Regional input-output modelling in Germany: The case of North Rhine-Westphalia

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Abstract

The political system of Germany is characterized by strong federalist elements, which means that many important decisions of economic policy are made by the governments of the federal states or *Länder*. It is unfortunate, then, that the statistical offices of the *Länder* do not produce regional input-output tables, claiming that they lack the resources (i.e. manpower) to do so. The lack of official input-output tables for the *Länder* forms a significant obstacle to the study of regional economic developments and hampers the ability of economists to provide well-informed advice to regional policy-makers. A similar situation prevails in many other European countries.

This paper attempts to meliorate the situation by describing the process of constructing a regional input-output table (RIOT) for North Rhine-Westphalia (NRW), the largest federal state. A first approximation is produced by applying the CHARM method to the national input-output table on the basis of regional and national employment data. This first approximation is then improved upon by adding additional information from various sources, including the statistical office of NRW and the household survey of income and expenditure (EVS). The result is a RIOT for NRW that allows us to compare the economy structure of the region with that of Germany as a whole. Based on the RIOT, we then construct an input-output model for NRW in order to estimate the employment generated by the production of renewable energy in NRW, an analysis which would not be possible without a RIOT.

Given the lack of official RIOT in Germany and many other countries, and in light of their usefulness, we conclude that policymakers should allocate additional resources for the construction of such tables. We also provide recommendations on how to construct a RIOT by derivative means when resources (i.e. time and money) are severely limited.

Keywords: regional input-output, nonsurvey method, renewable energy, employment effects.

Topic: 1. Construction and adjustment of input-output tables.

1. Introduction

A popular application of models that are based on input-output tables is the investigation of regional economic developments, where they are often used for impact analysis. Until the early nineties of the past century official input-output tables for some of Germany's federal states were available and at least updated irregularly. As the construction of input-output via survey methods is highly recourse consuming and, hence, the statistical offices stopped working on regional tables, economists are reliant upon non-survey methods in many cases. Because the performance of non-survey methods is controversial in the literature, additional data is often used to improve the quality of the regional input-output table, which is known as hybrid approach. We follow this approach for the construction of an input-output table for North Rhine-Westphalia, in order to estimate the employment effects generated by the operation and production of renewable energy power plants.

This paper is structured as followed: Section 2 presents CHARM (Cross-Hauling Adjusted Regionalization Method) as a non-survey method, followed by a description of the hybrid estimation procedure using additional data including the income and expenditure survey, foreign trade data and the national supply table in Section 3. Section 4 finally presents the estimation of employment effects using a static model with endogenised consumption of households and gives an interpretation of the modelling results.

2. CHARM as a non-survey method

In the literature, pure non-survey methods are often criticized to produce at best imprecise or, even worse, systematically biased results, due to the fact that they insufficiently account for the size of regional trade (Harris and Liu, 1998; Tohmo, 2004). Richardson (1985) laments that popular methods like Location-Quotient (LQ) or Commodity Balance (CB) approches are prone to overestimate regional multipliers, because they ignore the simultaneous exportation and importation of commodities, which is known as cross-hauling. Recent evidence (Flegg and Tohmo, forthcoming) suggests that the FLQ method performs better than the traditional approaches that were subject to Richardson's critique. However, for the present study we choose to adopt the

CHARM method because it has been shown to generate satisfactory results for other German *Länder* (Kronenberg, 2009, 2010). Formally cross-hauling can be expressed as:

$$q_i = v_i - |b_i| = (e_i + m_i) - |(e_i - m_i)| \quad (1)$$

,where q_i denotes cross-hauling, $v_i \equiv e_i + m_i$ denotes the sum of exports e_i and imports m_i or rather the trade volume and $b_i \equiv e_i - m_i$ denotes the trade balance of a commodity i.

Traditional non-survey methods can only account for the net exports $(e_i - m_i)$ and are usually based on the assumption that each industry is either export- or import oriented, which causes either e_i or m_i to be set equal to zero and, according to equation (1), cross-hauling not to occure(Kronenberg, 2009). Norcliffe (1983) argues that cross-hauling is the main problem that must be solved to increase the accuracy of non-survey methods.

Particularly two reasons for the occurence of cross-hauling are dominant in the literature. The first one is related to the geographical size of region. Firms that are located at the frontier of a region are likely to operate on markets on the opposite side of the border. Since smaller regions have longer frontiers in relation to their geographical space, more firms are affected and, hence, cross-hauling is more important. This argument is given by Flegg et al. (1997) with regard to the regional size in their FLQ formula. Apart from that,product heterogeneity is frequently mentioned as a reason for the occurrence of cross-hauling. In accordance with Harris and Liu (1998) cross-hauling appears especially in those industries where "product differentiation and brand preference is important" (p. 853). This argument is based on an empirical investigation by Norcliffe (1983), who compared estimations of the regional trade volume of several LQ with survey-data on regional trade. He found that LQ-methods considerably underestimatethe trade volume of industries that produce heterogeneous commodities like cars or furniture, whereas the estimates for homogeneous commodities e.g. fishery products are almost in accordance with survey-data. Isserman (1980) suggests to implement non-survey methods using data on a very high level of disaggregation, where product groups are relativly homogeneous. However, in many countries sufficiently detailed data are simply not available. CHARM therefore includesproduct heterogeneity as a variable explicitly in the procedure of estimating regional trade (Kronenberg, 2009).

The first steps of the regionalization procedure are carried out analogically to the traditional CB approach. For a more detailed description see e.g. Miller and Blair (2009). After this step all components apart from exports and imports of the regional input-output table are estimated and we carry on with the estimation of exports and imports via CHARM. As already suggested by the name CHARM allows to estimate cross-hauling explicitly by assuming that cross-hauling q_i is a function of product heterogeneity h_i, domestic production x_i, total intermediate use z_i^d and final domestic use d_i, thus $q_i = q_i(h_i, x_i, z_i^d, d_i)$. The estimation of product heterogeneity h_i requires, then, a specific functional from that must be consistent with some requirements. Kronenberg (2009) assumes cross-hauling to be proportional to the sum of domestic production $x_i$and total use $z_i + d_i$ with the degree of product heterogeneity h_i as the factor of proportion:

$$\boldsymbol{q_i = h_i(x_i + z_i + d_i)}. \qquad \textbf{(2)}$$

Substituting (1) into (2) and solving for h_i yields

$$\boldsymbol{h_i = \frac{v_i - |b_i|}{x_i + z_i + d_i}}. \qquad \textbf{(3)}$$

Since product heterogeneity is a characteristic of a commodity and not of geographical location, it is reasonable to assume that product heterogeneity on the regional level equals its counterpart on the national level for each commodity i. Given that h_i may be estimated from data of the national input-output table. Substituting the estimated product heterogeneity h_i into equation (2) combined with the values of d_i, z_i^d

and x_i from the regional input-output table yields an estimation of the regional degree of cross-hauling.

Gross exports and imports are then calculated by solving the definitions of trade volume $v_i \equiv e_i + m_i$ and $b_i \equiv e_i - m_i$ for e_i and m_i, which yields

$$\boldsymbol{e_i = (v_i + b_i)/2.} \quad \textbf{(4)}$$

$$\boldsymbol{m_i = (v_i - b_i)/2.} \quad \textbf{(5)}$$

b_i is simply given through its definition as the difference of output x_i and total domestic use $z_i + d_i$ from the regional input-output table, whereas the trade volume v_i may be obtained through solving (1) for v_i, which yields $v_i = q_i + |b_i|$.

Following these steps yields a regional input-output table based on CHARM as a pure non-survey method. The following chapter describes how the accuracy can be improved by the use of data from statistical offices and the income and expenditure survey.

3. The hybrid approach

This Section presents the four steps of the hybrid approach. At first the estimation of the intermediate and primary inputs is demonstrated in Subsection 3.1.Subsection 3.2 describes the estimation of the consumption of the private households from data of the income and expenditure survey and the estimation of the remaining (domestic) final demand. The estimation of trade pattern by using trade data in combination with CHARM is demonstrated in subsection 3.3.

3.1 Intermediate and primary inputs

The estimation of the intermediate and primary inputs within the hybrid approach incorporates a national input-output and a national supply table as well as data of output, value added and wages on national and regional level. Since the latest input-output table is published for 2007 all data also refer to 2007. Unfortunately the data are classified in economic activities (WZ classification) whereas the data from the national input-output account is classified in products (CPA classification). A car manufacturer, who also owns a bank, in order to provide financial services to car buyers, shall serve as an example to make this difference clear: According to the classification in economic activities the activities of this bank are related to the sector "motor vehicles", because the main activity of a car manufacturer is to produce cars, whereas the same bank is related to the sector "financial services" according to the classification in products. Since the supply table allocates the output of every economic activity to the products, we make a detour and estimate the regional output from the supply table for this reason, because the row totals of a supply table are equal to the output of an industry in the input-output table.

The columns j are structured in 59 economic activities, whereas the rows i are divided in 71 product. The national supply table is regionalized by multiplying each column j with wage quotients for each economic activity s_j:

$$s_j^r = \frac{w_j^r}{w_j^n} s_j^n \quad \textbf{(6)}$$

where the indices r and n indicate variables related to the regional and the national level and w_j denotes the wages by economic activity. The column totals must be equal to the official output data and the row totals are our estimates of the output that have to be integrated in the regional input-output table without company-internal deliveries. The data on regional output is unfortunately only available in structure of 16 economic activities. For this reason the column totals have to be aggregated on the same level of detail, in order to compare the estimated values with the official data. The estimated outputs are adjusted by multiplying each column of the supply table with a quotient from the estimated output and the output from the official data $\tilde{s}_j^r / s_j^r$, where $\tilde{s}_j^r$ denotes the regional output from the official data. Before the row totals of the supply table can flow into the regional input-output table, the estimated company-internal deliveries on the regional level have to be estimated and added to the estimated output. Assuming that the share of company-internal deliveries on the regional level the regional output is estimated as:

$$x_j^r = s_j^r * (1 + \frac{l_j^n}{s_j^n}) \qquad (7)$$

Where l_j^n denotes the monetary value of company-internal deliveries on the national level.

The next step contains the estimation of the regional value added and the regional wages. Both are available in WZ classification, but unfortunately only structured in 60 sectors. At first we calculate the regional value added on the more aggregated level by multiplying the regional value added data $v_j^{r,WZ}$ with a correction term:

$$v_j^{r,CPA} = v_j^{r,WZ} * \frac{v_j^{n,CPA}}{v_j^{n,WZ}}. \qquad (8)$$

We assume that the ratio of value added $v_j^{n,CPA}/v_j^{n,WZ}$ classified in CPA and WZ on the national level is equal to ratio on the regional level. In cases where the value added of an economic activity exceeds the value added of a product on the national level$v_j^{n,CPA}/v_j^{n,WZ} < 1$ and, hence, the value added of the same product on the regional level decreases in comparison to the data. Thus,$v_j^{n,CPA}/v_j^{n,WZ} > 1$ causes a correction in the opposite direction. As this estimation yields value added for only 60 sectors because of the data limitations, the estimated value added must be disaggregated in 71 sectors. The only data that are available in an appropriate structure are employment data. Value added of those sectors that possess a higher level of aggregation in data then needed for the input-output table is allocated to the subsectors via their share in employment. The estimation of the compensation of employees is conducted in the same fashion as the estimation of the value added.

Given that we are able to estimate the remaining properties of the value added namely the (net) operating surplus π_j^r, the net taxes on production t_j^r and the consumption of fixed capital α_j^r. Since the value added and the compensation of employees are already known the difference between both must be allocated on π_j^r, t_j^r and α_j^r. Because of lacking information about the regional values of these components, we assume that their share on the value added is the same as on the national level.

$$\boldsymbol{\pi_j^r} = (\boldsymbol{v_j^r} - \boldsymbol{w_j^r}) * \frac{\boldsymbol{\pi_j^r}}{(\boldsymbol{v_j^n} - \boldsymbol{w_j^n})} \quad \textbf{(9a)}$$

$$\boldsymbol{t_j^r} = (\boldsymbol{v_j^r} - \boldsymbol{w_j^r}) * \frac{\boldsymbol{t_j^r}}{(\boldsymbol{v_j^n} - \boldsymbol{w_j^n})} \quad \textbf{(9b)}$$

$$\boldsymbol{\alpha_j^r} = (\boldsymbol{v_j^r} - \boldsymbol{w_j^r}) * \frac{\boldsymbol{\alpha_j^r}}{(\boldsymbol{v_j^n} - \boldsymbol{w_j^n})} \quad \textbf{(9c)}$$

In a final step the estimation of the interindustry matrix is conducted. The total of the intermediate inputs is due to the difference between the output and the value added of a sector j: $z_j^{u,r} = x_j^r - v_j^r$. We assume the structure of the intermediate inputs on the regional level to be equal to those on the national level. The elements of the interindustry matrix are then given by:

$$\boldsymbol{z_{i,j}^r} = \boldsymbol{z_{ij}^n} * \frac{\boldsymbol{z_j^{u,r}}}{\boldsymbol{z_j^{u,n}}} \quad \textbf{(10)}$$

After this step the primary and intermediate inputs of our regional input-output table are estimated and we move on to the estimation of the final domestic use.

3.2 Final domestic use

The final domestic use is sub-divided into government purchases, the consumption of organisations without pecuniary reward, capital expenditure, stock variations and, finally, the consumption of households. Due to the crucial role of consumption of private households, the estimation of these relies on the income and expenditure survey (*Einkommens- und Verbrauchsstrichprobe* – henceforth EVS) from 2003 of the federal statistic office. The remaining components of the final domestic use are simply estimated by multiplying the rows with shares of North Rhine-Westphalia's governmental purchases, consumption of organisations without pecuniary reward, capital expenditure and GDP, for stock variations, in the according factors of the federal republic, as we assume the regional final use to be proportional to the national one (Kronenberg, 2007).

The participants of the income and expenditure survey allocate their expenditures that accumulate within three month on 133 groups of intended use according to the SEA classification standard. As the participation is voluntary, note that these data are a quoted sample, because the return rates differ considerably over population groups. For this reason data of a single household must be weighted with an expansion factor, which indicates the number of households that are represented by a pooled household. The average of an intended use over all households is calculated afterwards. The structure of the expenditures may be expressed in the form of consumption coefficientsγ^m

$$\gamma^m = \frac{c^m}{c} \tag{11}$$

, where *m* denotes the intended use, *c* denotes the total consumption of a household and c^m denotes the expenditure of a household for an intended use *m*. The expenditures for the whole economy are then estimated by multiplying the consumption coefficients, with the number of households *H* and the total consumption of an average household *c*.

$$C^m = \gamma^m c\, H. \tag{12}$$

Lehmann (2004) observed that consumption of private households based on data of the income and expenditure survey is likely to be underestimated. It is therefore necessary to proceed with an adjustment via correction coefficients DQ^mthat denote the share of estimated expenditures for an intended use *m* based on EVS data in the consumption of the national social accounting. Thus we assume that the degree of deviation on the regional and the national level is the same.

As mentioned above the EVS data are structured according to the SEA classification (the German version of the international COICOP standard). In order to integrate the consumption of private households into the regional input-output table, a conversion into the product groups of the CPA classification is needed. This happens by making use of the consumption interdependence table, which is published by the federal statistical office. Because this table contains only 41 categories of intended use, we must aggregate the estimated expenditures first. Table 1 shows a simplified consumption interdependence table.

The elements of this table may be interpreted as follows: If the product group 1 denotes agricultural products and the intended use 1 stands for foods, then is $V_{1,1}$ the monetary value of agricultural products that are used as food (Kronenberg, 2008).

Table 1: Consumption interdependence table

Expenditures of private households...		intended use				
		1	2	...	$\tilde{m}$	sum
product groups	1	$V_{1,1}$	$V_{1,2}$	...	$V_{1,\tilde{m}}$	C_1
	2	$V_{2,1}$	$V_{2,2}$	...	$V_{2,\tilde{m}}$	C_2
	$\vdots$	$\vdots$	$\vdots$	$\ddots$	$\vdots$	$\vdots$
	n	$V_{n,1}$	$V_{n,2}$	...	$V_{n,\tilde{m}}$	C_n
	sum	C^1	C^2	...	$C^{\tilde{m}}$	$\bar{C}$

In order to proceed with the conversion, we define a consumption allocation quotient $v_{i,m}$.

$$v_{i,m} \equiv \frac{V_{i,m}}{C^m} <=> V_{i,m} = v_{i,m} C^m \tag{13}$$

Obviously the private consumption structured in product groups can be estimated by summing up the elements of a row; hence in combination with (13) we receive

$$C_i = \sum_{m=1}^{\tilde{m}} v_{i,m} C^m. \qquad (14)$$

(14) delivers an extrapolation of household's consumption according to the CPA classification.

Before we are able to include the estimated consumption into the regional input-output table, we have to carry out two last steps. As the EVS participants valuate their expenditures in the prices they have actually paid, whereas transactions within the input-output framework are valued at basic prices, we have to discount taxes less subsidies as well as transport and profit margins. A special statistical evaluation of federal statistical office in form of a table permits such a discount. At last we adjust our estimated consumption from 2003 to 2007 by multiplying the consumption with a growth rate of the total consumption within this time, which is calculated from the consumption data the national account.

Table 2 shows the of consumption coefficients for North Rhine-Westphalia (NRW), Mecklenburg Western-Pomerania (MP) and Germany as a whole. The consumption coefficients of NRW are very close to those of Germany, which indicates that NRW is representative of Germany in terms of consumption, so one might question whether the effort for our estimation via EVS data is at the appropriate rate. For this reason we also present the coefficients for MP, the poorest of the Länder in terms GDP per capita. As we usually do not know whether the structure of consumption is significantly different in the region from that of the nation before the estimation, we think that the effort of estimation via EVS data is justified.

Table 2: Comparison of consumption coefficients

Sectors	Consumption coefficients		
	NRW	FRG	MP
Agriculture, hunting, forestry	1.59%	1.60%	1.78%
Fishing	0.03%	0.03%	0.03%
Mining and quarrying	0.52%	0.53%	0.60%
Manufacturing	26.01%	25.85%	27.95%
Electricity, gas and water supply	2.65%	2.62%	2.78%
Construction	0.31%	0.34%	0.22%
Wholesale and retail trade, repair services	17.57%	17.68%	19.25%
Hotels and restaurants	5.10%	5.19%	3.84%
Transport, storage and communication	5.92%	6.13%	6.24%
Financial intermediation	6.90%	6.88%	7.04%

Real estate, renting and business support activities	20.72%	20.76%	21.34%
Publ. Admin., defense and compul. social security	0.37%	0.39%	0.28%
Education	0.99%	1.03%	1.06%
Health and social work	4.88%	4.50%	1.69%
Other community, social and personal services	5.83%	5.88%	5.45%
Activities of households	0.60%	0.60%	0.46%

3.3 Estimation of trade pattern

As the estimation of imports and exports requires the presence of all remaining components of our input-output table, the estimation is conducted as the last step. We first estimate the trade pattern as described in Section 2. Thereafter we compare the estimated imports and exports with foreign trade data. These data are available from the statistical office of North Rhine-Westphalia and we define $\tilde{e}_i$ as the exports and $\tilde{m}_j$ as the imports from the foreign trade data. Table 3 shows this comparison, whereby four cases can be distinguished:

- Both estimated exports and imports are greater than the exports and imports from the foreign trade statistic. $e_i > \tilde{e}_i$ and $m_j > \tilde{m}_j$. In this case no adjustment is necessary.
- Both estimated exports and imports are smaller than the exports and imports from the foreign trade data meaning that $e_i < \tilde{e}_i$ and $m_j < \tilde{m}_j$.This case concerns the manufacturing of non-metallic mineral products and manufacturing of motor vehicles (shaded in purple).
- $e_i < \tilde{e}_i$ and $m_j > \tilde{m}_j$ so only the estimated exports deceed those from the foreign trade data. Forestry, other mining and the manufacturing of communication equipment are hit by this case (shaded in yellow).
- $m_j < \tilde{m}_j$ and $e_i > \tilde{e}_i$ meaning that only the estimated imports are lower than the imports from the foreign trade data. This case concerns the mining of coal as well as the manufacturing of textiles, wearing apparel and coke (shaded in blue).

Table 3: Comparison of the estimation with foreign trade data

Products	Foreign trade data		CHARM estimation	
	exports	imports	exports	imports
Agriculture	827	4.996	1.262	6.407
Forestry	147	130	97	577
Fishing	4	51	31	159
Coal	62	1.263	187	110
Crude petroleum, natural gas	325	15.521	182	14.898
Metal ores	36	1.774	58	2.613
Other mining	296	437	251	599
Food products, beverages	7.116	10.085	7.996	11.864
Tobacco products	84	60	208	784
Textiles	2.383	3.908	3.300	3.299
Wearing apparel	559	5.626	2.887	5.570
Leather and related products	325	1.611	818	2.047
Wood products	1.068	1.102	1.998	1.368
Paper products	4.117	2.994	6.381	4.533
Printing and recorded media	1.076	640	2.874	1.397
Coke, refined petroleum	2.546	5.452	5.511	4.077
Chemical and pharmaceutical products	28.627	18.625	35.459	23.441
Rubber and plastic products	6.266	4.332	8.964	4.826
Non-metallic mineral products	2.765	2.106	2.505	1.799
Basic metals	25.644	27.419	44.190	28.298
Fabricated metal products	10.332	5.791	21.167	6.393
Machinery	27.697	11.376	35.480	13.589
Computer	2.090	5.476	6.284	7.370
Electrical equipment	8.076	6.469	11.817	6.730
Communication equipment	6.064	9.697	4.749	9.831
Medical instruments, optical products	3.299	3.496	3.797	4.304
Motor vehicles	21.025	16.906	10.838	10.562
Other transport equipment	1.455	1.717	4.146	7.343
Furniture	2.847	3.722	4.991	4.525
Materials recovery	0	0	0	712
Electricity	1.181	396	10.843	1.991
Water supply	0	0	99	0
Prefabricated construction	0	0	119	1.047
Other products	6.119	3.129	61.236	36.081

The first case requires no adjustment, since our estimations are consistent with the foreign trade data. On the contrary it is obvious that our estimations have to be adjusted in the three other cases, yet we expect the total trade volume to exceed the total foreign trade considerably. Hence, we proceed with a new estimation of trade pattern that explicitly incorporates the foreign trade data, thereby the new estimates must fulfil two conditions: $e_i > \tilde{e}_i$ and $m_j > \tilde{m}_j$ must hold and the ratio of the new exports and imports must be such that the identity $u \equiv s$ is retained.

Generally the imports and exports of a region can be divided into the trade with other federal states ($\breve{e}_i$ resp. $\breve{m}_j$) and trade with foreign countries ($\tilde{e}_i$ resp. $\tilde{m}_j$), such that

$$\boldsymbol{e_i = \tilde{e}_i + \breve{e}_i} \qquad \textbf{(15a)}$$

$$\boldsymbol{m_j = \tilde{m}_j + \breve{m}_j}. \qquad \textbf{(15b)}$$

Furthermore the trade balance of the trade with the other federal states is given as

$$\boldsymbol{\breve{b}_i = \breve{e}_i - \breve{m}_j = b_i - \tilde{b}_i}, \qquad \textbf{(16)}$$

whereby $\tilde{b}_i = \tilde{e}_i - \tilde{m}_j$ can be calculated from foreign trade data and $b_i = z_j^u + n_j - z_i^d - d_i$ is predetermined, as the identity $u \equiv s$ would be violated otherwise. The trade volume of the trade with other federal states can be written as

$$\boldsymbol{\breve{v}_i = \breve{e}_i + \breve{m}_j = |\breve{b}_i| + \breve{q}_i} \qquad \textbf{(17)}$$

where $\breve{q}_i$ denotes the degree of cross-hauling on the level of regional trade. The trade balance is given through equation (16), but we neither have information about the degree of cross-hauling on the regional level nor do we know the regional trade volume. As a consequence of this problem we have to assume that the degree of regional cross-hauling equals the degree of cross-hauling that we observe in the trade with foreign countries. Such an assumption is surely questionable, but due to the lack of more information, it is one way to calculate trade pattern according to the two conditions we have mentioned above.

On the analogy of (4) and (5) substituting (16) in (17) yields the regional exports and imports:

$$\breve{e}_i = \frac{\breve{v}_i + \breve{b}_i}{2} \qquad (18)$$

$$\breve{m}_j = \frac{\breve{v}_i - \breve{b}_i}{2}. \qquad (19)$$

Substituting (18) and (19) into (15a) and (15b) yield an estimation of the total imports and exports for those product groups with requirement for amendment. Since the product group “non-metallic mineral products” contains two sectors in the input-output table that are aggregated n the trade data, we must separate this product group in a last step. We use the distribution prior to our adjustment as a distribution coefficient.

Table 4 presents a comparison of the import quotas for North Rhine-Westphalia and Germany as whole. Apart from electricity, gas and water supply, financial intermediation and other community, social and personal services the dependence on imports is significantly higher on the regional level. As smaller regions are expected to be more dependent on imports than the nations they belong to, these results answer our expectations.

Table 4: Comparison of import quotas on the regional and the national level

Sectors	Import Quotas		
	NRW	FRG	Difference
Agriculture, hunting, forestry	43.78%	28.69%	15.09%
Fishing	93.49%	51.70%	41.79%
Mining and quarrying	83.21%	80.41%	2.80%
Manufacturing	36.26%	28.60%	7.66%
Electricity, gas and water supply	5.38%	5.95%	-0.57%
Construction	2.55%	1.55%	1.00%
Wholesale and retail trade, repair services	2.77%	1.12%	1.64%
Hotels and restaurants	17.33%	8.16%	9.17%
Transport, storage and communication	14.58%	11.25%	3.32%
Financial intermediation	4.84%	6.34%	-1.50%
Real estate, renting and business support activities	8.46%	4.65%	3.81%
Publ. Admin., defense and compul. social security	3.58%	0.47%	3.11%
Education	0.00%	0.00%	0.00%
Health and social work	0.00%	0.00%	0.00%
Other community, social and personal services	0.72%	2.78%	-2.06%
Activities of households	0.00%	0.00%	0.00%
Total	21.99%	16.40%	5.59%

4. Employment effects of renewable energy

This chapter shall demonstrate an application of our regional input-output table by an estimation of the employment effect of production and the operation of renewable energy power plants. We use technical coefficients of the production of renewable energy power plants and the maintenance cost of existing power plants to estimate the effective demand. On the basis of the input-output table we construct a static input-output model with endogenised consumption of private households, in order to estimate direct, indirect and induced employment effects. The first subsection deals with the estimation of the effective demand. Followed by a presentation of the model results in subsection 4.2. Subsection 4.3 gives an interpretation of the results.

4.1 Estimation of the effective demand

Our analysis relies on two column vectors of technical coefficients, which describe the cost structure associated with the production and maintenance of renewable energy power plants. We received these vectors from the German Institute for Economic Research (Deutsches Institut für Wirtschaftsforschung – DIW Berlin), who were involved in a study about the employment effects of renewables in Federal Republic of Germany on behalf of the Federal Environmental Ministry(Staiß et al., 2006). The vectors are composed of the different technologies weighted with their ratio in production and operation in 2007. Note that these weighting factors are those of the Federal Republic, so we assume implicitly that there is no difference in the share of the technologies between the regional and the national level, meaning that regional disparities in production and operation are ignored. The technologies we take into account are wind power, photovoltaics, hydro energy, solarthermics, biomass and biogas. For reasons of data confidentiality, all model results are aggregated into 16 sectors in order to prevent inferences on the detailed structure. Figures 1 and 2 show the technical coefficients of those products, whose technical coefficients exceed 0.5%.

Since we need the monetary values to estimate the effective demand rather than technical coefficients, we have to estimate the output for the production and operation of renewables, because there are no output data from official or other sources neither on the regional nor on the national level. There are several options for such an estimation. If, for instance, total intermediate or primary inputs are known or may be estimated plausibly, we can calculate the effective demand by making use of the technical coefficients. We make use of this approach for the estimation of effective demand caused by the operation of renewable energy power plants. Another option is to draw on sales data, as they are equivalent to the output without company-internal deliveries. If we assume them to be negligible, we are able to estimate the effective demand by multiplying the technical coefficients with the volume of sales.

Figure 1: Important technical coefficients for production of renewable energy power plants

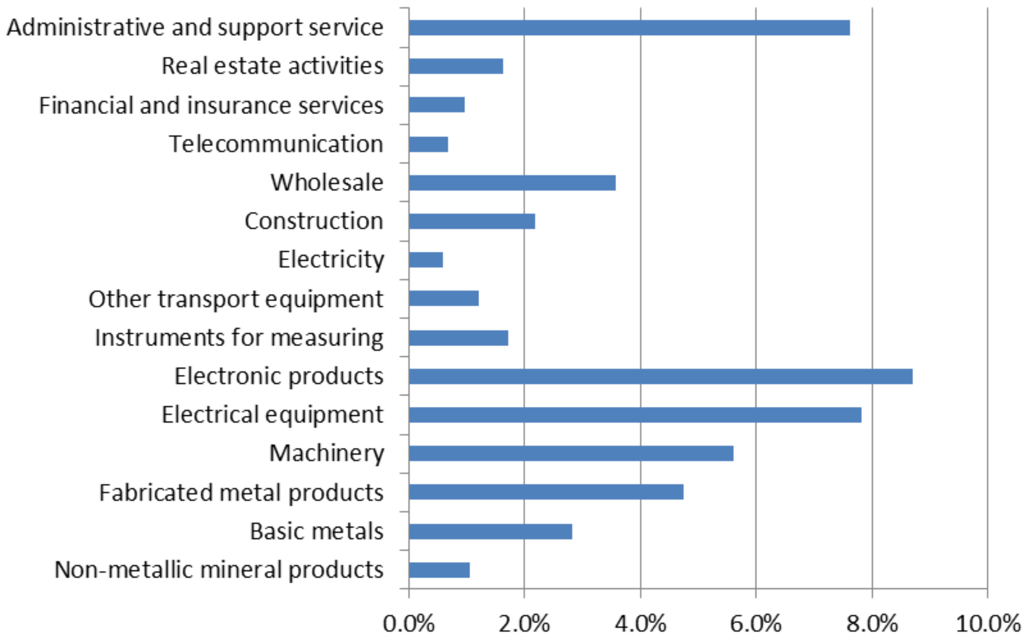
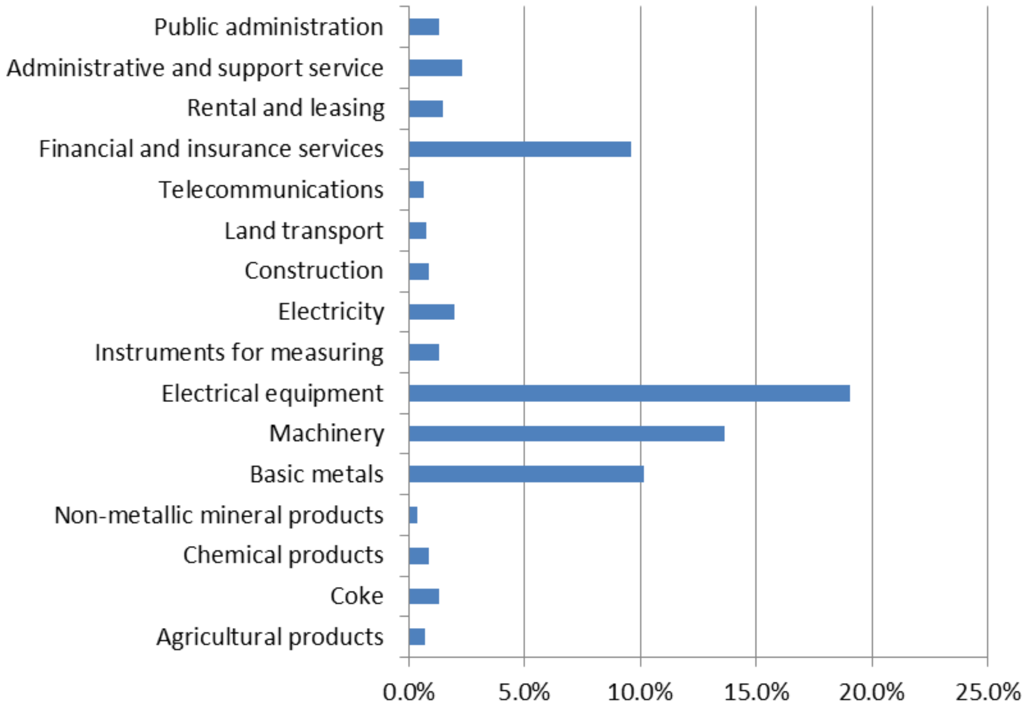


Figure 2: Important technical coefficients for operation of renewable energy power plants



The estimation of the output of the production of renewable energy power plants is significantly hindered due to several reasons. There are neither on the national nor on the regional level data about direct employment, payments or sales volume available. Only the "Internationales Wirtschaftsforum erneuerbare Energien" (IWR) publishes data about sales volume and employment in North Rhine-Westphalia, but they do not distinguish between manufacturers of renewable energy power plants and supply firms (Allnoch et al., 2008). However, the structure of manufacturers and supply is de facto predetermined within the input-output model, as the ratio between supply industries and manufacturers in output responds is not affected on altitude of the effective demand. The share of output of manufacturers accounts for approximately 55%. According to Allnoch et al. the sales volume of manufacturers in North Rhine-Westphalia adds up to 3.08 billion €, which has to multiplied with the ration in sales volume of the manufacturers with the result that the output accounts for 1.708 billion €.Another aspect hampers the analysis of employment effects caused by the production of renewable energy power plants: There are no manufacturers of wind energy power plants in North Rhine-Westphalia, but there is a strong supply industry, which delivers to manufacturers particularly located in Germany's northern federal states. Because of this fact, the employment of the supply firms would be ignored. Hence, we denote the effective demand without demand of manufacturers of wind energy power plants as scenario 1 and assume for a second scenario that the total demand of the wind energy manufacturers in Germany for manufactured goods is delivered by North Rhine-Westphalia's supply industry. Yet we assume that physical intermediate inputs like gears or bearings are imported from North Rhine-Westphalia, whereas services are provided by firms in proximity to manufacturers of wind energy power plants. In this way we obtain at least a ceiling (scenario 2) and a floor (scenario 1) of the employment effects caused by the production of renewable energy power plants. The sales volume of the manufacturers of wind energy power plants in Germany is published by Kratzat et al. (2008) and amounts to 5.65 billion €. As the technical coefficients for the production of wind energy power plants are only illustrated graphically in the study about the employment effects in Germany, we estimated them roughly (Staiß et al., 2006). Table 5 shows these coefficients and the resulting demand for manufactured intermediate inputs. Compared to the effective demand from manufacturers of the remaining renewable energy technologies the effective demand from wind energy manufacturers seems very high, but, note, that it is just an upper boundary.

The effective demand due to the operation of renewable energy power plants arise from the repair- and maintenance costs of the operators. The repair- and maintenance costs as well as the installed power for the different technologies in Germany 2004 may be obtained from Staiß et al. (2006). It is plausible to assume that the costs are proportional to the installed power of the respective existing power plants, therefore we calculate quotients from the power in North Rhine-Westphalia, which is available from the study of Allnoch et al. (2008), and the power in Germany in its entirety.

Table 5: Technical coefficients and effective demand of manufactured intermediate inputs

Products	Techn. Coefficients [%]	Effective demands [Mio. €]
Non-metal mineral products	1.00	57
Basic metals	3.00	170
Fabricated metal products	5.00	283
Machinery	6.00	339
Electrical equipment	9.50	537
Other transport equipment	3.50	198
Total	28.00	1,582

We multiply the costs with these quotients in order to obtain the repair and maintenance cost on the regional level in prices of 2004. According to our calculations sum of effective demand from operators adds up to 322 million €. Table 6 shows our calculations.

As our input-output table is valid for 2007, we have to update the repair- and maintenance cost making use of producer price indices. These data are available from the federal statistical office and encompass agricultural, forestry and manufactured products.

Table 6: Calculation of repair and maintenance costs

Technology	FRG 2004				NRW 2007		
	Cost [mio €]	Electric [MW]	Thermal [MW]	Cost per [MW]	Electric [MW]	Thermal [MW]	Cost [mio €]
Hydro energy	250	605	-	0.41	187	-	77
Wind energy	975	16636	-	0.06	2,557	-	150
Photovoltaics	49	860	-	0.06	480	-	27
Solarthermics	96	-	4200	0.02	-	592	14
Biomass	734	725	34,960	0.02	625	870	31
Biogas	185	672	-	0.28	83	-	23
Total	2,289	19,498	39,160	1.00	3,932	1,462	322

Particularly the prices of basic metals, fabricated metal products and electricity increased sharply. Note that due to different price trends of the products the structure of the intermediate inputs shifts slightly.

Table 7 shows the effective demand caused by the production in both scenarios and operation of renewable energy power plants.

Table 7: Effective demand

products	effective demand		
	Production	Production (we)	0peration
Agriculture, hunting, forestry	0	0	6
Fishing	0	0	0
Mining and quarrying	4	4	0
Manufacturing	875	2,905	297
Electricity, gas and water supply	13	13	13
Construction	38	38	4
Wholesale and retail trade, repair services	68	68	2
Hotels and restaurants	1	1	0
Transport, storage and communication	37	37	10
Financial intermediation	17	17	48
Real estate, renting and business activities	189	189	23
Publ. Admin., defence and compul. social security	4	4	6
Education	2	2	1
Health and social work	0	0	0
Other community, social and personal services	9	9	4
Activities of households	0	0	0
Total	1,257	3,287	413

Before these may be used as an impulse within our model, the values must be increased by the import quotas of the specific products, since the interindustry transaction matrix contain the entire intermediate consumption of products, domestically produced as well as imported.

The employment created by producers and operators themselves is estimated via employment coefficients, which were included in the delivery of the technical coefficients vectors. They denote the number of employees that are required to produce goods one million € worth. The coefficients approximately amount to 5.8 for producers and 7.4 for operators.

4.2 The model extensions and endogenisation of consumption

In order to estimate the employment effects that are created directly, indirectly and induced by the increase of overall consumption, we have to extend our model with regard to the employment and endogenise the consumption of households. A detailed description is for example given by Miller and Blair (2009). We extend our model by making use of employment coefficients, which denote number of employees per one million € of output. Since employment data in a useful classification are only available for Germany as a whole, we assume that the employment coefficients on the national and the regional level are equal and use the respective employment data that are published along with the input-output table.

In addition to the direct and indirect employment effects we also want to estimate the induced effects on employment. An expansion in final demand causes the output to increase and, hence, an increase in employment. The overall income increases causes due to the higher employment effects an expansion of consumption of households, which causes another expansion of the output, which induces an increase of employment. We assume that the consumption may be described by a Keynesian consumption function. We therefore need to estimate the marginal rate of consumption by making use of time series data about available income and consumption. A brief description of the procedure is given by Koschel et al. (2006). We have to use national data and assume the marginal rate of consumption to be equal on the regional and the national level, as no regional time series are available. Our estimated marginal rate of consumption amounts to 0.904. This rate cannot be used for the endogenisation, because this rate refers to the net income, whereas the gross income is entered in the input-output table. Thus, we have to multiply it with the share of net income in gross income, which amounts to 0.53 and yields a marginal consumption quota of 0.47.

4.3 The model results

As unemployment is one of the major economic problems in European countries, the job creation is, besides climate protection, one of the most commonly mentioned arguments for the support of renewable energies in the public dialogue. In order to compare the employment effects in North Rhine-Westphalia with those on the national level (O’Sullivan et al., 2008), we also report gross employment, which is the sum of employment of producers or operators and the employment of other firms along their supply chains. The estimated employment of the producers and operators amount to 9.918 and 3.529 employees respectively.

Table 8 presents the direct, indirect and induced employment effects for the production of renewable energy power plants without the demand due to wind energy. The employment amounts to 12,200, whereby 5,772 (47%) employees are connected with directly supplying firms, 4,138 (33%) with indirectly supplying firms and 2,289 (20%) are induced due to an increase of overall economic income. There are 9,981 additional employees in the production of renewable energy power plants, so that the gross employment amounts to 19,829. In other words 50% of the employment is approximately generated in supply firms. Overall manufacturing and also real estate, renting and business support activities benefit from the production of renewable energy power plants, whereby 3,380 of 3,744 employees concentrate on administrative and support services. This is on the one hand attributable to the high employment coefficients within the scope of services and on the other hand due to the high demand of manufacturing industries for administrative and support services. Within the manufacturing industries 2,126 employees concentrate on machinery, electrical equipment and fabricated metals. Although electronic products have the highest technical coefficients, only 190 jobs are created in North Rhine-Westphalia, since almost 80% of electronic products are imported. In the direct sphere especially manufacturing, construction, wholesale and retail trade as well as business support activities are affected by employment effects. Construction benefits from its high intensity of labour in the direct sphere, whereas the induced effects are relatively low, because their deliveries mainly flow into fixed asset investments. The induced effects concentrate mainly on retail trade, hospitality industry, real estate health and social work and also community and social services, since these industries have a substantial share in the consumption of households and a high intensity of labour.

Table 8: Employment effects in scenario 1

Sectors	Employment effects (scenario 1)			
	Total	Direct	Indirect	Induced
Agriculture, hunting, forestry	54	0	7	47
Fishing	0	0	0	0
Mining and quarrying	27	6	17	3
Manufacturing	3,464	2,288	961	215
Electricity, gas and water supply	86	25	43	18
Construction	520	377	107	35
Wholesale and retail trade, repair services	1,715	648	388	679
Hotels and restaurants	297	32	42	223
Transport, storage and communication	796	237	421	139
Financial intermediation	382	98	174	110
Real estate, renting and business support activities	3,744	1,852	1,609	283
Publ. Admin., defence and compul. social security	142	52	68	22
Education	142	42	57	44
Health and social work	180	2	2	176
Other community, social and personal services	540	112	243	185
Activities of households	111	0	0	111
Total	12,200	5,772	4,139	2,289

The employment effects due to the production of renewable energy power plants including wind energy are presented in Table 9. Direct, indirect and induced effects add up to 30,070 employees, whereby 41% (12.376) arise in the direct sphere, 38% (11,507) in the indirect sphere and 21% (6,186) in the induced sphere. Thus the gross employment amounts to 33,801 employees. The addition of demand from producers of wind energy power plants finds expression in a massive increase in gross employment, at the same time the effect shifts from the direct to the indirect sphere, because of the additional demand especially for administrative and support services from supply firms of the producers of wind power plants. Aside from the manufacturing industry, there is no change in the employment effects of the remaining sectors in the direct sphere.

Table 10: Employment effects in scenario 2

Sectors	Employment effects (scenario 1)			
	Total	Direct	Indirect	Induced
Agriculture, hunting, forestry	138	0	12	126
Fishing	0	0	0	0
Mining and quarrying	50	6	36	8
Manufacturing	13,158	8,893	3,684	582
Electricity, gas and water supply	199	25	125	49
Construction	675	377	203	95
Wholesale and retail trade, repair services	3,696	648	1,213	1,834
Hotels and restaurants	733	32	97	604
Transport, storage and communication	1,530	237	918	374
Financial intermediation	791	98	396	298
Real estate, renting and business support activities	6,655	1,852	4,039	763
Publ. Admin., defence and compul. social security	283	52	172	59
Education	291	42	131	118
Health and social work	483	2	5	476
Other community, social and personal services	1,089	112	476	500
Activities of households	299	0	0	299
Total	30,070	12,376	11,507	6,186

Table 11 represents the employment generated by the operation of renewable energy power plants. The total effect amounts to 4,950 employees and is composed of 41% (1,856) in direct, at 39% (1,809) in indirect and at 20% (950) in induced effects. Besides these effects, 3,529 jobs are created by operators themselves, so that the gross employment amounts to 7,554. Approximately 53 %of these employees are working in the supply industries.

The employment effects are primarily concentrated in the manufacturing, wholesale and retail trade, financial intermediation and business support activities. The effect in the direct sphere is clearly dominated by the manufacturing industry, whereas the employment within the business support activities benefits indirectly, due to the demand from the manufacturing industry. They play, however, only a subordinated role for the operation of renewable energy power plants. The employment effects within the manufacturing industry concentrate on machinery, electrical equipment and fabricated metal, as already observed for the production of power plants. More than 80% of the employment effects account for these sectors.

Table 11: Employment effect due to the operation

Sectors	Employment effect (operation)			
	Total	Direct	Indirect	Induced
Agriculture, hunting, forestry	80	50	7	24
Fishing	0	0	0	0
Mining and quarrying	16	0	14	2
Manufacturing	1,715	1,125	501	89
Electricity, gas and water supply	52	22	22	7
Construction	86	42	30	14
Wholesale and retail trade, repair services	459	35	153	272
Hotels and restaurants	106	2	14	89
Transport, storage and communication	228	51	122	55
Financial intermediation	403	193	166	44
Real estate, renting and business support activities	946	179	654	113
Publ. Admin., defence and compul. social security	132	90	33	9
Education	52	15	19	18
Health and social work	72	0	1	70
Other community, social and personal services	198	52	72	74
Activities of households	44	0	0	44
Total	4,590	1,856	1,809	925

4.4 Interpretation of the results

We observed that the (gross) employment effects due to the production of renewable energy power plants lie in the range of 19,829 (scenario 1) and 33,801 (scenario 2) employees. Because of a lack of data that may indicate the size of the renewable energy power plant industry (e.g. output or employment data), it is advisable to compare our results with results from other studies.

Allnoch et. al. (2008) publish studies on the situation of the renewable energy industry annually and quantify the number of employees within this industry at 21.165. It is not clear whether these are full-time jobs, but it is clear that they account for employees within the renewable energy industry as well as for the directly supplying industries. However, the indirect supply industries(i.e. the supply industries of the supply industries)are not considered. This result indicates that our employment effects in scenario 1 are far too low. On the contrary the employment effects in scenario 2 seem to by too high, as the whole supply industry of producers of wind energy power plant is surely not located in North Rhine-Westphalia. Nevertheless we think that the real value of employment is closer to the result of scenario 2, since we do not account for demand for intermediate inputs from producers of renewable energy power plants other than wind energy located in foreign countries or other federal states of Germany, that might be delivered by North Rhine-Westphalian firms. More precise results are not possible due to the dissatisfying availability of regional data, what also is complained by Diekmann et al. (2008), who published a comparison of efforts and successes of Germany's federal states to promote renewable energies. One indicator they use is the share of employees of producers of wind energy power plants and photovoltaics modules in the total employees of a federal state. Since we cannot differentiate between the technologies, we use our estimated gross employment, which includes all technologies as well as employment of supply industries. We find that these amount to 0.48% in scenario 1 and 0.59% in scenario 2. These shares are low judging from the fact that 0.43% of the total employees in Saxony-Anhalt are employed by producers of wind energy power plants and photovoltaics modules without the supply industries into account. Schleswig-Holstein (0.23%), Bremen (0.16%) and Lower Saxony (0.13%) also exhibit high shares (Diekmann et al., 2008). Another option for a comparison is given the annual estimation of the gross employment in Germany by O'Sullivan et al. (2008). They quantify gross employment due to the production and operation of renewable energy power plants at 146,300 and 47,400 respectively, so that the shares of North Rhine-Westphalia's (gross) employment amount to 13,5% (scenario 1), 23% (scenario 2) and 16%.As the share in population amounts to 21.8 %, it is safe to say that the importance of renewable energies to the regional economy is rather below-average compared to other federal states.

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	Agriculture, hunting, forestry	Fishing	Mining and quarrying	Manufacturing	Electricity, gas and water supply	Construction	Wholesale and retail trade, repair services	Hotels and restaurants	Transport, storage and communication	Financial intermediation	Real estate, renting and business support activities
Agriculture, hunting, forestry	1,301	0	14	7,111	0	0	3	123	10	1	129
Fishing	0	1	0	49	0	0	0	8	0	0	0
Mining and quarrying	70	0	572	14,836	3,127	293	108	9	9	12	34
Manufacturing	1,875	1	1,322	190,457	2,793	11,055	3,763	1,799	4,317	286	2,794
Electricity, gas and water supply	163	0	351	6,539	8,485	66	871	188	329	131	401
Construction	40	0	94	1,012	482	1,872	315	72	298	116	3,880
Wholesale and retail trade, repair services	491	1	187	14,580	541	2,029	3,686	590	987	67	458
Hotels and restaurants	0	0	9	259	6	40	220	6	206	58	119
Transport, storage and communication	42	1	97	9,552	1,137	257	11,639	112	15,071	581	1,101
Financial intermediation	151	0	38	3,258	546	743	1,519	201	804	13,002	4,180
Real estate, renting and business support activities	1,134	0	511	33,053	2,501	5,321	13,469	1,221	4,697	8,279	29,473
Publ. Admin., defense and compul. social security	21	0	43	896	1,509	198	151	30	75	35	558
Education	6	0	2	436	33	47	121	13	85	61	901
Health and social work	61	0	0	44	0	0	24	10	0	0	4
Other community, social and personal services	72	0	142	3,261	186	207	1,260	262	472	266	3,555
Activities of households	0	0	0	0	0	0	0	0	0	0	0
Total intermediate inputs	5,428	4	3,382	285,343	21,346	22,129	37,148	4,641	27,358	22,895	47,588
Commodity taxes less subsidiaries	854	1	255	9,404	1,612	1,192	2,887	1,389	5,542	7,851	4,962
Wages	1,467	3	2,218	64,331	4,621	10,313	40,069	4,967	14,465	11,771	35,151
Other duties	-758	0	-1,695	2,225	477	144	2,400	38	255	1,141	2,917
accruals	891	1	661	12,187	2,913	759	4,066	482	4,666	1,426	32,145
Net operating surplus	1,277	2	-668	22,691	4,018	5,415	14,168	2,161	4,006	2,746	57,050
Value added	2,877	6	515	101,434	12,030	16,631	60,702	7,650	23,391	17,084	127,264
Output	9,158	11	4,152	396,182	34,987	39,952	100,738	13,680	56,291	47,830	179,813
Output less company internal deliveries	7,323	11	2,785	353,635	33,991	39,952	100,738	13,680	56,291	47,830	179,813
Imports	7,131	159	20,584	225,365	1,991	1,047	2,868	2,867	9,605	2,432	16,609
Total supply	16,289	170	24,737	621,547	36,978	40,999	103,606	16,547	65,896	50,262	196,422

	Publ. admin., defence and compul. social security	Education	Health and social work	Other community, social and personal services	Activities of households	Total intermediate use	Final cons. exp. by households	Final cons. exp. by NPISH	Final cons. exp. by government	Gross fixed capital formation	Stock variations	Exports	Total final use	Total use
Agriculture, hunting, forestry	139	9	103	25	0	8,967	4,473	0	0	636	707	1,506	7,322	16,289
Fishing	0	0	4	0	0	62	75	0	0	0	1	31	107	170
Mining and quarrying	69	17	27	32	0	19,214	1,465	0	15	43	957	3,041	5,522	24,737
Manufacturing	1,503	429	2,574	1,352	0	226,321	73,139	0	3,237	35,257	-3,472	287,065	395,226	621,547
Electricity, gas and water supply	193	230	299	301	0	18,546	7,459	0	30	0	0	10,942	18,432	36,978
Construction	378	134	333	283	0	9,308	875	0	0	30,697	0	119	31,691	40,999
Wholesale and retail trade, repair services	346	128	768	591	0	25,451	49,398	0	2,830	4,050	-437	22,314	78,155	103,606
Hotels and restaurants	122	14	22	112	0	1,191	14,336	0	0	0	0	1,020	15,356	16,547
Transport, storage and communication	533	386	155	463	0	41,128	16,653	0	603	0	0	7,512	24,768	65,896
Financial intermediation	430	191	427	748	0	26,237	19,409	0	0	0	0	4,616	24,025	50,262
Real estate, renting and business support activities	1,741	452	2,250	2,900	0	107,003	58,264	835	1,528	6,980	0	21,812	89,419	196,422
Publ. Admin., defense and compul. social security	370	22	81	144	0	4,135	1,043	0	33,949	239	0	182	35,413	39,548
Education	133	1,569	26	59	0	3,493	2,793	2,136	17,095	0	0	642	22,666	26,159
Health and social work	30	21	676	29	0	898	13,713	2,320	31,590	0	0	939	48,562	49,460
Other community, social and personal services	547	116	548	4,131	0	15,025	16,378	3,142	1,986	568	62	2,053	24,188	39,214
Activities of households	0	0	0	0	0	0	1,684	0	0	0	0	145	1,830	1,830
Total intermediate inputs	6,534	3,719	8,295	11,171	0	506,981	281,157	8,434	92,862	78,471	-2,182	363,941	822,682	1,329,663
Commodity taxes less subsidiaries	6,101	2,341	6,601	3,964	0	54,957								
Wages	20,859	17,416	22,244	10,287	1,830	262,012								
Other duties	-65	-92	-915	-152	0	5,920								
accruals	4,703	1,857	3,933	5,083	0	75,773								
Net operating surplus	0	918	9,302	8,577	0	131,663								
Value added	25,497	20,099	34,564	23,795	1,830	475,368								
Output	38,132	26,159	49,460	38,930	1,830	1,037,305								
Output less company internal deliveries	38,132	26,159	49,460	38,930	1,830	990,560								
Imports	1,416	0	0	284	0	292,358								
Total supply	39,548	26,159	49,460	39,214	1,830	1,329,663								