RIWU- A MODEL OF REGIONAL ECONOMIC DEVELOPMENT AND INDUSTRIAL WATER USE IN THE CATCHMENT AREA OF THE UPPER DANUBE

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ABSTRACT

The regional-economic model RIWU describes the development of economy, demography and industrial water use in the Upper Danube catchment area at the smallest possible spatial dissolution. It is part of an interdisciplinary research project with the title: "GLOVA-Danube – integrative techniques, scenarios and strategies regarding global changes of the water cycle", funded by the Federal Ministry of Education and Research. The overall goal of this projects is to develop and validate integration techniques, integrated models, and integrated monitoring procedures for the functional type of a catchment in mountain forelands of the mumid latitudes and to implement them in a network-based Decision-Support-System which will be regionally transferable and thus applicable for a wide range of catchments.

The natural reource "water" can be introduced into economic models by two ways: On the one hand, as input to production processes, water is a limiting factor for regional economic development. On the other hand water use is positively correlated with economic activity and negatively correlated with water prices. As a consequence, there will be interactions between regional economic development, water extraction, water scarcity and water prices. The regional-economic model RIWU currently consists of eigh model equations with vhich seven endonenous variabels are forecast. The calculated industrial water demand and industrial water extraction are depending both on the costs of water extraction and on industrial value added which is again positively correlated with regional exports and negatively correlated with the price of land.

1 INTRODUCTION

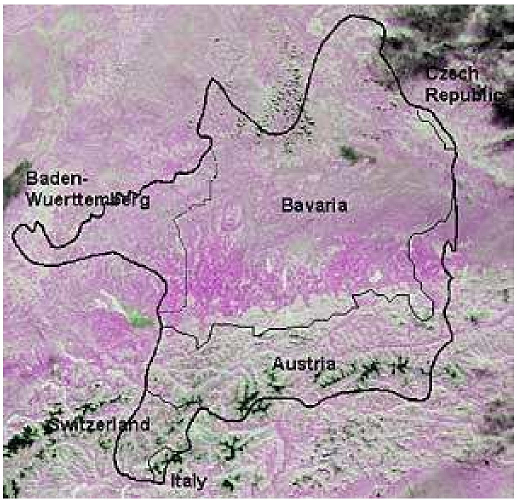
Water affects all economic, cultural, social and ecological aspects of daily life and forms the basis for functioning substance cycles and hence for a clean and stable environment. Economic development is only sustainable if resource use, especially water use, its environmental impacts, the effects of investment decisions, the direction of scientific and technological developments and institutional changes are brought into accordance with the needs of present and future generations world-wide. A prerequisite for a sustainable development and management of the natural resource water is the possibility to plan and act with foresight. Strategic and political concepts must be based upon farsighted analysis and evaluation of the possible future interactions in the natural system and the relationship between man and nature.

To develop methods for a sustainable water resource management, a group of researchers consisting of hydrologists, water resources engineers, meteorologists, glaciologists, geographers, ecologists, environmental economists, environmental psychologists and computer scientists has gathered within the framework of GLOWA-Danube. The overall goal of GLOWA-Danube is to develop and validate integration techniques, integrated models, and integrated monitoring procedures for the functional type of a catchment in mountain forelands of the humid latitudes. These models should contain the essential physical and socio-economic processes that are required for realistic modeling of water fluxes in mountain-foreland situations. They will be regionally transferable and thus applicable for a wide range of catchments (Mauser, Stolz & Colgan 2002).

The integrated models will be exemplarily applied in the Upper Danube Basin (see Figure 1), covering

an area of 77,000 km^2, with a population of 8.2 million people. The Upper Danube Basin covers parts of Germany, Austria, Switzerland and Italy. It is a region with a large sensitivity to Global Climate Change, where many water-related problems are exemplarily concentrated (e.g. up- and downstream conflict, water quality and environmental protection, tourism, flood risks, vulnerability due to climatic change). Through the best possible simulation of future scenarios, it is intended to deliver the basis to evaluate management alternatives concerning a foresighted water management and sustainable development of the fluxes of water and matter at regional scales under consideration of global eco-systematic connections and socio-economic boundary conditions.

Figure 1: Upper Danube Basin



Source: GLOWA-Danube

Ifo's part in this interdisciplinary project is to develop the economic component of GLOWA-Danube. The natural resource "water" can be introduced into economic models in two ways: On the one hand, as input to production processes, water is a limiting factor for regional economic development. On the other hand, water use is positively correlated with economic activity and negatively correlated with water prices. As a consequence, there will be interactions between regional economic development, water extraction, water scarcity and water prices. These interactions will be described by the regional-economic model RIWU. RIWU will be able to calculate simulations of possible future developments.

2 PROJECT GOALS

The conflict of interest between water demand and availability, with respect to water quantity as well as quality, has lead to manifold technical and cultural solutions. However, these solutions need to be re-examined in the near future, globally and regionally, due to increasing population figures, changes in use and pressing conflicts over use. Analysis and evaluation of these future trends requires the availability of suitable tools, which enable a prediction of various potential future states and which consider the most important natural and anthropogenic impacts. Evaluation of these impacts can help to develop alternative management plans.

Therefore, the aim of the economic component of GLOWA-Danube is to model industrial activity and water use, population density and household income on a regionally disaggregated level and to derive rules for the setting of water prices. For this purpose, the regional-economic model RIWU (*R*egional *I*ndustrial *W*ater *U*se) was developed for the Federal State of Bavaria, where the main area of the Upper Danube Basin is located. In the ongoing work, RIWU will be extended to the Federal State of Baden-Württemberg as well as to Austria, Switzerland and Italy.

3 METHODOLOGY

3.1 Theoretical Background

RIWU is based on the assumption of a representative profit-maximising industrial firm which uses two local inputs, land and water. All other inputs are ubiquitous. Industrial production and the local service sector dynamics determine the overall level of economic activity in the districts, which in turn determines household income and population density. The macroeconomic part of RIWU is based on the so-called "export-base theory". With respect to this theory, regional exports are the crucial basis for regional economic growth. Recent empirical studies which where conducted in the USA confirm the export-base theory (Terkla & Doeringer 1991). Regional labour supply is regarded to be elastic, in other words, it adapts to regional labour demand by means of migration and commuting (Dixon & Thirlwall 1975, Mathur & Song 1995). Demand shocks are the reason for regional different growth rates. Other studies come to the conclusion that regional labour supply, not external demand for exports, is the driving force of growth differences between regions and that it is determined by the regions' characteristics, for example climate and landscape, education and health systems, supply of dwellings and taxation (Borts & Stein 1964, Muth 1991).

A recent investigation for Bavaria also confirms the outcomes of the export-base theory: It comes to the result that regional development in 96 Bavarian districts depends on the existence of international competitive industries. Between 1980 and 1996 highly competitive regions could even strengthen their economic position compared to the other districts whereas less competitive regions experienced a further loss in their competitiveness (Ifo 2001).

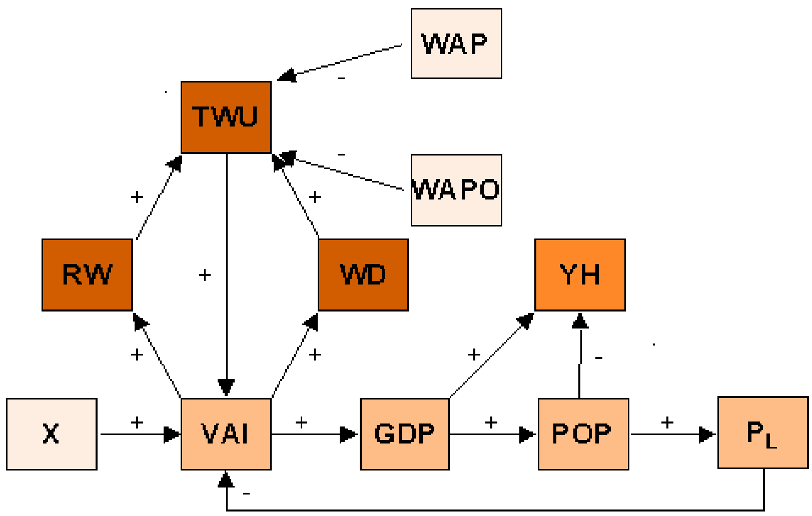
3.2 Characteristics of the model RIWU

From empirical research, two conclusions can be drawn for the design of the regional forecasting model. Firstly, it is justified to define exports as the exogenous variable of the model and population as the dependent variable. The precondition for an elastic labour supply can be regarded as given because the region examined is relatively small and uniform with regard to traffic infrastructure, and labour mobility can be assumed, also in the form of commuter flows. Secondly, a stable spatial distribution of the agglomerations may be assumed as basis of the forecast.

With respect to these theoretical considerations the assumptions of the export-base theory are the baseline of our model. As there is no information about the trade flows from one district to another, the districts' exports to foreign countries were used as indicator for regional competitiveness. Agglomeration costs, which have an adverse influence on economic growth, are represented by the price for land.

Figure 2:

A model of regional industrial water use (RIWU)



X: Exports, VAI: Value added of the industry, GDP: Gross domestic product, POP: Population, P_L: Price for land, YH: Household income, RW: Recycled water, WD: Water demand, TWU: Total water use, WAP: Water price, WAPO: Water price surface water

Source: Ifo-Institute

RIWU is able to calculate economic-environmental interactions at the level of the 96 rural and city districts of Bavaria. The model is integrated into the system of GLOWA-Danube: It provides other components with data concerning household income, population density and industrial water demand and uses data on water demand and supply from other components to set a water price.

3.3 The model structure

RIWU currently consists of nine model equations with which eight endogenous variables are forecast:

- value-added of industry (VAI)
- gross domestic product (GDP)
- price of land for construction (P_L)
- population (POP)
- household income (YH)
- industrial total water use (TWU)
- industrial water extraction/ water demand (WD)
- recycled water (RW)

There are three exogenous variables:

- exports (X)
- water prices (WAP, WAPO)
- the area of land (km^2)

Figure 2 shows the structure of the model. With regard to the export-base theory, value added of the industry (VAI) depends positively on the magnitude of regional exports (X) and negatively on the price for land (P_L). Industrial production is the basis for a district's economic performance, measured by the regional gross domestic product (GDP). Regional GDP depends highly on industrial value added. In addition, a dynamic economic structure which is characterized by a wide scale of branches is a characteristic of strong growing agglomerations. This influence is taken into account by introducing an additional variable (not shown in Figure 2) which describes the average annual rise of the service sector's share of GDP between 1980 and 1996.

The coefficients of the equations where estimated by means of regression analysis and appeared to be significant. By means of a cross-section analysis at the district level, a close logarithmically positive connection between value added of the industry (VAI) and the magnitude of regional exports (X) was found (Figure 3). Contrairly, the price for land (P_L) as an indicator for agglomeration costs has a negative impact on industrial value added, as equation (1) shows.

$$\text{(1)} \quad VAI = X^{0.52}\, L_P^{-0.16}\, TWU^{0.08}\, e^{3.19+1.26\,D1+0.53D2+1.48D3}$$

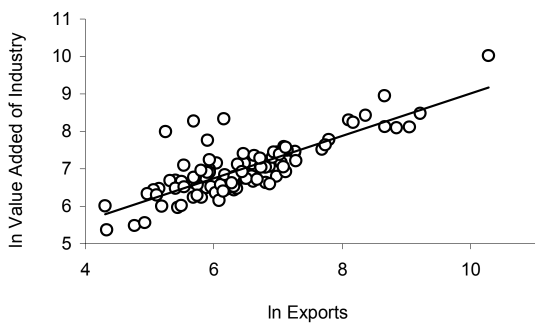


Figure 3: Value Added of Industry and Regional Exports

In some regions industrial activity was significantly higher than it could be expected with respect to export volumes and local land prices. This is an indication for the existence of positive agglomeration effects. These agglomeration effects are considered by the introduction of dummy variables D_i (i : 1 ... 5) for five different regions in equation (1).

Industrial production is the basis for a district's economic performance, measured by the regional Gross Domestic Product (GDP). Regional GDP depends highly on Industrial Value Added (Figure 4). Additional, a dynamic economic structure which is characterized by a wide scale of branches is a characteristic of strong growing agglomerations. This influence is taken into account by introducing the variable GS which describes the average annual rise of the service sector's share of GDP between 1980 and 1996 into equation (2).

$$\text{(2)} \quad GDP = VAI^{0.54}\, e^{4.57+1.62D1+0.77D2+0.18D4-0.23\,D5+38.83GS}$$

The higher the population density (POP/km^2), measured in inhabitants per square kilometer, the more scarce is land and the higher is the price for land P_L

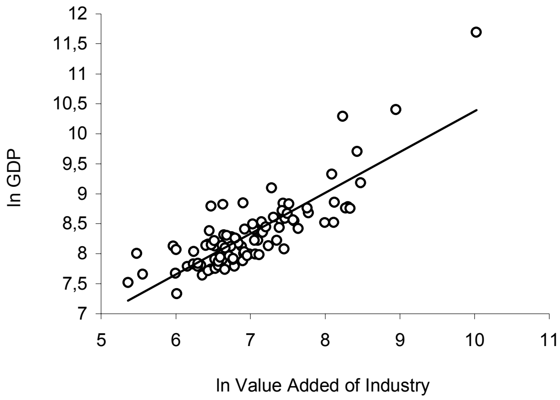


Figure 4: Gross National Product and Industrial Value Added

This fact is expressed in equation (3). A dummy variable D_4 for the region of Oberbayern was introduced, where the price of land is significantly higher than in other regions, the same population density given.

(3) $L_P = (POP/km^2)^{0.47}\, e^{2.66 + 1.04\, D4}$

The elasticity of the price of land with respect to population density is 0.5. In other words, if the population density of a certain district is 1.0 % higher than in neighbour districts, the price for land is 0.5 % higher.

Population Density is highly correlated with economic performance, expressed by Gross National Product per square kilometer GDP/km^2 (Figure 5) as expressed in equation (4). GDP is a comprehensive indicator for incentives to migrate into the region, because it is not only positively linked to wages but also to the amount of public goods and to business opportunities for entrepreneurs.

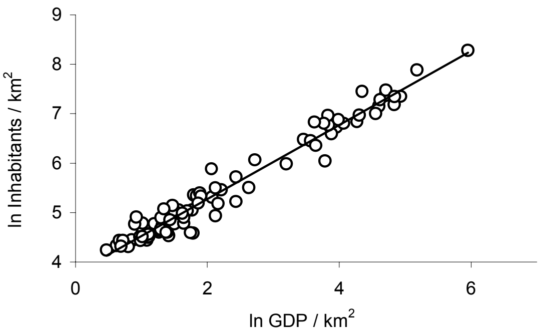


Figure 5: Population Density and GDP/ km^2

In a regional comparison, the elasticity of population with respect to GDP is 0.66. This means that if a district's GDP is 1 % higher than that of neighbour districts, its population is 0.66 % higher. But this is not true in a temporally view. If one district's GDP is growing at a rate of 1.0 %, population is growing at less than 0.66 % because of a raising productivity of the labour force.

$$(4) POP/km^2=(GDP/km^2)^{0.75}e^{3.77+0.01(-0.5-1.13D1-33D2+0.34D4)t}$$

As equation (4) has to explain both the spatial distribution of population and population change through time, it has to be supplemented by a variable, that diminishes the difference between the elasticities with respect to time and to spatial distribution. Therefore equation (4) includes the variable t describing the time horizon.

Household Income (YH) of a district is closely correlated to regional GDP, but not totally equal (Figure 6). The difference between YH and GDP is generated by commuters. In agglomerations where a big part of the labour force is supplied by commuters, a high share of household income is flowing to neighbour districts, which in contrairy are getting a household income that ist higher than their GDP. In equation (5) the relative Population

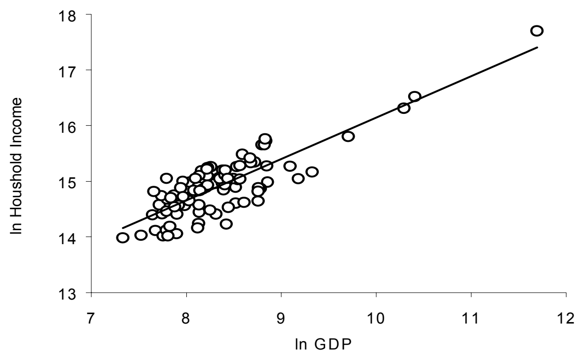


Figure 6: Household Income and Gross Domestic Product

Density $(Inhabitants/km^2)_{rel}$, measured as difference to the average district, is taken as indicatorfor the commuter balance.

$$(5)\ YH = GDP^{0.90}\,(POP/km^2)_{Rel}^{-0.19}\,e^{8.43\ -\ 0.40\ D3}$$

Drinking water delivery from water companies to industry and other water consumers is only slightly correlated with economic activities. Drinking water supply is very different between small districts and seems to be arbitrary. This refers to the fact that water is not scarce in the Upper Danube Basin which goes hand in hand with the observation, that the price of drinking water has no significant influence on water demand at all (Fig. 7).

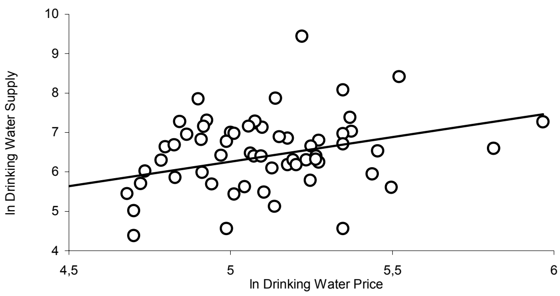


Figure 7: Drinking Water Supply and Drinking Water Price

Only 10% of industry's total water use is demand for drinking water out of the public water network. 90% of total water demand (WD) is satisfied by industry's own haulage of water. For this reason, industrial drinking water demand is neglected. More attention is to be paid to the amount of water that is recycled in internal loops. Both the amount of recycled water (RW) and the amount of industrial water extraction depend significantly on industrial value added (VAI) and on the calculated shadow prices of industrial ground water extraction (WAP) and surface water extraction (WAPO). Because of a lack of available data on industry's water haulage only a very simplified relationship between water demand and industrial value added can be derived, as shown in equations 6 to 8.

(6) $TWU = RW^{0.15}\, WD^{0.85}\, e^{1.13}$

(7) $RW = (VAI)^{1.12}\, WAP^{-1.10}\, WAPO^{0.05}\, e^{-2.22}$

(8) $WD = (VAI)^{0.76}\, WAP^{-0.55}\, WAPO^{-0.07}\, e^{4.31}$

WAP and WAPO are the shadow prices of industrial ground water extraction and surface water extraction, respectively. They are calculated under the assumption that the price for water corresponds to the marginal product of water in the Cobb-Douglas production function of the representative industrial firm.

Finally, in equation 9 an average growth trend for German exports derived from long-term trends is determined for the forecasting of foreign sales with t being the time horizon of the prognosis and $\Delta\pi/\pi_R$ being the growth rate of labour productivity during the last 15 years, measured as deviation from all districts' average.

(9) $X = X_0\,(1 + TREND + \Delta\prod/\prod_R)^t$

4 RESULTS

The model equations have been developed drawing on current results in the field of empirical regional-economic research. Data have been collected and the model equations have been estimated on the district level. In the outcome industrial activity depends positively on local exports and negatively on the prices of land and water use. The elasticity of industrial production with regard to the price of water use is markedly lower than with regard to land use. This reflects the fact that water is not scarce in the Upper Danube Basin. A first analysis of the simulation properties of the model shows satisfactory results.

In the following calculations the results of a simulation over 10 years are depicted (See Table 1).

Table 1. RIWU simulation for the period 1995 – 2005

Annual Rate (%)	Max.	Mean	Min.
Exports	5.0	0.6	8.3
Industrial Value Added	0.3	-1.6	1.7
Gross National Product	1.9	0.5	2.8
Population	1.2	0.5	-0.5
Price of Land	0.5	0.2	-0.2
Total Water Use	1.2	0.2	-1.2

Source: Calculations of the Ifo Institute

The simulation is based on the assumption that growth of regional exports is linked to the districts' relative growth of labour productivity, as described in equation (9) above, and that the service sector's share of GDP is increasing at the same rate as it did in the past.

The coefficients of the regional-economic forecasting model estimated for the reference year 1995 for Bavaria show a ratio between export and GDP growth of approximately 0.3. Using a trend rate of 5.0% as a basis for German exports, the results for Bavaria show an average annual export growth of also 5.0%. For the single districts there is a range of export growth between 0.6% and 8.3%. Industrial value added is growing at 0.3% per annum in average. In the slowest growing district VAI is even decreasing at an annual rate of – 1.6% while it is increasing at a rate of 1.7% in the best performing district. Regional gross national product grows at an average annual rate of 1.9% with a minimum of 0.5% and a maximum of 2.8%. Population grows at 0.5% on average. It is taken into account that Upper Bavaria is a favoured residential area. The elasticity of population growth with respect to exports in this case is 0.1, which approximately corresponds to the value observed for Germany as a whole in the 1990s. In the slowest growing district people are migrating and population is decreasing by – 0.5% whereas it is increasing at 1.2% in the fastest growing district. The price of land for construction is growing at 0.2% per annum on average, it is decreasing in the weakest district at an annual rate of – 0.2% and increasing at 1.2% per annum in the best performing district. Finally, industrial total water use grows at 0.2% per annum, which is less than growth in industrial value added of 0.3%. The elasticity of industrial total water use with respect to industrial value added is around 0.66. That is the reason why in the slowest growing district, where VAI is decreasing at an annual rate of -1.6%, total water use is decreasing at only – 1.2% per annum and in the best performing district TWU is increasing at only 1.2% while VAI is growing at 1.7%.

Results for the single districts are rather different (see Table 2). Some medium-sized districts like Rosenheim and Altötting are growing much faster than the district of the metropolitan area of Munich and therefore both industrial value added and industrial total water use are increasing, too. In slowly growing districts like Ingolstadt and Berchtesgaden industrial value added is decreasing and so is industry's total water use. In the district of Munich, VAI and TWU are decreasing, too. Also the population is diminishing there, due to general suburbanization trends.

Table 2. RIWU simulation results for selected districts

District	VAI	GDP	POP	TWU
		Annual Rate 1995-2005 (%)		
Ingolstadt	-1.2	1.3	0.0	-1.2
München	-0.3	1.1	-0.1	-0.3
Rosenheim	1.7	2.8	1.2	1.1
Altötting	1.2	2.0	0.6	1.2
Berchtesgaden	-0.6	1.0	-0.1	-0.5

Source: Calculations of the Ifo Institute

Finally, the impact of the water price on total water demand is demonstrated. This is done by a cross section analysis between the 96 Bavarian districts, in which productivity gains are neglected. The calculations show the impact of a 1% increase of an district's exports on its production and industrial water use (see Table 3). In the first case, as shown in column 2 of table 3, the exogenous water price (which is the shadow price for industry's own extraction of water) stays constant. Then the increase in exports leads to an increase in industrial value added of 0.53% corresponding to an increase in total water use of 0.40%. At the same time, regional GDP increases at 0.34%, population at 0.25% and the price of land for construction at 0.12%.

In column 3 of Table 3 it is shown how much the price of water has to rise to keep industrial total water use constant in a growing region. The result is that an increase of 0.68% in the water price is necessary to keep total water use constant at an export growth rate of 1.0%. The impact of this situation on regional growth is rather small: The increase in VAI falls to 0.49%, GDP's increase to 0.31%, population growth to 0.24% and the price of land for construction to 0.11%.

Table 4. Simulation of a 1.0% increase of exports*

(%)	WAP =const.	TWU =const.
Industrial Value Added	0.53	0.49
Gross National Product	0.34	0.31
Population	0.25	0.24
Price of Land	0.12	0.11
Total Water Use	0.40	**0.00**
Water Price	**0.00**	0.68

* at constant productivity

Source: Calculations of the Ifo Institute

5 CONCLUSIONS

The regional economic model RIWU proved to be an appropriate tool to forecast regional economic development and industrial water use. It turned out that water scarcity and raising water prices have only a small impact on a region's industrial growth. The reason is that industry will substitute water extraction by increased water recycling in the case of water scarcity or increasing water prices. However, in combination with other models from natural sciences, RIWU can be used for water resource management and can be transferred to other river basins.

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