DISCUSSION PAPER

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RURAL WATER SUPPLIERS AND EFFICIENCY – EMPIRICAL EVIDENCE FROM EAST AND WEST GERMANY

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ABSTRACT

This discussion paper attempts the investigation of inefficiency with respect to water suppliers in rural areas of East and West Germany. This is done by using a nonradial measure of input-specific allocative inefficiency based on the demand system derived from a flexible cost function for the variable inputs labour, energy and chemicals. Distributional dependency with respect to the composed error term is reduced. The cost structure is modelled by applying a modified symmetric generalized McFadden functional form and the imposition of concavity restrictions as required by economic theory. Data on 47 rural water suppliers was collected by a written survey in 2002/2003. The applied second order flexible functional form performs well in the estimations. Efforts towards increasing suppliers' allocative efficiency should focus on the relatively inefficient usage of the inputs energy and chemicals. With exception of the category 'size' the measures of input specific allocative inefficiency are found to be superior to those of overall allocative inefficiency. No significant difference between the efficiency of East and West German suppliers was found. Widely assumed economies of scope for the joint production of water and sewage services as well as vertically integrated utilities are not confirmed by the results. The positive correlation between firm size and overall efficiency finally suggests negative effects on efficiency by the legally set supplying areas.

JEL: C31, D24, Q25

Keywords: Rural water supply, flexible functional form, input-specific allocative efficiency

ZUSAMMENFASSUNG

LÄNDLICHE WASSERVERSORGUNGSUNTERNEHMEN UND EFFIZIENZ – EINE EMPIRISCHE ANALYSE FÜR OST- UND WESTDEUTSCHLAND

Das vorliegende Diskussionspapier untersucht die relative Ineffizienz von Wasserversorgern in ländlichen Regionen Ost- und Westdeutschlands. Hierzu wird ein faktorspezifisches Maß allokativer Ineffizienz auf der Grundlage des Input-Nachfragesystems einer flexiblen Kostenfunktion für die variablen Inputs Arbeit, Energie und Chemikalien angewandt. Die Abhängigkeit des stochastischen Fehlerterms von der Wahl spezieller Verteilungsannahmen wird hierdurch reduziert. Die grundlegende Kostenstruktur eines ländlichen Wasserversorgers wird anhand einer modifizierten, symmetrischen und verallgemeinerten McFadden Kostenfunktion modelliert. Die von der ökonomischen Theorie geforderten Konkavitätsbedingungen können so global berücksichtigt werden. Der verwandte Datensatz für 47 Wasserversorgungsunternehmen in ländlichen Regionen Deutschlands wurde mittels einer schriftlichen Umfrage in 2002/2003 erhoben. Die angewandte und flexibel zweiten Grades funktionale Form liefert effiziente und konsistente Schätzergebnisse. Maßnahmen zur Verbesserung der Effizienz sollten demnach den ineffizienten Einsatz der Faktoren Energie und Chemikalien fokussieren. Mit Ausnahme der Kategorie ‚Unternehmensgröße' konnte eine statistische Überlegenheit der inputspezifischen Effizienzmaße festgestellt werden. Ein signifikanter Unterschied in der Effizienz ost- und westdeutscher ländlicher Versorger liegt demnach nicht vor. Gemeinhin unterstellte ökonomische Vorteile einer Verbundproduktion von Wasser- und Abwasserleistungen sowie solche infolge einer vollständig integrierten Unternehmensform werden empirisch nicht bestätigt. Die positive Korrelation zwischen Unternehmensgröße und allgemeiner Effizienz legt schließlich negative Effizienzeffekte der rechtlich kodifizierten Versorgungsgebiete nahe.

JEL: C31, D24, Q25

Schlüsselwörter: Ländliche Wasserversorgung, flexible funktionale Form, inputspezifische allokative Effizienz

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LIST OF ABBREVIATIONS

AWWA	American Water Works Association
BMWI	German Ministry of Economics
ISAI	Input-specific allocative inefficiency
LR	Likelihood ratio
OC	Operational cost
OFWAT	Office of water regulation
OAI	Overall allocative inefficiency
OUT	Output
SGM	Symmetric generalized McFadden
SUR	Seemingly unrelated regression procedure
WAB	Wasserversorgungs- und Abwasserentsorgungsbetriebe (water and sewage companies)

1 INTRODUCTION

The German water market is characterised by public operated local monopolies, only for a small number of water suppliers privat stakes are important. First discussions about the productivity and efficiency of the German water sector trace back to a study of the WORLDBANK water division in 1995.[1] Initiated by the then German Ministry of Economics (BMWI)[2] in early 2000 a comprehensive debate about the need and the possibilities as well as borders of a water sector liberalisation is going on (see SAUER/STRECKER. 2003a). Water supplying firms in rural areas of East and West Germany extract, treat, transport and distribute potable water and are increasingly restricted by scarce raw water resources as well as tight financial budgets. They are basically subject to the regulatory constraints set by the legal framework of the water market. Due to that research on the efficiency of water suppliers in rural areas seems to be of interest from the perspectives of resource and public economics, the economics of regional development as well as competition and regulation theory. No empirical based research has been conducted with respect to the efficiency of rural water suppliers in Germany or water suppliers in East Germany so far.[3]

The inefficiency of various production units has been examined by numerical studies up to now (see KUMBHAKAR/LOVELL 2001). The majority of researchers used the Cobb-Douglas or the translog production resp. cost function framework. As the estimates are affected by the extent of restrictiveness of the underlying functional form, it seems to be desirable to use flexible functional forms. Nevertheless the latter are only an approximation of the 'true' function and the global satisfaction of concavity in factor prices can not be expected (see DIEWERT/WALES 1987). As e.g. CONRAD/JORGENSEN (1977) point out most empirical studies therefore fail to satisfy the concavity condition.[4] To the background of economic theory it would be preferable to apply a cost function allowing for global imposition of curvature conditions. The functional form used in this study is the symmetric generalized McFadden (SGM) cost function, which, as shown by DIEWERT/WALES (1987), satisfies the second-order flexibility conditions.[5]

Measures of overall allocative inefficiency (OAI) are not able to identify the sources of inefficiency and decompose it by input. Resulting management as well as policy efforts could be therefore ineffective as well as inefficient. In this paper an econometric model – first introduced by KUMBHAKAR (1989) – is applied which is able to accommodate a non-radial measure of input-specific allocative inefficiency (ISAI) in the relative performance of individual production units or groups of production units. Total-cost inefficiency is decomposed specific to each variable input. ISAI is introduced in the demand system derived from the SGM cost function. As only cross-sectional data is available and nevertheless to reduce the dependence on distributional assumptions for ISAI, sub-groups of rural water suppliers are defined with respect to e.g. regional location, administrative competence, form of ownership, firm size or public funding.

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1 See BRISCOE (1995).

2 See e.g. EWERS et al. (2001).

3 HANUSCH/CANTNER conducted a stochastic frontier analysis with respect to production efficiency using data on 13 mostly urban water suppliers in West Germany for the period 1970–83. See HANUSCH/CANTNER 1991.

4 The observed data which do not satisfy the concavity condition are incompatible with the hypothesis of cost minimization.

5 The SGM cost function has been rarely applied in resource or agricultural economics (see recently FROHBERG/WINTER 2003) and never with respect to water infrastructure (by February 2004).

The remainder of this paper is organised as follows: Section 2 sets out the basic cost function framework. After a brief description of the sampling process by section 3, the theoretical model is presented in section 4. Section 5 briefly deals with the structure of water production, the German water sector and sources of inefficiency whereas section 6 summarizes earlier water frontiers. Section 7 describes the estimation model and section 8 contains the empirical results. Finally section 9 discusses conclusions and implications.

2 DATA AVAILABILITY AND SAMPLING

Due to still severe constraints with respect to data availability (as well as comparability and reliability) in the former socialist economies, in a first step technical, financial as well as institutional data on suppliers in rural areas of the East German Bundesländer (the territories of the former GDR) as well as the West German Bundesländer have been collected.[6] The category 'rural area' was defined by regressing on the policy relevant OECD methodology (see OECD 1994) re-worked by the DG VI of the European Commission (see EC 1997). Due to that nearly 15% of the EU15 population is living in rural communities, covering appr. 80% of the EU territory. By applying this methodology on Germany and by using the NUTS classification[7], 60 'predominantly rural regions' were identified corresponding to the NUTS 3 level (Landkreise, see Figure 1). These rural areas consist of 3632 communities.

Rural communities (less than 100 inhabitants/km^2) operate their own water supplying system, are part of a water association supplying a group of communities in a certain region or are supplied by a nearby municipal utility. Private operation of such forms of water supplying companies is rare due to the legal framework and the liberalisation efforts which are still at an early stage. Hence a total population of 632 water suppliers in rural regions was identified. With respect to this target population a comprehensive questionnaire[8] was developed in order to collect valid technical, financial and institutional data on the different stages of rural water production and provision.[9] Till the end of March 2003 about 32% of the suppliers answered positive or negative (see Figure 2 for the regional location of the water suppliers in the sample). The analyses as well as conclusions drawn on the basis of this sample on rural water suppliers can be regarded as more than a first hint where the journey 'efficiency discussion in the water sector' should be focused on to in the future. This even more, if one takes into account that there is rarely any valid data set on rural water suppliers available in East Germany or the transition countries of Eastern and Central Europe.

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[6] 'Befragung deutscher Wasserversorger zu ausgewählten Betriebs- und Investitionsdaten (11/2002) – IAMO'.

[7] Nomenclature Units Territoriale Statistique.

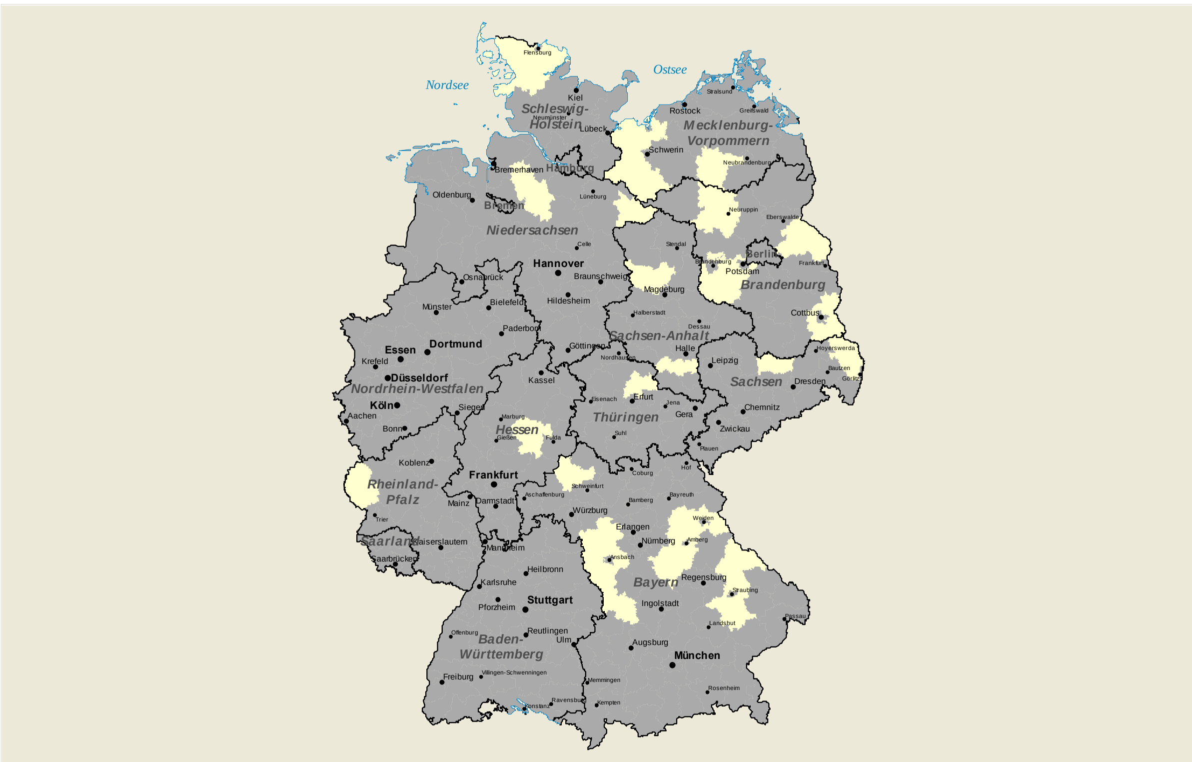
[8] This was done by working together with technical experts of the Technical University Hamburg-Harburg on water production and supply.

[9] Due to the financial year 2000 or 2001. This questionnaire was sent to all suppliers of the described total population in November 2002.

Figure 1: Rural Water Supplier Survey 2002 – Total Population

Source: BUNDESAMT FÜR BAUORDNUNG UND RAUMWESEN (2002), own modifications (white regions: total population).

Figure 2: Rural Water Supplier Survey 2002 – Estimation Sample (white regions)



Source: BUNDESAMT FÜR BAUORDNUNG UND RAUMWESEN (2002), own modifications (white regions: sample).

3 THE COST FUNCTION FRAMEWORK

Given a positive vector of input prices, $p \equiv (p_1, p_2, \ldots, p_N)^T >> o_N^T$, the cost function C* dual to the production function $y = f^*(x, z)$, where $x \equiv (x_1, x_2, \ldots, x_N)^T$ is the vector of variable inputs utilized and $z \equiv (z_1, z_2, \ldots, z_N)^T$ is the vector of fixed inputs, may be defined as follows:

$$C^*(p, y, z) \equiv \min_x \{p^T x : f^*(x, z) \geq y, x \geq 0_N\} \quad [1]$$

The characteristics of the underlying production function can be summarized with the cost function if the following conditions are satisfied:

$$C^*(\lambda p, y, z) = \lambda C^* (p, y, z), \nabla\lambda \geq 0 \quad [2]$$

i.e. linear homogeneity in prices[10],

$$C^*(p, y, z) > 0, \nabla p > 0_N, \nabla y > 0 \quad [3]$$

i.e. non-negativity[11],

$$\nabla_p C^*(p, y, z) \geq 0_N \quad [4]$$

i.e. monotonicity in input prices[12],

$$\nabla^2{}_{pp} C^*(p, y, z) = \text{negative semidefinite (nsd)} \quad [5]$$

i.e. cost minimization. ∇_i denotes the column vector of the first order partial derivatives with respect to the components of i, and $\nabla^2{}_{io}$ denotes the matrix of second-order partial derivatives with respect to the components of i and m.

4 THEORETICAL MODEL

The unknown true cost function is denoted by $C^0(p^*, y, z)$ as a linearly homogenous function which is concave in the input prices p of order n, z is a vector of m fixed inputs and shift variables. It is assumed to be twice differentiable with respect to its arguments at (p*, y*, z*) if $p^*_{nx1} >> 0$, $y^* > 0$ and $z^*_{mx1} > 0$. Following DIEWERT/WALES (1987) the linear homogeneity of $C^0(\cdot)$ in p and symmetry implies $(1 + (n + m + 1) + (n + m)(n + m + 1)/2)$ restrictions. A twice-differentiable cost function $C^0(\cdot)$ is flexible at the point (p*, y*, z*) if the $(n + m + 1)$ first derivatives and $(n + m + 1)^2$ second partial derivatives of C^0 and C* coincide at (p*, y*, z*). Therefore a flexible C* must have at least $(n(n + 1)/2 + m(m + 1)/2 + nm + n + m + 1)$ free parameters.[13] The subsequent analysis uses the SGM cost function as the appropriate $C^*(\cdot)$.

The following modified symmetric generalized MCFADDEN cost function is a generalization of the functional form initially proposed by MCFADDEN (1978) with respect to cross-sectional data:[14]

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[10] A restatement of the familiar economic principle that only relative prices matter to rational economic agents.

[11] The production of a positive output at zero cost is impossible.

[12] Increasing any input price must not decrease cost.

[13] $1 + (n + m +1) + (n + m + 1)^2 - (1 + (n + m + 1) + (n + m)(n +m + 1)/2) = n(n + 1)/2 + m(m + 1)/2 + nm + n + m + 1$ (see DIEWERT/WALES 1987).

[14] Here g(p) is defined to be symmetric, see also DIEWERT/WALES (1987). It is modified in the sense as we allow for the inclusion of (second-order flexible) fixed inputs z_r.

$$C(\cdot) = g(p)y + \Sigma_i b_i p_i + \Sigma_i b_{iy} p_i y + b_{yy}(\Sigma_i ß_i p_i)y^2 + y\Sigma_i\Sigma_r b_{iry} p_i z_r + \Sigma_r b_r(\Sigma_i \gamma_i p_i)z_r + \Sigma_r b_{rr}(\Sigma_i \delta_i p_i)z_r^2 \quad [6]$$

with i = 1, …, n; r = 1, …m and $g(p_i)$ is defined as:

$$g(p_i) \equiv p^T Sp/2\theta^T p = \frac{1}{2}\,\frac{\begin{bmatrix} p_1, p_2, \ldots, p_n \end{bmatrix}\begin{bmatrix} s_{11} & s_{12} & \ldots & s_{1n} \\ s_{21} & s_{22} & \ldots & s_{2n} \\ . & . & \ldots & . \\ s_{n1} & s_{n2} & \ldots & s_{nn} \end{bmatrix}\begin{bmatrix} p_1 \\ p_2 \\ . \\ p_n \end{bmatrix}}{\begin{bmatrix} \theta_1, \theta_2, \ldots, \theta_n \end{bmatrix}\begin{bmatrix} p_1 \\ p_2 \\ . \\ p_n \end{bmatrix}} \quad [7]$$

where: $\theta \equiv (\theta_1, ..., \theta_N)^T \geq 0_N^T$, $b_{iy} \equiv (b_{1y}, b_{2y}, ..., b_{Ny})^T$, $b_i \equiv (b_1, b_2, ..., b_N)^T$, $b_{iry} \equiv (b_{11y}, b_{12y}, ..., b_{NNy})^T$, b_{yy}, b_r, b_{rr}, $ß_i \equiv (ß_1, ß_2, ..., ß_N)^T$, $\gamma_{ir} \equiv (\gamma_{11}, \gamma_{12}, ..., \gamma_{NN})^T$, $\delta_{ir} \equiv (\delta_{11}, \delta_{12}, ..., \delta_{NN})^T$ are the parameters of the model. θ_i is set as $\theta_i = x'_i$ for i = 1, ..., N[15] and $b_{yy} = b_r = b_{rr} = 1$. The remaining parameters of the model: b_i, b_{iy}, b_{iry} as well as $ß_i$, γ_{ir} and δ_{ir} are estimated. As a consequence the cost function is then third-order flexible in y and z and the factor-demand equations are second-order flexible in y and z. S denotes a N x N symmetric negative semidefinite (nsd) matrix satisfying N extra restrictions Sp = 0 for some $p >> 0_N$. The cost function $C^*(\cdot)$ defined in [6] and [7] is linear in p, its input-demand functions are linear in the unknown parameters and $C^*(\cdot)$ has (n(n + 1)/2 + m(m + 1)/2 + n + m + nm + 1) free parameters.

Differentiating [6] with respect to input prices, applying Shephard's Lemma and dividing by output[16], the conditional input-demand equations (the ratios of input use to output) are:

$$(dC(\cdot)/dp_i) / y = x_i^*/ y = Sp/\theta^T p - \tfrac{1}{2}\theta[p^T Sp/(\theta^T p)^2] + b_{iy} + b_i y^{-1} + b_{yy} ß_i y + b_{iry} z_r + b_r \gamma_i z_r y^1 + b_{rr}\delta_i z_r^2 y^{-1} \quad \text{for } i = 1, \ldots, N \quad [8]$$

where $x_i \equiv (x_1, ..., x_N)^T$. The concavity restrictions[17] for all p >> 0N, y > 0 and z > 0 are satisfied if and only if the S matrix is nsd. Thus if the estimated S matrix is nsd, $C(\cdot)$ will be globally concave. DIEWERT/WALES (1987) show that concavity in input prices can be imposed by following a technique due to WILEY et al. (1973). Here the matrix S is reparametrized by replacing it by minus the product of a lower triangular matrix of dimension N-1 x N-1, A, times its transpose, A^T:

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15 x'_i as the average amount of input i used over the sample (see DIEWERT/WALES 1987).

16 This is done to reduce possible heteroscedasticity (as DIEWERT/WALES 1987, p. 59 put it: "[…] makes the assumption of homoscedasticity of the disturbance more plausible.").

17 $\nabla^2_{pp} C^*(p, y, z)$ = negative semidefinite, i.e. cost minimization. ∇_i denotes the column vector of the first order partial derivatives with respect to the components of i, and ∇^2_{im} denotes the matrix of second-order partial derivatives with respect to the components of i and m.

$$S = -AA^T \quad [9]$$

where $A = [a_{ij}]$ and $a_{ij} = 0$ for $i < j$, $i, j = 1, ..., N-1$. Using LAU'S (1978) theorem[18], it follows that any nsd S has the representation given by [4] and as DIEWERT/WALES note, this technique is equivalent to those given by LAU and imposing negative semidefiniteness on S does not destroy the flexibility of the SGM functional form (if $\theta > 0_N$).

Adding the usual statistical noise, the conditional demand functions given in [8] can be written as:

$$x_i / y = x_i^* + \varepsilon_i \quad [10]$$

The disturbance term in [10] is further decomposed as

$$\varepsilon_i = v_i + \tau_i \quad [11]$$

v_i in [11] is normally distributed to reflect the random variation of the cost function across the observations and capture effects of statistical noise, measurement error and exogenous shocks beyond the control of the production unit.[19] τ_i represents allocative inefficiency associated with input i for the n^{th} production unit and can be interpreted as the amount by which the use of input i could be reduced while using the same amount of other inputs had the production process allocatively efficient.[20] If $\tau_i^* = 0$ the specific production unit is on the stochastic frontier and can be considered as fully allocative efficient.[21]

This concept of input-specific allocative efficiency is based on the notion that "(…) the demand for each and every input, given all other shift variables and output, may not increase equally because of allocative inefficiency." (KUMBHAKAR 1989, p. 255). This approach is in contrast to those radially measuring overall allocative inefficiency in which the demand for each input, given output, increases equiproportionally (see with respect to water suppliers e.g. HANUSCH/CANTNER 1991; STEWART 1993; PRICE 1993; BHATTACHARAYYA et al. 1995; CRAMPES et al. 1997; CUBBIN/TZANIDAKIS 1998; ESTACHE/ROSSI 1999 and 2002). The hypothesis that ISAI is a superior description of the production process than OAI can be tested statistically by imposing the restriction that τ_i^* takes the same value for all i.

Input-specific allocative efficiency for input x_i is defined as

$$AE_{iw} = x_{iw}^* / x_{iw} = 1 - (\tau_{iw}^* / x_{iw}) \quad [12]$$

18 LAU (1978) shows, that every positive semi-definite matrix S has the following representation: $S = BDB^T$, where $B = [b_{ij}]$ $(i,j = 1, ..., N-1)$, $b_{ij} = 0$ for $i < j$, $b_{ii} = 1$ $(i = 1, ..., N-1)$ and D as a non-negative diagonal matrix.

19 "The rationale behind normality is simply convenience at the estimation stage plus the fact that we lack information upon which to base alternative stochastic specification assumptions." (CHRISTOPOULOS et al. 2001, p. 69).

20 Compared to a production unit on the frontier, employment of input i for any inefficient production unit exceeds by τ_i^* keeping employment of all other inputs unchanged.

21 Equation (11) does not contain any term for allocative inefficiency. As also KUMBHAKAR stresses, allocative inefficiency can be defined as $C_i/C_j \neq x_i/x_j$ with $C_i = dC/dp_i$, nevertheless can not be identified and therefore is not introduced separately here.

with w = 1, … n denoting the production unit or groups of production units resp. water suppliers, x_{iw} as the minimum quantity of input i required to produce a given level of output keeping all other inputs unchanged (see KUMBHAKAR 1989). Allocative inefficiency therefore depends also on factor quantities.[22] The cost increase due to the specific inefficiency can be calculated by

$$CAE_{iw} = 1 - (p_{iw}\tau_{iw}^*) / C \qquad [13]$$

Such cost indices provide information on the input(s) with the greatest potential for cost reduction. As CAE_{iw} is related to input prices p_{iw} the cost reductions through elimination of ISAI vary with input prices and hence relatively inefficient physical input usage can be relatively efficient with respect to costs (KOPP 1981).

Introducing firm subscripts into [10] leads to

$$x_{iw} / y_w = (x_{iw}^* / y_w) + \tau_{iw} + v_{iw} \qquad [14]$$

As cross-sectional data is used, sub-groups of observations are defined due to specific characteristics with respect to e.g. regional location, form of ownership or size. This is necessary to maintain sufficient degrees of freedom for estimation purposes and therefore the subscript w = 1, …, n denotes sub-groups of production units. By this procedure no special distributional assumptions are needed on τ_{iw} as it is not necessary to assume that τ_{iw} is independent of other regressors in the demand system (see KUMBHAKAR 1989). The term τ_{iw} is estimated by

$$\tau_{iw} = \zeta_{iw} - \min(\zeta_{iw}) \qquad [15]$$

where ζ_{iw} is the estimated parameter of a dummy variable added to the conditional input demand system defined in [8] (suppressing the common intercept) for each input i and sub-group w and allowing the coefficients of these dummies to vary across the inputs i. Hence sub-group- as well as input-specific allocative inefficiency can be measured. The overall allocative efficiency model emerges as a special case when ζ_{iw} takes the same value for each input i and consequently:

$$\tau_{iw} = \tau_w \text{, for all } i \qquad [16]$$

[23]

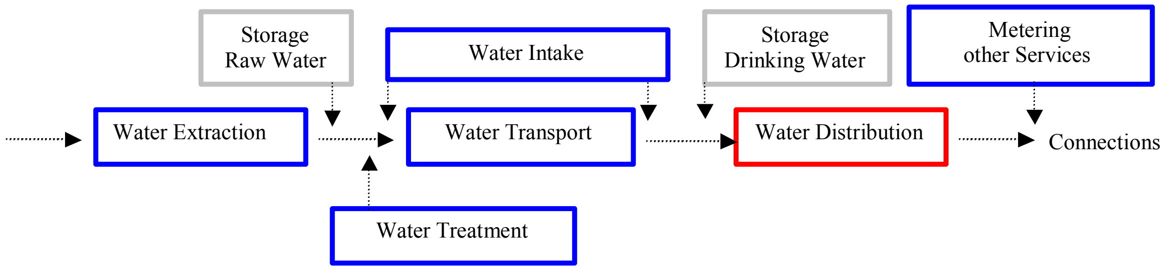
[22] If $\tau_{iw}^* > 0$ increasing use of input i by production unit w implies higher inefficiency, if $\tau_{iw}^* < 0$ increasing factor usage results in lower inefficiency.

[23] HAY/LIU (1997) interpret τ_{iw} as structural or long-run input-specific inefficiency components reflecting geographical factors, long-run policy actions or institutional arrangements.

5 THE STRUCTURE OF WATER PRODUCTION AND SOURCES OF INEFFICIENCY

The basic stages of water production can be described by Figure 3:[24]

Figure 3: Water Production Stages (Cost-Oriented)



Source: Own figure.

Water storage is usually not regarded as an integral part of the production process. If relevant, water intake is delivered by other water producers. Metering and other services are mostly conducted by the supplier itself, nevertheless can be 'contracted-out'. The process of water treatment is regarded as a central part of the rural water undertaking, but is – compared to other stages – less cost intensive. The highest costs are generated by the transport of water as well as the distribution of drinking water to the consumers. The costs of water extraction are in particular a function of the regional hydrological setting (ground, spring or surface water). Only the stage of water distribution can be economically defined as a natural monopoly (see SAUER, 2004a). Assuming the realisation of economies of vertical integration, the organisation of the majority of rural water suppliers in Germany are characterized by total vertical integration.[25]

The German water industry consists of about 6,500 supplying firms operating nearly 17,800 waterworks. The biggest 1,650 companies supply water to more than 83 % of the total population. In most cases water supply and sewage are provided by different companies. In the course of the German reunification the former 16 state-owned East German WABs[26] were splitted up into 550 water suppliers as well as 1,000 sewage companies and subsequently modernised by relatively high public investments (see figure 4). Only about 1.7 % of all water suppliers are totally private owned, 85 % are exclusively in the hand of the public sector in the form of municipal or communal governmental bodies (even about 95 % with respect to rural suppliers). In 2000 about 80 % of the total water output was supplied to household consumers and about 14 % to industrial and commercial customers. The density of water suppliers in the market largely varies with respect to the region: Focusing on the Bundesländer and ignoring the large city states Berlin, Hamburg and Bremen the ratio inhabitants supplied per supplier is the highest for North Rhine-Westfalia (about 90,000), the lowest for Rhineland-Palatinate (about 26,000). On average in West Germany about 47,000 inhabitants are supplied by one firm and about 65,000 in East Germany.[27]

German law regards water supplying services as part of the core activites of the public administrative body on the municipal or communal level. Economic acitivites of the

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[24] For a more detailed discussion of the characteristics of the water production structure and the modelling implications see SAUER 2004a.

[25] This holds for about 84% of all German water suppliers and even for 95% of the rural water suppliers in 2000/2001 (see SAUER 2004a).

[26] 'Wasserversorgungs- und Abwasserentsorgungsbetriebe' (water distribution companies and sewage disposal companies).

[27] On the basis of BGW, 2001.

communal body are restricted by the purpose – which has to be a ‘public’ one – and the territorial borders of the individual communal administration. Competition in the water market is excluded by law.[28] Hence water suppliers in Germany have to be regarded as legally protected monopolies, serving high quality water[29] at increasing consumer prices and comparatively high total investment costs (of which 65% are due to the transport and distribution net). The amount of water consumed is steadily decreasing. Economists usually mark the core infrastructure sectors as the water sector as a natural monopoly pointing on high sunk costs, subadditivity of the cost funtion and economies of scale (see e.g. FRITSCH et al. 2001).[30]

There is no effective competitive pressure in the market which could lead to cost and resource oriented and efficient management (see SCHEELE 2000; SAUER/STRECKER 2003a). Nevertheless as a consequence of the liberalisation efforts in other infrastructure sectors (gas, electricity) private shares in public water supplying companies are increasing.[31] Despite growing discussions on the need for liberalisation and applicable deregulation steps in the market (see e.g. EWERS et al. 2001; MANKEL/SCHWARZE 2000 or SCHEELE 2000) no effective political decisions have been made so far. Hence the judgement about the missing economic incentives for German water suppliers made by the chief of the water division of the World Bank BRISCOE in 1995 still holds: “There is no incentive as well as study for German water suppliers to compare their cost efficiency with the ‘international frontier’ of water supplying firms.” (BRISCOE 1995, p. 430).

Rural water suppliers are specifically confronted with a low supplying density, a relatively large transport and distribution net as well as a very low level of private investment shares. Rural suppliers in East Germany experienced high levels of publicly funded investment expenditures in the 1990s with respect to plant enhancement and modernisation (see Figure 4).

The preceeding description of the German water industry revealed the following sources for inefficiency on the rural supplier's level:

Heterogeneity of the Production Process: The process of water production and supply might vary from one rural supplier to another due to the hydrogeological and geographical setting the individual rural water supplier is operating in, the quality and source of the extracted water, the applied treatment technology and storage facilities as well as connection density and size of the supplying area (see SAUER 2004a).

Lack of Private Activities / Lack of Competition: As set out above there is no effective competition in the German water sector due to the concepts of the economic theory of competition. Albeit the firm concentration is relatively low in the sector, private activity in the market is rare due to lacking openness (regulatory constraints) as well as contestability (sunk costs of network investments).

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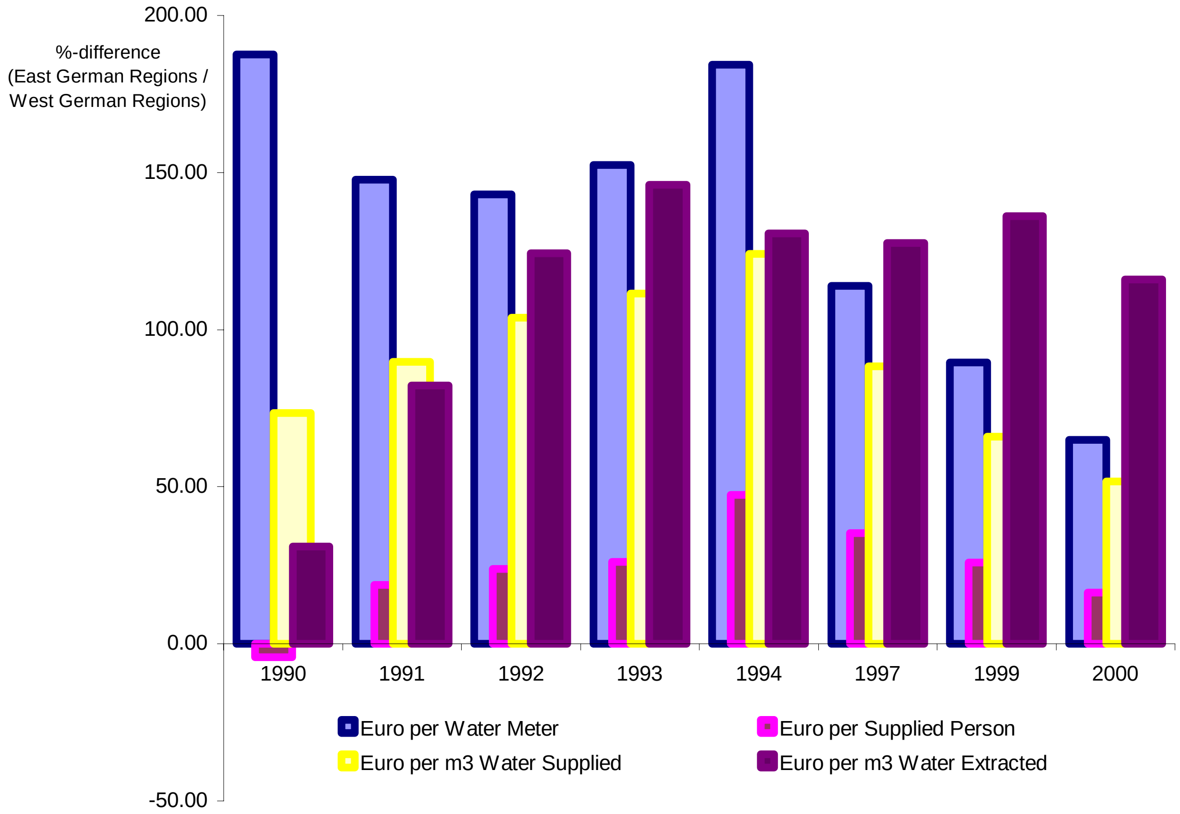
28 Municipal self-administration with respect to core infrastructural services (‘Kommunale Selbstverwaltung im Rahmen der Daseinsvorsorge’), see Constitutional Law of the Federal Republic of Germany (‚Grundgesetz’) article 28; local competence of the communal body ('kommunalwirtschaftliches Örtlichkeitsprinzip’); excemptions of the anti-trust law (‚kartellrechtlicher Ausnahmebereich’).

29 The water quality is regulated by the ‘Trinwasserverordnung 1998 und 2003’, ‘DIN 2000’ and the ‘Gesundheitsämter’ on the regional level.

30 Nevertheless no effort to empirically verify such assumed economies of scale and scope for the German water industry has been undertaken so far (SAUER 2004a).

31 Big private energy suppliers as e.g. EON propagate the ‘vision’ of the ‘multi-utility’.

Figure 4: Investments in Water Supply – Percentage Difference East to West Germany



Source: BGW statistics and own calculations.

Management and Organisation: Managerial and organisational factors affect the efficiency of firms' operations. Property rights theory point out the costs of state ownership (see e.g. ALCHIAN 1965). Due to the principal-agent concept (see e.g. ARROW 1985) the tax payers are confronted with low incentives for the control of the water supplier's management and lacking possibilities to influence the decision making process. In addition control and valuation of the management's activities via the market is no option. Hence, the problems of 'hidden action' and 'hidden information' prevail. NISKANEN (1971) points to the incentives of bureaucracies to maximise their own budgets, whereas WILLIAMSON (1964, 1985) theorises that bureaucracies are characterised by discretionary behaviour. All these concepts assume inefficiencies of bureaucracies as a consequence of lacking internal and external control mechanisms. Nevertheless among economists there is no clear empirical evidence that partly or fully private firms' economic performance is superior to that of publicly owned firms. The sample consists of a number of different forms of public ownership.[32] However the majority of rural water suppliers is organised by the form of a 'special purpose vehicle' ('Zweckverband').

Public Policy: Public funding or the allowance of investment grants for water suppliers due to different selection criteria of the various programms could be another source of inefficiency. Here the implications of the concepts of institutional economics hold also for the bureaucrats deciding about the granting of investment funds for the individual rural supplier. There are

32 In general there are different forms of ownership in the German water sector ranging from totally state owned ('Regiebetrieb') or operated by the communal body ('Eigenbetrieb') to partly privatised forms ('GmbH') (see e.g. VEST 1998).

numerous funding programms with respect to water treatment and supply on the regional, national or supra-national level.

Transition Process: Finally the ongoing process of economic transition in the Eastern regions of Germany in the form of employment rates, inhabitants' movement or public tax revenue could explain some of the efficiency variation on the supplier's level.

The preceding discussion of the German water market and the specific situation of rural suppliers lead to the following hypotheses:

(1) *The allocative efficiency in the rural water sector varies widely with respect to regional location as a consequence of heavily differing spatial conditions of water extraction, treatment, transport and distribution.*

(2) *Due to the different market structure in East and West Germany – a higher density of suppliers in the West – but more recently invested capital (plant and equipment) by East German suppliers, the efficiency of rural water suppliers in West Germany is expected to be not significantly higher than those of rural water suppliers in the East.*

(3) *Institutional and organizational characteristics – as e.g. the form of ownership or joint operation with sewage services (economies of scope) – have a significant effect on efficiency.*

(4) *In order to secure appropriate water supplying services for every inhabitant in rural regions, rare public resources should be directed to the less efficient suppliers with respect to the production and supplying environment. As economic performance measures on the suppliers' level are not relevant for the funding decision by public authorities, no significant difference between the efficiency of funded and non-funded suppliers is assumed.*

6 EARLIER WATER FRONTIERS

Several cost efficiency analyses have been conducted with respect to water supplying services but till now none exclusively for suppliers in rural regions and none for the German water sector.[33] By preparing a report for the UK office of water regulation (OFWAT) STEWART estimated a cost function for the UK water sector by focusing on operational costs (STEWART 1993). As explanatory variables he considered: the size of the distribution network, the volume of water sold, the volume of water put through the distribution network, the number of properties rented, the volume of water sold to non-residential users. Further the sources of raw water, the nature of demand (peak vs. average), the need for rehabilitation of pipes in poor state – are included. Another study prepared for OFWAT (PRICE 1993) estimated the operational costs per unit of water distributed. BHATTACHARAYYA et al. (1995) based their stochastic efficiency measurement on the estimation of a translog cost function for more than 200 urban water suppliers in the USA in 1992.[34] The data for this study were originally collected by a survey of the water industry conducted by the American Water Works Association (AWWA) in 1992. The estimation of the cost frontier uses the total costs as dependent variable and energy, labour, capital, total production, system loss, net output,

[33] By March 2004. With respect to production efficiency HANUSCH/CANTNER (1991) estimated a translog frontier on panal data (1970-83) for 13 German water suppliers in urban areas.

[34] BHATTACHARAYYA et al. estimated also a production frontier on 26 rural water suppliers of Nevada/USA in 1992. See BHATTACHARAYYA et al. (1995b).

materials, surface source, combined surface and ground source as explanatory variables. Here a very good fit for the model could be reported.[35]

CRAMPES et al. (1997) estimated a water cost function for Brazil regressing among others the explanatory variables of volume of water produced, the relation between the volume of water billed and the volume of water produced and the number of connections per employee on total and average costs. CUBBIN and TZANIDAKIS (1998) applied regression analysis on 1993/1994 data with respect to the regulated water industry in England and Wales. By this estimation operating costs were regressed on a number of potentially important explanatory variables. ESTACHE and ROSSI (1999) estimated a cost function for 50 Asian water companies (in 1995) on the base of data published by the Asian Development Bank in 1997. These include data on operational and maintenance costs, number of clients, the daily water production, the population density in the area served, the number of connections, the percentage of water from surface sources, the treatment capacity, the market structure represented by the relation between residential sales and total sales, the number of hours where water is available, the number of employees and the salary. Further a set of qualitative variables with respect to the way of treatment are used (conventional, rapid sand filters, slow sand filters, chlorification, desalination). The first function estimated by ESTACHE and ROSSI is similar to the ones estimated by STEWART and CRAMPES ET AL. but includes certain control variables: GDP per capita and a quality indicator (number of hours where water is available). Further dummy variables were tested reflecting ownership and possible concessioning. ESTACHE and ROSSI further conducted a cost efficiency frontier in order to determine the effect of ownership on the supplier's efficiency. Table 1 gives a summary of the most important estimation models so far.

Table 1: Exemplary Stochastic Cost Efficiency Estimations for Water Suppliers

Study			Efficiency Estimates					
Country (level)	*Author, Year*	*Indep. Variable*	*Mean*	*SD*	*Variance*	*Min*	*Max*	*N*
USA (urban)	*Bhattacharayya et al., 1995*	Operational Costs	0.8895	0.1727	0,0281a	0,4308a	0,9844a	221
UK (regional)	*Cubbin/Tzanidakis, 1998*	Operational Costs	0.7780	0.1040	0.0108	0.5720	1.0000	29
Asia (urban, rural)	*Estache/Rossi, 1999*	Total Costs	0.6393	0.2467	0.0609	0.1500	1.0000	44

('a' : calculated on the basis of sub-samples averages)

Source: Own calculations.

7 THREE VARIABLE, FOUR FIXED-FACTOR WATER COST FUNCTION

In contrast to other flexible approximations as the translog function, the application of a SGM cost function allows the incorporation of all theoretical neoclassical restrictions without sacrificing the fit of the functional form (see DIEWERT/WALES 1987). The SGM cost function defined by chapter 2 is now applied to describe a three variable – labour (xl), energy (xe) and chemicals (xch) -, and four fixed-factor – equity capital (xeq), number of supplied connections (xcon), supplying net in km (xnet) and share of groundwater intake (xgrws) - water production and supply process with respect to rural suppliers. It is estimated on the base of cross-sectional data by an iterative seemingly unrelated regression procedure (SUR)[36]. The dependent variable is operational cost (OC) as the sum of costs for labour, energy and

[35] ($R^2_g = 0.99$).

[36] ZELLNER's seemingly unrelated regression procedure contained in STATA/SE version 8.0 was used for the demand system estimation.

chemicals. As explanatory variables the input prices (pl, pe, pch), water output (out) as well as the fixed factors are considered:

$$OC = g(p)out + b_{ly}plout + b_{ey}peout + b_{chy}pchout + b_{l}pl + b_{e}pe + b_{ch}pch + b_{yy}ß_{l}plout^2 + b_{yy}ß_{e}peout^2 + b_{yy}ß_{ch}pchout^2 + b_{leqy}plxeqout + b_{eeqy}pexeqout + b_{cheqy}pchxeqout + b_{eq}\gamma_{leq}plxeq + b_{eq}\gamma_{eeq}pexeq + b_{eq}\gamma_{cheq}pchxeq + b_{eqeq}\delta_{leq}plxeq^2 + b_{eqeq}\delta_{eeq}pexeq^2 + b_{eqeq}\delta_{cheq}pchxeq^2 + b_{lcony}plxconout + b_{econy}pexconout + b_{chcony}pchxconout + b_{con}\gamma_{lcon}plxcon + b_{con}\gamma_{econ}pexcon + b_{con}\gamma_{chcon}pchxcon + b_{concon}\delta_{lcon}plxcon^2 + b_{concon}\delta_{econ}pexcon^2 + b_{concon}\delta_{chcon}pchxcon^2 + b_{lnety}plxnetout + b_{enety}pexnetout + b_{chnety}pchxnetout + b_{net}\gamma_{lnet}plxnet + b_{net}\gamma_{enet}pexnet + b_{net}\gamma_{chnet}pchxnet + b_{netnet}\delta_{lnet}plxnet^2 + b_{netnet}\delta_{enet}pexnet^2 + b_{netnet}\delta_{chnet}pchxnet^2 + b_{lgrwsy}plxgrwsout + b_{egrwsy}pexgrwsout + b_{chgrwsy}pchxgrwsout + b_{g}\gamma_{lgrws}plxgrws + b_{g}\gamma_{egrws}pexgrws + b_{g}\gamma_{chgrws}pchxgrws + b_{gg}\delta_{lgrws}plxgrws^2 + b_{gg}\delta_{egrws}pexgrws^2 + b_{gg}\delta_{chgrws}pchxgrws^2 \quad [17]$$

where g(p) is defined as:

$$g(p) = (s_{le}plpe + s_{lch}plpch + s_{ech}pepch + ½s_{ll}pl^2 + ½s_{ee}pe^2 + ½s_{chch}pch^2) / (\theta_{l}pl + \theta_{e}pe + \theta_{ch}pch) \quad [18]$$

the conditional variable input demand system is derived as:[37]

$$x_l/out = [dOC(•)/dpl]/out = [(s_{ll}pl + s_{le}pe + s_{lch}pch) / (\theta_{l}pl + \theta_{e}pe + \theta_{ch}pch)] - \theta_{l}[(s_{le}plpe + s_{lch}plpch + s_{ech}pepch + ½s_{ll}pl^2 + ½s_{ee}pe^2 + ½s_{chch}pch^2) / (\theta_{l}pl + \theta_{e}pe + \theta_{ch}pch)^2] + b_{ly} + b_{l}/out + b_{yy}ß_{1}out + b_{leqy}xeq + b_{eq}\gamma_{leq}(xeq/out) + b_{eqeq}\delta_{leq}(xeq^2/out) + b_{lcony}xcon + b_{con}\gamma_{lcon}(xcon/out) + b_{concon}\delta_{lcon}(xcon^2/out) + b_{lnety}xnet + b_{net}\gamma_{lnet}(xnet/out) + b_{netnet}\delta_{lnet}(xnet^2/out) + b_{lgrwsy}xgrws + b_{g}\gamma_{lgrws/}(xgrws/out) + b_{gg}\delta_{lgrws}(xgrws^2/out) + \varepsilon_{l} \quad [19]$$

$$x_e/out = [dOC(•)/dpe]/out = [(s_{ee}pe + s_{le}pl + s_{ech}pch) / (\theta_{l}pl + \theta_{e}pe + \theta_{ch}pch)] – \theta_{e}[(s_{le}plpe + s_{ech}pepch + s_{lch}plpch + ½s_{ll}pl^2 + ½s_{ee}pe^2 + ½s_{chch}pch^2) / (\theta_{l}pl + \theta_{e}pe + \theta_{ch}pch)^2] + b_{ey} + b_{e}/out + b_{yy}ß_{e}out + b_{eeqy}xeq + b_{eq}\gamma_{eeq}(xeq/out) + b_{eqeq}\delta_{eeq}(xeq^2 /out) + b_{econy}xcon + b_{con}\gamma_{econ}(xcon/out) + b_{concon}\delta_{econ}(xcon^2 /out) + b_{enety}xnet + b_{enet}\gamma_{enet}(xnet/out) + b_{netnet}\delta_{enet}(xnet^2 /out)+ b_{egrwsy}xgrws + b_{g}\gamma_{egrws}(xgrws/out) + b_{gg}\delta_{egrws}(xgrws^2 /out) + \varepsilon_{e} \quad [20]$$

$$x_{ch}/out = [dOC(•)/dpch]/out = [(s_{chch}pch + s_{lch}pl + s_{ech}pe) / (\theta_{l}pl + \theta_{e}pe + \theta_{ch}pch)] – \theta_{ch}[(s_{lch}plpch + s_{ech}pepch + s_{le}plpe + ½s_{ll}pl^2 + ½s_{ee}pe^2 + ½s_{chch}pch^2) / (\theta_{l}pl + \theta_{e}pe + \theta_{ch}pch)^2] + b_{chy} + b_{ch}/out + b_{yy}ß_{ch}out + b_{cheqy}xeq + b_{eq}\gamma_{cheq}(xeq/out) + b_{eqeq}\delta_{cheq}(xeq^2/out) + b_{chcony}xcon + b_{con}\gamma_{chcon}(xcon/out) + b_{concon}\delta_{chcon}(xcon^2/out) + b_{chnety}xnet + b_{net}\gamma_{chnet}(xnet/out) + b_{netnet}\delta_{chnet}(xnet^2/out) + b_{chgrwsy}xgrws + b_{g}\gamma_{chgrws}(xgrws/out) + b_{gg}\delta_{chgrws}(xgrws^2 /out) + \varepsilon_{ch} \quad [21]$$

[37] A unique feature of the SGM cost function is that the dependent variables in the input demand system are not cost shares as in the more commonly used translog form. After dividing by output here the dependent variable of each demand equation is the ratio of input use to output.

Additive disturbance terms ε_i with a zero mean and a constant variance are assumed for the demand equations. Symmetry are imposed by $s_{ij} = s_{ji}$, the adding up constraint is $\Sigma_i s_{ij} = 0$ for i, j = l, e, ch. The s_{ij} parameters define the Hessian from which the regularity conditions are checked. The θ_i are set to the sample average values for each input quantity. With respect to the relatively small sample size (n = 47) a more flexible estimation of $ß_i$, γ_{ir}, δ_{ir} is reached by setting the values for b_{yy}, b_{eq}, b_{eqeq}, b_{con}, b_{concon}, b_{net}, b_{netnet}, b_g and b_{gg} to unity:

$$s_{ij} = s_{ji}\text{, for i, j = labour, energy, chemicals} \quad [22]$$

$$\Sigma_i s_{ij} = 0\text{, for i, j = labour, energy, chemicals} \quad [23]$$

$$\theta_i = x_i'\text{ for i = labour, energy, chemicals} \quad [24]$$

$$b_{yy}, b_{eq}, b_{con}, b_{net}, b_g, b_{eqeq}, b_{concon}, b_{netnet}\text{ and }b_{gg} = 1 \quad [25]$$

Estimation of the parameters is done by using the demand system [19] to [21]. As the cost function contains no additional information it is not estimated. As defined by equation [16] for each input i and sub-group w a dummy variable ζ_{iw} is added to the conditional input demand system [19] to [21]:

$$\begin{aligned} x_i/out = {} & [dOC(\bullet)/dpi]/out = (\Sigma_i\Sigma_j s_{ij}pi / \Sigma_i\theta_i pi) - ½\theta_i[(\Sigma_i\Sigma_j s_{ij}pipj) / (\Sigma_i\theta_i pi)^2] + b_{iy} + b_i/out \\ & + b_{yy}ß_i out + b_{ieqy}xeq + b_{eq}\gamma_{ieq}(xeq/out) + b_{eqeq}\delta_{ieq}(xeq^2/out) + b_{icony}xcon + \\ & b_{con}\gamma_{icon}(xcon/out) + b_{concon}\delta_{icon}(xcon^2/out) + b_{inety}xnet + b_{net}\gamma_{inet}(xnet/out) + \\ & b_{netnet}\delta_{inet}(xnet^2/out) + b_{igrwsy}xgrws + b_g\gamma_{igrws/}(xgrws/out) + b_{gg}\delta_{igrws}(xgrws^2/out) \\ & + \zeta_{iw} + v_i \end{aligned} \quad [26]$$

The case of overall allocative efficiency is estimated by imposing the restriction(s)

$$\zeta_{lw} = \zeta_{ew} = \zeta_{chw}\text{ for w = 1, …, n} \quad [27]$$

8 DATA AND SUB-GROUPS

The data used for this analysis are based on a survey of water suppliers in rural Germany for the year 2000/2001 (see chapter 2). This cross-sectional data set includes beside others output, operational cost, quantity and expenditure for labour and energy, the expenditure for chemicals, the share of various sources of water intake, equity and debt, number of supplied connections and length of the transport and distribution net, form of ownership, regional location, form of integration with respect to other utility operations and public funding.[38]

Output is measured as water output in m^3 as it is conventionally used in the water sector and previous economic studies. Quality issues with respect to output as e.g. amount of chemical and biological contents removed in the course of water treatment, are ignored due to lacking data.[39] Operational costs consist of the expenditures for the variable endogenous inputs. The price of labour is obtained by dividing the expenditure for labour – the sum of total wages and salaries paid including benefits and pensions - by the quantity of full time equivalent employees' working hours per year. All rural suppliers in the sample used electricity as the

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[38] Public funding for water suppliers in Germany is mainly granted via various investment programms on the different administrative levels: national: KfW-Infrastrukturprogramm, KfW-Umweltinvestitionen, DtA-Umweltprogramm, Gemeinschaftsaufgabe Verbesserung der regionalen Infrastruktur, Bund – Umrüstung wasserbaulicher Maßnahmen; regional: Förderung wirtschaftsnaher Infrastruktur / Kommunalkredit-programm, Förderung Ländlicher Raum / Entwicklung, Wasserwirtschaftliche Vorhaben / Grundwasser, Abwasser / Kläranlagen, Umweltgerechte Wasser- und Abwasserwirtschaft / Gewässergüte / Nachhaltigkeit; EU: Regionalförderprogramm, ERP Umwelt- und Energiesparprogramm, Förderung nachhaltiger Stadtent-wicklung, ISPA-Förderung, EIP-Darlehen, INTERREG III.

[39] A quality adjusted output index is the aim of future research.

source of energy. The price of energy is defined as the ratio of energy cost divided by equivalent thermal units. Water treatment is based to a large extent on the use of activated charcoal filter which is produced out of brown coal. Hence with respect to the price of chemicals the market prices for coal for the specific year adjusted for regional transport costs are used. The quantity of employed chemicals are obtained by dividing the specific expenditure by the generated price per unit of chemical.

Water intake can be based on various sources: groundwater reservoirs, surface water as e.g. lakes and rivers, and spring water. The cost effect of the fixed factor water intake is modelled by incorporating a variable reflecting the percentage share of groundwater intake. Finally the quantity of equity capital, the number of supplied connections (households, industrial, commercial and others) and the length of the supplying net in km are incorporated as fixed inputs.

For the efficiency analysis various sub-groups of rural water suppliers are generated along the following characteristics:

- *regional location*: a) East or West Germany located, b) administrative competence on the regional level ‘Bundesland’: Bavaria, Brandenburg, Lower Saxony, Mecklenburg-Western Pomerania, Rhineland-Palatinate, Saxony, Saxony-Anhalt, and Schleswig-Holstein.
- *form of ownership*: special purpose association or other form.
- *public funding*: funded suppliers or not funded suppliers.
- *degree of operational integration*: a) integration of sewage services or not, b) fully integrated utility (water, sewage, electricity, gas, thermal power) or disintegrated utility (only water supplying services).
- *size of operations*: four classes of size: less than 250,000 m^3, 250,000 - 500,000 m^3, 500,00 - 1,000,000 m^3, more than 1,000,000 m^3.

Table 2 contains descriptive statistics on the variables included in the estimations, Table 3 contains the number of observations on the defined sample sub-groups.

Table 2: Descriptive Statistics Variables

Variable	Obs.	Mean	Std. Dev.	Min	Max
operational costs (Euro)	47	1422690	4308437	3067.751	2.87E+07
water output (m^3)	47	1231615	2578482	15000	1.66E+07
labour (hours/year)	47	58399.48	147400.9	871.5	973590
energy (kWh)	47	889681.1	1906692	83.06931	1.19E+07
chemicals (kg)	47	5872209	1.92E+07	13574.12	1.28E+08
price of labour (Euro/h)	47	9.277508	6.281475	0.2053381	19.94982
price of energy (Euro/kWh)	47	0.087932	0.0234748	0.0496409	0.1859581
price of chemicals (Euro/kg)	47	0.1108511	0.0035691	0.105	0.115
equity capital (Euro)	47	9.51E+07	1.68E+08	112001.8	8.09E+08
number of connections (n)	47	6748.105	15524.44	85	102716
net length (km)	47	281.0049	551.2715	1.5	3545
share of groundwater intake (%)	47	0.7170483	0.3996352	4.35E-11	1

Source: Own calculations.

Table 3: Observations Efficiency Sub-Groups

Variable	Obs.	Variable	Obs.
I: regional location (a)	47	**IV: public funding**	37
- East Germany	15	- public funding	13
- West Germany	32	- no public funding	24
II: regional location (b)	46	**V: operational integration (a)**	47
- Bavaria	25	- sewerage	20
- Brandenburg	4	- no sewerage	27
- Lower Saxony	2		
- Mecklenburg - Western Pomerania	4	**VI: operational integration (b)**	47
- Rhineland - Palatinate	2	- integrated utility	9
- Saxony	3	- disintegrated utility	38
- Saxony - Anhalt	3		
- Schleswig - Holstein	3	**VII: size of operations**	47
		- < 250.000 m^3	21
III: form of ownership	47	- 250.000 - 500.000 m^3	4
- special purpose association	16	- 500.000 - 1.000.000 m^3	10
- others	31	- > 1.000.000 m^3	12

Source: Own calculations.

9 RESULTS

The three factor demand equations are estimated as a SUR system without the original cost function since the latter contains no additional information. All the parameters are obtained by the demand equations. A large number of constrained and unconstrained estimations were run to determine the final model specification with respect to technological characteristics. The parameter estimates for the SGM rural water cost function are shown in Table 4:

Table 4: Parameter Estimates / Modified SGM Rural Water Cost Function

Parameter [a, b, c]		Parameter		Parameter	
s_{ll}	**-2.66E-12**	b_{lcony}	**2.06E-05**	δ_{lcon}	**-0.0014**
	[-611.95]***		[0.49]		[-0.38]
s_{le}	**6.08E-12**	b_{econy}	**-2.85E-04**	δ_{econ}	**0.0267**
	[1.17]		[-0.89]		[0.95]
s_{lch}	**-3.42E-12**	b_{chcony}	**3.06E-05**	δ_{chcon}	**-0.0162**
	[-0.25]		[0.02]		[-0.12]
s_{ee}	**-2.45E-07**	b_{lnety}	**5.37E-05**	γ_{lnet}	**-117.74**
	[-718.79]***		[0.14]		[-1.59]*
s_{ech}	**2.47E-07**	b_{enety}	**1.02E-03**	γ_{enet}	**-883.42**
	[1160.24]***		[0.35]		[-1.57]*
s_{chch}	**-5.00E-07**	b_{chnety}	**-3.96E-03**	γ_{chnet}	**-5737.20**
	[-3700.54]***		[-0.29]		[-2.19]**
b_{ly}	**0.0144**	b_{lgrwsy}	**0.0815**	δ_{lnet}	**0.0530**
	[0.24]		[2.55]***		[0.07]
b_{ey}	**0.3577**	b_{egrwsy}	**0.5248**	δ_{enet}	**-0.8944**
	[0.78]		[2.17]**		[-0.16]
b_{chy}	**-0.9748**	$b_{chgrwsy}$	**-0.4232**	δ_{chnet}	**6.24394**
	[-0.46]		[-0.38]		[0.24]
b_{l}	**5920.20**	γ_{leq}	**2.01E-04**	γ_{lgrws}	**-6102.35**
	[6.95]***		[0.98]		[-0.20]
b_{e}	**7184.36**	γ_{eeq}	**0.0034**	γ_{egrws}	**273792.40**
	[1.11]		[2.18]**		[1.20]
b_{ch}	**-7105.7**	γ_{cheq}	**9.98E-03**	γ_{chgrws}	**357743.3**
	[-0.24]		[1.38]		[0.34]
$ß_{l}$	**-1.00E-07**	δ_{leq}	**-1.74E-12**	δ_{lgrws}	**1932.68**
	[-0.91]		[-1.11]		[0.06]
$ß_{e}$	**4.41E-07**	δ_{eeq}	**-2.69E-11**	δ_{egrws}	**-260877.90**
	[0.53]		[-2.28]***		[-1.15]
$ß_{ch}$	**9.75E-07**	δ_{cheq}	**-4.57E-11**	δ_{chgrws}	**-293097.4**
	[0.25]		[-0.83]		[-0.28]
b_{leqy}	**4.49E-10**	γ_{lcon}	**-5.2318**		
	[1.73]*		[-0.51]		
b_{eeqy}	**4.46E-09**	γ_{econ}	**-46.88**		
	[2.27]**		[-0.61]		
b_{cheqy}	**7.59E-09**	γ_{chcon}	**850.74**		
	[0.83]		[2.37]***		

Input Demand Equations

	R^2	N
Labour	0.8570	47
Energy	0.8485	47
Chemicals	0.8834	47

a: 'l' - labour, 'e' - energy, 'ch' - chemicals, 'eq' - equity, 'con' - connections, 'net' - net, 'grws' - groundwater share, 'y' - output

b: t-statistics are reported in parentheses; *,**,*** : significant at 10-, 5- or 1%-level

c: symmetry ($s_{ij} = s_{ji}$) and adding-up constraints ($\Sigma s_{ij} = 0$) are imposed; concavity is imposed by constraining $S = -A*A^T$

Source: Own calculations.

The R^2 values for the individual demand equations are relatively high (0.86, 0.85 and 0.88), but not all coefficients are statistically different from zero at a significant level. The relative efficiency of the defined sub-groups was estimated by using the described SGM cost structure with the overall allocative efficiency specification (OAI) as well as the more general specification of input specific allocative efficiency (ISAI). The estimates of allocative efficiency for each sub-group are discussed in the following section.

– *Regional location*: (a) Rural water suppliers in East Germany are found to produce and supply water about 8 % more efficient than those in West Germany (see Table 5). With respect to input specific efficiency East German suppliers' allocative efficiency with respect to labour is about 7 % higher and those for energy even 110 % higher compared to West German suppliers in rural areas. But nevertheless ISAI with respect to chemicals was found to be about 16 % lower than those for the West German water suppliers. The costs of inefficiency are the highest for the usage of chemicals by East German suppliers (about 6.9 % of total operational costs).

Table 5: Relative Efficiency – Regional Location (a) Region

MODEL	OVERALL (OAI)	INPUT SPECIFIC (ISAI)					
		Efficiency Ratio (east / west)			Costs of Inefficiency (%)		
Subsample	Overall	Labour	Energy	Chemicals	Labour	Energy	Chemicals
'region (a)'							
- east / west	1.08	1.07	**2.10**	0.84	0.46	3.88	**6.88**

Source: Own calculations.

(b) The overall efficiency of water suppliers in rural areas of the northern region Schleswig-Holstein was found to be the highest of all suppliers in the sample. Those of suppliers in the eastern region Brandenburg was found to be the lowest (about 78 %) in the sample (see Table 6). The estimation of the ISAI model revealed that the most labour efficient as well as energy efficient suppliers are located in Saxony-Anhalt, the most labour inefficient suppliers are those in Bavaria (about 15 %). With respect to energy the most inefficient suppliers are located in rural regions of Saxony (about 54 %). Chemicals are most efficiently used by suppliers in Schleswig-Holstein and most inefficiently again by those in Saxony (about 28 %). Consequently the relative costs of input specific inefficiency are the highest in Bavaria (labour) and Saxony (energy and chemicals).

Table 6: Relative Efficiency – Regional Location (b) Bundesland

MODEL	OVERALL (OAI)	INPUT SPECIFIC (ISAI)					
		Efficiency Score (%)			Costs of Inefficiency (%)		
Subsample	Overall	Labour	Energy	Chemicals	Labour	Energy	Chemicals
		(%)	(%)	(%)	(%)	(%)	(%)
'region (b) Bundesland'							
-Bavaria	93.44	**14.80**	95.34	96.91	**6.87**	5.29	1.53
-Saxony-Anhalt	89.42	100.00	100.00	75.13	0.00	0.00	12.19
-Brandenburg	**77.96**	52.07	92.78	67.93	2.98	5.96	11.31
-Mecklenburg-Western Pomerania	96.36	65.78	94.92	80.58	1.85	3.68	7.62
-Saxony	96.10	57.00	**28.93**	**27.84**	2.94	**11.41**	**30.67**
-Schleswig-Holstein	100.00	54.12	92.83	100.00	3.08	7.73	0.00
-Lower Saxony	98.99	74.44	95.62	98.74	1.63	6.33	0.57
-Rhineland-Palatinate	80.35	56.29	75.09	58.39	2.76	10.01	16.63

a: not applicable for Thuringia as there was only 1 observation available

Source: Own calculations.

There is evidence for hypothesis (1). The standard deviation of the relative efficiency of rural suppliers with respect to regional location is the highest for chemicals (about 24.6). There is further also evidence for hypothesis (2) which assumed no big difference between the allocative efficiency of water suppliers in rural areas of East and West. Due to the usage of the variable inputs labour and energy the relative efficiency of suppliers in East Germany is even higher than those in West Germany.

– *Form of ownership*: The OAI model showed nearly the same value for the allocative efficiency of suppliers in the form of special purpose associations and those with other forms of ownership (e.g. ‘Eigenbetrieb’, ‘Regiebetrieb’). Input specific efficiency with respect to energy is higher for special purpose associations (about 14 %) but lower with respect to chemicals. They may save up to 75 % of chemicals to move to the frontier (defined by the ‘best practice’ supplier).

Table 7: Relative Efficiency – Form of Ownership

MODEL	OVERALL (OAI)	INPUT SPECIFIC (ISAI)					
	Efficiency Ratio (spass/others)				Costs of Inefficiency (%)		
Subsample	Overall	Labour	Energy	Chemicals	Labour	Energy	Chemicals
'ownership'							
- special purpose ass. / others	1.01	1.01	1.14	0.25	0.03	0.60	29.33

Source: Own calculations.

– *Operational integration:* (a) The estimated overall allocative efficiency for water suppliers with joint sewage services was found to be not significantly different from those suppliers without sewage services (see Table 8 (a)). Nevertheless the efficiency with respect to energy was shown to be about 27 % higher for suppliers without sewage services, even about 58 % for the efficiency of chemicals usage. The costs increase due to inefficiencies in the use of chemicals by up to 25.9 % for suppliers with sewage services.

Table 8: Relative Efficiency – Operational Integration (a) Sewage and (b) Utility

MODEL	OVERALL (OAI)	INPUT SPECIFIC (ISAI)					
	Efficiency Ratio (sew / no sew, integr / disintegr)				Costs of Inefficiency (%)		
Subsample	Overall	Labour	Energy	Chemicals	Labour	Energy	Chemicals
'integration (a)'							
- sewerage / no sewerage	0.99	0.99	0.73	**0.42**	0.05	1.21	**25.89**
'integration (b)'							
- int. utility / disint. utility	0.95	0.97	**0.25**	0.37	0.20	4.93	**28.70**

Source: Own calculations.

(b) Comparing the relative efficiency of integrated utilities with those of rather disintegrated suppliers (see Table 8 (b)) it is shown that the overall allocative inefficiency is about 5 % higher with respect to integrated utilities. Integrated utilities in the sample could reduce their use of energy by up to 75 % resp. those of chemicals by up to 63 % to move to the ‘best practice’ frontier.

The estimation of overall as well as input specific allocative efficiency delivered mixed evidence for the significance of operational integration (hypothesis (3)). With respect to the joint production of sewage services as well as the total integration of various utility services even allocative diseconomies of scope and/or no significant transaction cost savings are confirmed for energy and chemicals. With respect to the form of ownership a positive correlation of the associative arrangement and energy efficiency is confirmed but on the other side a negative one for chemicals efficiency.

– *Public Funding*: Rural water suppliers financially supported by public funds are found to be only slightly less overall efficient than non-funded ones in the sample (see Table 9). Compared to suppliers with no funding, funded ones could employ up to 57 % less energy as well as up to 62 % less chemicals.

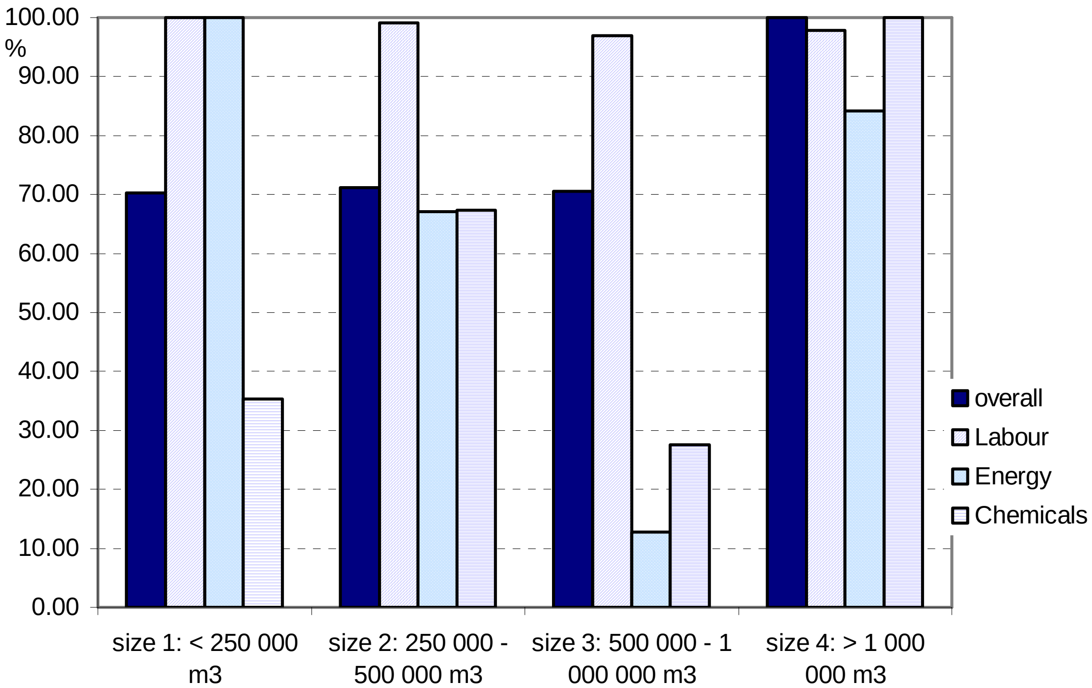
Table 9: Relative Efficiency – Public Funding

MODEL	OVERALL (OAI)	INPUT SPECIFIC (ISAI)					
		Efficiency Ratio (funds / no funds)			Costs of Inefficiency (%)		
Subsample	Overall	Labour	Energy	Chemicals	Labour	Energy	Chemicals
'public funding' - funding / no funding	0.93	0.96	0.43	**0.38**	0.22	2.89	**27.32**

Source: Own calculations.

The analysis confirmed hypothesis (4) for the sample of rural water suppliers with respect to overall as well as labour specific efficiency. Based on OAI measurement the economic reasoness of such funding actions has to be questioned. On the other side a significant difference between the input efficiency of funded and non-funded suppliers with respect to energy and chemicals are found. Hence if granted public funds were directed to increase the efficiency of energy and chemicals usage in the production process of the funded suppliers, such financial resources would not be wasted.

Figure 5: Relative Efficiency Scores by Firm Size



Source: Own calculations.

– *Size:* The overall efficiency measure indicates that as firm size increases allocative efficiency increases as well (see Figure 5): the PEARSON product moment correlation coefficient is 0.881. Suppliers with a water output more than 1 Mio m^3 per year are the relatively most efficient ones. With respect to input specific efficiency it was found that suppliers with a size of up to 250.000 m^3 are most labour and energy efficient, whereas suppliers with a size above 1 Mio m^3 water per year are most chemical efficient. In order to move to the 'best practice' frontier with respect to chemicals suppliers up to 1 Mio m^3 water per year have to reduce the employment of chemicals by at average 43.4 %.

Table 10: LR-Tests Summary Statistics

Subsample / Model	test statistics	df	R^2_L	R^2_E	R^2_{CH}
'Bundesland'					
ISAI	---	68	0.896	0.903	0.923
OAI	---	53	-0.285	0.883	0.893
OAI nested in ISAI	37.13 ($ch^2_{0.01}$: 30.58)	not rejected at 1%-level, ISAI superior			
'region'					
ISAI	---	45	0.879	0.867	0.884
OAI	---	44	0.879	0.853	0.883
OAI nested in ISAI	7.08 ($ch^2_{0.01}$: 6.63)	not rejected at 1%-level, ISAI superior			
'ownership'					
ISAI	---	47	0.857	0.850	0.896
OAI	---	44	0.857	0.849	0.883
OAI nested in ISAI	8.18 ($ch^2_{0.05}$: 7.81)	not rejected at 5%-level, ISAI superior			
'sewerage'					
ISAI	---	46	0.860	0.856	0.896
OAI	---	45	0.859	0.849	0.884
OAI nested in ISAI	5.60 ($ch^2_{0.05}$: 3.81)	not rejected at 5%-level, ISAI superior			
'public funding'					
ISAI	---	45	0.877	0.871	0.913
OAI	---	47	0.877	0.859	0.906
OAI nested in ISAI	5.28 ($ch^2_{0.10}$: 4.61)	not rejected at 10%-level, ISAI superior			
'integrated utility'					
ISAI	---	44	0.868	0.871	0.884
OAI	---	45	0.868	0.852	0.884
OAI nested in ISAI	7.06 ($ch^2_{0.01}$: 6.63)	not rejected at 1%-level, ISAI superior			
'size'					
ISAI	---	46	0.860	0.871	0.890
OAI	---	52	0.859	0.853	0.886
OAI nested in ISAI	9.29 ($ch^2_{0.10}$: 10.6)	rejected at 10%-level, OAI superior			

Source: Own calculations.

The preceding analysis consists of the estimation of the SGM model with overall allocative inefficiency (OAI) as well as the SGM model with input specific inefficiency (ISAI) as the most general model specification. OAI is a special case of ISAI with (W x I-1) restrictions imposed (see equation [16]). Since the OAI models are nested in the ISAI models, it is possible to perform a likelihood ratio (LR) test to identify the appropriate functional form for the individual efficiency estimation. The LR tests show that – with the exception of the estimation models ‘size’ – all other OAI models are rejected against the more general model specification with input specific inefficiency (see Table 10), which means that the hypothesis of ‘OAI is nested in ISAI’ is not rejected. For the subsamples ‘Bundesland’, ‘region’ and ‘integrated utility’ the OAI specification is rejected at the 1 %-level of significance, for 'ownership' and 'sewage' at the 5 %-level and for 'public funding' at the 10 %-level of significance. This means that for our sample of 47 rural water suppliers and with respect to the generated sub-groups the measurement of input specific allocative inefficiency is superior to the measurement of overall allocative inefficiency. The OAI specification can not be rejected against the ISAI specification for the subsamples with respect to 'size' at the 10 %-level of significance.

10 CONCLUSIONS AND POLICY IMPLICATIONS

The preceding analysis attempted the estimation of inefficiency specific to the variable inputs used in the production and supply of water in rural areas of East and West Germany. The cost frontiers (here defined by the 'best group') is based on the second order flexible functional form of a symmetric generalized McFadden cost function modified to incorporate fixed inputs. Concavity restrictions are imposed as required by economic theory. Contrary to popular overall efficiency models an input specific efficiency approach allowing for the decomposition of inefficiency by variable input and therefore identifying more precisely the sources of allocative inefficiency is applied. Allocative efficiency specific to labour, energy and chemicals are calculated for various sub-groups of water suppliers out of a sample of 47 rural firms collected for the year 2000/2001.

The estimation results have implications for short- and medium-term policy actions as well as strategic planning in the long-run as discussions on water sector liberalisation and industry restructuring are even intensifying and are not based on empirical investigations at all. In general it can be concluded that policy efforts to increase efficiency in the rural water sector should be directed towards the (heavily) inefficient used production factors energy and chemicals. With respect to the widely found political and public characterisation of water supplying activities as a natural monopoly no empirical evidence for economies of scope either by joint water and sewage services or totally integrated utility services could be confirmed. On the other side even diseconomies of scope have to be reported in both cases. The same holds for widely assumed transaction cost savings as a consequence of associative forms of ownership ('Zweckverbände'): relatively efficient labour and energy use is offset by heavily inefficient use of chemicals, no convincing overall efficiency advantage can be stated. Finally a positive correlation between firm size (measured by water output) and overall efficiency implies negative effects of the legally set supplying area traditionally oriented at administrative borders of municipalities and communal bodies with respect to the majority of water suppliers. Future research on rural water infrastructure should be finally focused on further verification of the reported empirical relations and an identification of institutional factors for suppliers' relative efficiency.

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