-output account can deliver insight into the impact chain in an economy and the results are quite simple to understand and to communicate to the public. Therefore, an input-output model is a useful additional tool to economic models with a closed model framework, where price and substitution effects are considered.

Future research in the field of input-output analysis will be the derivation of small scale input-output tables for German regions and the implementation of adaptation measures in the impact analysis.

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