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ECONOMETRIC MODEL AS AN INSTRUMENT FOR ANALYSING STRUCTURAL CHANGES IN FISHERIES MANAGEMENT OF LAKES

Marek Ramczyk✉

Department of Ecoengineering and Environmental Physicochemistry, Faculty of Civil and Environmental Engineering and Architecture, University of Science and Technology in Bydgoszcz,
Al. prof. S. Kaliskiego 7, 85-796 Bydgoszcz

ABSTRACT

The econometric model can be a precise instrument for analysing the impact of natural environment deterioration on the fishing economy. The paper presents the results of empirical studies regarding the influence of water quality changes (water pollution) in Charzykowskie Lake on the fisheries management. We have developed the economic-ecological models, which explain, from the point of view of the fisheries management, the changes of economic yield of fishing in the conditions of increased water pollution and optimum content of various substances in the water of the lake. In the empirical studies we conducted, we have analysed the impact of environmental factors on the natural structure of fish caught in Charzykowskie Lake. The empirical results show that most measures of water pollution cause changes in the structure of caught fish. Also, it can be clearly concluded that the increase in the pollution level of the lake supports the increase in proportion of the caught species that yield lower economic benefits, while it inhibits the increase in the caught volume of species that are more economically valuable. Hence the conclusion that the actions aimed at limiting the pollution of the lake will stimulate the increase in the share of species that are much more economically viable. This type of structural changes testify to a particular kind of competition between fish species having different environmental requirements, although the empirical results of econometric modelling suggest the existence of such competition also in the group of fish sharing similar needs regarding the quality of their habitat. Consequently, this situation determines the nature of the impact on the fisheries management of Charzykowskie Lake. When we take into account the changes in the structure of fish population in Charzykowskie Lake within the observed variability range of the model's variables, there also exist neutral factors that were potentially considered to be actively impacting the changes in the caught fish structure indicators. The proposed procedures of optimisation can serve as an instrument for programming the effectiveness of fisheries management in order to maintain ecological balance.

Keywords: econometric model, pollution of lake water, fisheries management

INTRODUCTION

In addition to decreasing the volumes of fish caught, the consequence of water pollution is the change in their structure. It is evident that different species of fish show different degrees of resistance to increasing the content of various substances in water. Therefore, it can be expected that with the increase of lake water pollution, the share of species requiring clean water will decrease, and the population of fish species that are more resistant to pollution will increase. In empirical studies, the impact of various water quality characteristics of Charzykowskie Lake, located in the Bory Tucholskie forest, on changes in the share of the volume of economically significant fish species in the total volume of fish caught has been analysed.

✉e-mail: marek.ramczyk@utp.edu.pl

METHOD

By the term structure, we mean the layout and mutual correlations between the elements constituting the whole. The subject of interest in the present work is the structure of fish caught in Charzykowskie Lake. The proportions of economically important fish species caught will form a structure. In this particular study, by the structure of fish caught, we shall understand the natural structure. The natural structure is the percentage of the mass of individual fish species caught in the total weight of caught fish. The structure of caught fish in this particular option is therefore considered collectively (en masse).

The analysis of numerical data on caught fish clearly demonstrates that the share of particular species caught in the total volume of fish caught during the studied period is variable. Analysis of the structure of fish caught in Lake Charzykowskie indicates the instability of that structure during the studied period. Variability of the proportions of particular fish species caught in the considered water basin results from specific causes. Therefore, a question arises about the nature of the causes for these changes. What, in what direction, and with what intensity is shaping the structure of the fish volume caught? Consequently, a detailed question was asked, whether environmental conditions during the studied period affected the change in the structure of fish caught in Lake Charzykowskie, considered collectively (en masse), In order to answer that question, it is necessary to analyse the impact of various environmental characteristics of the lake on changes in the share of the volume of economically important fish species in the total volume of fish caught in the considered reservoir. The economic arguments speak for searching for stimulators and obstacles to the development of the fishing economy.

The proportions of individual elements, which make up the structure of fish caught, are changing over time. It can be assumed that the variability of the components of the caught fish volumes is conditioned by many varied environmental factors. The classic model analysis of the impact of important variables on the selected component of the caught fish volume makes it possible to address only the assessment of the impact of each of these variables on the size of this component. However, such research does not create conditions for direct indication of the change in the rank of the given element in the total caught fish volume, nor does it explain the role of individual factors in changing the weight of the considered component within the structure.

An important and necessary solution seems to be an indication of habitat characteristics favouring the increase in the proportion of caught volume of a given fish species in the mass of the total volume of all fish caught, or pinpointing the reasons for the decrease of the considered fraction. Such analysis will also indicate features of the neutral environment, which were hypothetically believed to be actively involved in causing the change to the structure of the volume of caught fish. Understanding the stimulators, deterrents and neutral factors of changes in the proportion of individual elements of caught fish volume in the whole structure is of great cognitive value and of importance to decision making, irrespective of how the lake's economy is managed.

Thus, the question arises: how to investigate these kinds of empirical problems?

Without delving too deep into the traditional methods of analysing structural changes, it is worth pointing out that the measure of the element's share in the total structure (that is, the structure index) belongs to the so-called restricted variables, whose numerical values fall within the range of [0.1] or [0.100] (%). These variables create a more general class of bilaterally limited endogenous variables (Y) characterized by the fact that their observations y_t^* fall within the range of $y_t^* \in \left[y_{\min}^*; y_{\max}^* \right]$, whereas $y_{\min}^*$ is the lowest possible size of the restricted variable, while $y_{\max}^*$ is the maximum size of the observation on this variable.

Restricted variables have a number of disadvantages that make it difficult to use them in the econometric model as endogenous variables. For this reason, we have postulated to use appropriate transformations of such variables, allowing us to avoid shortcomings of the restricted variable. It is easy to demonstrate that any bilaterally restricted variable can be transformed into a variable from the probability range. In order to do this, it will suffice to perform the following transformation:

$$y_t = \frac{y_t{}^* - y_{\min}{}^*}{y_{\max}{}^* - y_{\min}{}^*}, \tag{1}$$

where: y_t – observation after the transformation belonging to the range of $y_t \in (0.1)$,
y_t^* – observation before the transformation.

This paper focuses on the basic transformation ($y_t^{(p)}$), which is a direct transformation of the bilaterally restricted dependent variable (Wiśniewski 1986, 1989, Ramczyk 2001). The basic transformation was calculated according to the following formula:

$$y_t^{(p)} = \frac{y_t}{1 - y_t}. \qquad (2)$$

It "stretches" the observations y_t^* from the range of $\left[y_{\min}^*; y_{\max}^*\right]$, into values falling within the range of $\left\{y_t^{(p)} \in \left[0; +\infty\right)\right\}$.

The basic transformation ($y_t^{(p)}$) of probability is therefore characterized by the fact that the observations $y_t^{(p)}$are non-negative. The values of $y_t^{(p)}$ make up a unilaterally restricted endogenous variable, and as a result they behave identically to the majority of economic variables, such as costs, production volume, employment, fixed assets, labour productivity, etc. The endogenous variable of the econometric model in the form of basic transformation of a restricted variable has analogous properties, like other non-negative economic variables. This means that the basic transformation, in numerical terms, does not deviate from a majority of economic variables. It possesses the quality of invariability in relation to a restricted dependent variable, which makes it easy to interpret its variability. It can be demonstrated that the basic transformation is suitable for any bilaterally restricted endogenous variable. Substituting y_t in the equation (2) with the values of y_t^*, $y_{\max}^*$ and $y_{\min}^*$, we get the basic transformation of each bilaterally restricted dependent variable (y_t^*):

$$y_t^{(p)} = \frac{y_t^* - y_{\min}^*}{y_{\max}^* - y_t^*}. \qquad (3)$$

If there is a need to obtain an observation value of y_t^* based on the value of the basic transformation, there is a simple, general way of calculating that:

$$y_t^* = \frac{y_t^{(p)} y_{\max}^* + y_{\min}^*}{1 + y_t^{(p)}}. \qquad (4)$$

The share of the caught volume of various fish species in the volume of the total fish caught is an indicator of the structure, which belongs to the class of bilaterally restricted variables. It follows that $y_{\min}^* = 0$, whereas $y_{\max}^* = 100\%$. In this situation, the basic transformation of the structure index is as follows:

$$y^{(p)} = \frac{y_t}{100 - y_t}. \qquad (5)$$

The instrument for analysing structural changes in the fisheries management is a linear econometric model in the following form:

$$y_{it}^{(p)} = \sum_{j=0}^{k} \alpha_j \chi_j + \eta_i \ (i = 1, ..., G \text{ oraz } t = 1, ..., n), \qquad (6)$$

where:

$y_{it}^{(p)}$ – endogenous variable of the econometric model in the form of basic transformation of the restricted variable, meaning the share of the i-th economic result in the global efficiency of the lake in the time period of t,

χ_{ij} ($j = 1, ..., k$) – observations on exogenous variables, expressing the values of environmental characteristics from among k considered in the period of t,

α_{ij} – structural parameters of the model being the measures of the individual impact of each of the environmental characteristics on the share of the considered i-th result of the management of the lake's economy,

η_{ti} – random element of the i-th equation,

i – number of equation,

G – number of equations within the model,

n – number of observations.

Further in our work, the subject under consideration is the empirical analysis of structural changes in the fisheries economy of Charzykowskie Lake, using an econometric model with the basic transformation of a limited endogenous variable.

RESULTS AND DISCUSSION

An empirical linear econometric model of type (6) was constructed, consisting of G stochastic equations, and describing the variability in the structure of the volume of fish caught in Charzykowskie Lake. The purpose behind the model's construction is to obtain statistical assessment of the impact of various sequences of environmental factors upon changes in the natural structure of fish caught in the analysed water basin. The parameters of equations for each of the endogenous variables were estimated depending on the environmental variables in the hypolimnion of the lake. The estimation of individual equations was carried out using the classic method of least squares, based on quarterly statistical data.

In the empirical equations of the econometric model describing the impact of changes in the quality of lake waters upon the changes in the structure of fish caught in Charzykowskie Lake, exogenous variables came about, representing the environmental conditions of the lake. Each of these variables turned out to be statistically significant in multiple equations. Endogenous variables of the model (6) reflect the basic transformations of individual indicators of the natural structure of the volume of fish caught. The endogenous variables of the econometric model are therefore:

$UODPŁ_t^{(p)}$ – share of the caught volume of roach in the total volume of fish caught, in the form of basic transformation,

$UODL_t^{(p)}$ – basic transformation of the share of the caught volume of bream in the total volume of fish caught,

$UODK_t^{(p)}$ – share of the volume of carp caught to the total volume of fish caught, in the form of a basic transformation,

$UODSL_t^{(p)}$ – basic transformation of the share of the volume of vendace caught in the total volume of fish caught,

$UODSJ_t^{(p)}$ – basic transformation of the share of the volume of whitefish caught in total volume of fish caught,

$UODW_t^{(p)}$ – basic transformation of the share of the volume of eel caught in the total volume of fish caught,

$UODSZ_t^{(p)}$ – share of the volume of pike caught in the total volume of fish caught, in the form of a basic transformation.

Table 1. Estimated results of the equations describing the shares of individual fish species caught in the total volume of fish caught, depending on changes in the environmental characteristics of the hypolimnion of Charzykowskie Lake (basic transformation)

Endogenous variables Exogenous variables	Evaluation of structural parameters at exogenous variables x_{tj} (j = 1,...,19) Student's t – distribution (t_j)						
	$UODPŁ_t^{(p)}$	$UODL_t^{(p)}$	$UODK_t^{(p)}$	$UODSL_t^{(p)}$	$UODSJ_t^{(p)}$	$UODW_t^{(p)}$	$UODSZ_t^{(p)}$
1	2	3	4	5	6	7	8
U_{t-1}	–0.011 **(3.048)**	0	0	–0.002 **(1.680)**	0.001 **(4.528)**	0.001 **(2.297)**	0
O_{t-1}	0.026 **(3.595)**	–0.003 **(1.738)**	0	–0.008 **(3.068)**	0.001 **(2.197)**	0.001 **(1.194)**	–0.0001 **(1.350)**
PW_{t-1}	0.740 **(1.258)**	0	0.165 **(3.044)**	0	0.056 **(1.492)**	0	–0.021 **(1.900)**
TP_{t-1}	–0.314 **(3.607)**	–0.049 **(1.525)**	0.0009 **(1.676)**	0.114 **(3.352)**	0	–0.025 **(2.485)**	0
WW_t	0.630 **(6.126)**	–0.074 **(2.411)**	0.023 **(2.039)**	0	0	0	–0.005 **(2.590)**
TW_t(d)	–0.622 **(5.179)**	0	0	0.048 **(1.697)**	0	0	0
TR_t(d)	0	–0.070 **(2.320)**	0.040 **(3.831)**	0.073 **(3.159)**	0	–0.018 **(1.357)**	0

Table 1. cd.

1	2	3	4	5	6	7	8
$PEL_t(d)$	0	0	0	0	0	0	0
$FF_t(d)$	0	0	0.227 **(1.871)**	0.866 **(3.098)**	–0.441 **(5.319)**	0	0
$NMIN_t(d)$	0	0.199 **(2.098)**	0	–0.220 **(2.211)**	0	0.058 **(1.339)**	0
$NOG_t(d)$	–0.266 **(1.612)**	0	0,065 **(3.387)**	0	–0.065 **(4.575)**	0	0
$BZT5_t(d)$	0	–0.106 **(3.417)**	0.030 **(2.363)**	0.106 **(3.100)**	-0.018 **(2.384)**	–0.050 **(2.434)**	0.004 **(1.811)**
$CL_t(d)$	–0.375 **(2.475)**	0.165 **(3.428)**	0 **(2,272)**	0	0	0.028 **(1.049)**	0
$OW_t(d)$	2.755 **(4.445)**	–0.376 **(1.623)**	0,175 **(3.244)**	–0.274 **(1.377)**	–0.122 **(2.751)**	0	–0.027 **(2.303)**
$CA_t(d)$	0	–0.034 **(2,584)**	0.007 **(1.601)**	0.032 **(2.412)**	0.008 **(2.279)**	0	0 **(2.281)**
$MG_t(d)$	0.233 **(5,348)**	–0.032 **(1.944)**	0,006 **(1,477)**	–0.045 **(3.384)**	–0.011 **(3.510)**	0	–0.002 **(2.107)**
$TWOG_t(d)$	–1.498 **(3.137)**	0.109 **(2.623)**	0.034 **(2.484)**	0	–0.021 **(2.269)**	0	–0.004 **(1.610)**
$PZOS_t(d)$	0.128 **(4.555)**	–0.018 **(1.478)**	0.009 **(3.354)**	0	–0.005 **(2.978)**	–0.004 **(1.244)**	–0.001 **(3.337)**
$PZOOD_t(d)$	–0.671 **(3.518)**	0.134 **(2.101)**	–0.024 **(1.346)**	0.101 **(1.935)**	0.017 **(1.330)**	0.095 **(4.007)**	0
R^2	0.8617	0.8278	0.8520	0.7193	0.8851	0.5743	0.6319
$\hat{\alpha}_\eta$	0.8923	0.2616	0.0856	0.2741	0.0657	0.1490	0.0214
DW	2.4040	2.3070	2.5750	5.4410	2.5050	2.1500	2.3580
$\hat{\rho}_1$	–0.1615	–0.1896	–0.2895	–0.2476	–0.2776	–0.2679	–0.2105

Source: Author's own calculations.

Table 1 presents the estimated results of the equations describing transformations ($y_t^{(p)}$) of the volume share of the following fish species caught: roach, bream, carp, vendace, whitefish, eel, and pike, in the total volumes of fish caught, depending on changes in the environmental factors within the hypolimnion of Charzykowskie Lake. In the equations of $UODP£_t^{(p)}$, $UODL_t^{(p)}$, $UODK_t^{(p)}$, $UODSL_t^{(p)}$, $UODSJ_t^{(p)}$, $UODW_t^{(p)}$ and $UODSZ_t^{(p)}$, in general, many statistically significant exogenous variables have been found. Thus, there are few characteristics of hypolimnion water that are neutral for the transformation of basic, highlighted structure indicators. It can be assumed that this state of affairs results from greater pollution of the demersal waters in the analysed reservoir. Higher concentrations of various types of contaminants in the demersal layer of the reservoir, as compared to the surface waters of the lake, are conducive to the escalation of impact on endogenous variables.

A significant number of stimulators for the increase in the proportion of carp fish caught in the total volume of fish caught deserves our attention. On the other hand, the increase in the basic transformation of this structure index was inhibited in the observed variability range due to the excessive concentration of chlorides in the demersal zone of the lake, as well as excessive content of organic matter in bottom sediments. Even the more contaminated hypolimnion water of Charzykowskie Lake (carp can also tolerate such waters) still remained favourable at the time of the study in terms of the share of the *Blicca bjoerkna* caught in the global volume of all fish caught. This means that changes in the water quality in the Charzykowskie Lake during the studied period favoured the increase in the population of the *Blicca bjoerkana* species, generally more resistant to the increase of water pollution.

In the case of variables $UODP£_t^{(p)}$ and $UODL_t^{(p)}$, the interpretation of modelling results is different, though. Among the statistically significant exogenous variables of the equation describing the transformation ($y_t^{(p)}$) of the volume share of roach caught in the total volume of fish caught, we can indicate both the factors favouring the increase of the above structure index, and the factors causing the decrease of the considered share. The $UODL_t^{(p)}$ equation demonstrates that the vast majority of exogenous variables, which are significant in the statistical sense, participate as a deterrent in changes to the structure of *Abramis brama* species structure of fish caught. Higher pollution of the lake in the demersal zone strengthened the above correlation.

Therefore, the question arises as to the reasons for such differentiation of the impact of environmental factors on the basic transformation of the share of caught volume of the considered cyprinids in the total volume of fish caught. It can be assumed that this results from similar requirements that the bream, roach, and carp have regarding water quality. The observed increase in the pollution of lake waters, with similar habitat requirements of these fish species, may cause a kind of competition between them that negatively influences the development of some of these species' populations. This is clearly indicated by the empirical results obtained.

It is also worth emphasizing that among exogenous variables, only $CL_t^{(d)}$, $OW_t^{(d)}$, $MG_t^{(d)}$, $TWOG_t^{(d)}$, $PZOS_t^{(d)}$, $PZOOD_t^{(d)}$, TP_{t-1} and WW_{t-1} are statistically significant in shaping the share of the caught volume of each of the analysed cyprinids in the total volume of all fish caught, however the direction of the influence of none of the variables is the same for all these structure indicators.

Table 1 also shows that a relatively large number of statistically significant exogenous variables in the observed variability range, in general, inhibited the basic transformations in the volume share of freshwater whitefish and predatory fish in the total volume of fish caught in Charzykowskie Lake. Particularly worth noting is the considerable number of factors that significantly affect the variation in the volume share of *Coregonus albula* in the total volume of fish caught.

The species of: *Coregonus albula, Coregonus lavaretus, Anguilla anguilla* and *Esox lucius* are less resistant to water pollution than the considered species of fish in the carp family (*Rutilus rutilus, Abramis brama*, and *Blicca bjoerk*na). In the conditions of the hypolimnion contamination of the analysed lake observed during the sampling period, the decrease in the fraction of the caught freshwater whitefish and predatory fish in the total volume of all fish caught becomes understandable. Of course, this also favours the growth of fish populations that are more resistant to poorer water quality.

The analysis of the influence of environmental factors on the basic transformations of the caught volumes of the considered fish species in the total volumes of fish caught reveals that none of the variables affects all the listed indicators of the natural structure in a statistically significant way during the sampling period. At most, we are able to indicate – as in the case of fish from the carp family – the common determinants of the structure of caught fish volume for the analysed predatory fish and freshwater whitefish. These include the variables of: O_{t-1} and $BZT5_t^{(d)}$. We also note that the $PEL_t^{(d)}$ variable, in the sense of statistical criteria, did not affect any of the analysed indicators of the natural structure of caught fish volumes in the observed variability range. The large number of statistically significant exogenous variables in the equations describing the structure of the volume of fish caught depending on the water quality in the hypolimnion seems to indicate a significant measurable impact of the habitat conditions of the Charzykowskie Lake demersal zone on the basic transformations of the studied aspects of the fisheries economy management structure.

CONCLUSIONS

In the conducted empirical studies, the impact of environmental factors on the natural structure of fish caught in Charzykowskie Lake was analysed. The empirical results indicate that most measures of water pollution cause changes in the structure of caught fish volumes. At the same time, it is evident that increasing the degree of pollution of the lake is conducive to increasing the proportion in the total volume of fish caught of species that yield lower economic benefits, while it inhibits the increase in the fraction of species that are more economically valuable. Thus, the activity aimed at limiting the pollution of the lake is conducive to increasing the share of species that are much more economically efficient. Structural changes of this type therefore indicate a specific competition between fish species with different environmental requirements, although the empirical results of econometric modelling suggest the existence of this type of competition also in the group of fish with similar needs regarding the quality of the habitat. Therefore, this situation determines the nature of the effects in the fisheries economy of Charzykowskie Lake. From the point of view of changes in the structure of fish population in Charzykowskie Lake, in the observed variability range of the model variables, there are also neutral factors that had been potentially considered to be actively involved in changing the caught fish volume structure indicators.

The constructed linear econometric model of the impact of changes in the quality of lake waters on changes in the structure of caught fish volume is stable in the conditions prevailing during the sampling period. The research method, and the empirical results are encouraging and the studies should continue. Further research should focus on the nature of changes in the structure of caught fish in conditions of limiting the inflow of pollutants to Charzykowskie Lake.

REFERENCES

Ramczyk, M. (2001). Ekonometryczny model wpływu zmian jakości wód jeziornych na zmiany struktury odłowów ryb. Zagadnienia metodyczne, Zeszyty Naukowe Uniwersytetu Szczecińskiego, 320, 335–344.

Wiśniewski, J. W. (1986). Ekonometryczne badanie zjawisk jakościowych, Toruń: UMK.

Wiśniewski, J. W. (1989). Uwagi o logitowej transformacji ograniczonej zmiennej endogenicznej w dynamicznym modelu ekonometrycznym. Wiadomości Statystyczne, 3, 27–30.

MODEL EKONOMETRYCZNY JAKO INSTRUMENT ANALIZY ZMIAN STRUKTURALNYCH W GOSPODARCE RYBACKIEJ JEZIOR

STRESZCZENIE

Model ekonometryczny może być precyzyjnym narzędziem analizy wpływu pogorszenia stanu środowiska naturalnego na efekty gospodarowania. W pracy przedstawiono wyniki badań wpływu zanieczyszczenia wód Jeziora Charzykowskiego na skutki gospodarki rybackiej. Zostały wykonane modele gospodarczo -ekologiczne, tłumaczące zmiany efektów ekonomicznych połowów w jeziorze w warunkach wzrostu zanieczyszczenia wody i optymalnego poziomu zawartości różnych substancji w wodzie jeziora, z punktu widzenia gospodarki rybackiej. W przeprowadzonych badaniach empirycznych analizowano oddziaływanie czynników środowiskowych na strukturę naturalną odławianych ryb w Jeziorze Charzykowskim. Wyniki empiryczne wskazują, że większość miar zanieczyszczenia wód powoduje zmiany struktury odłowów ryb. Przy czym widać wyraźnie, że zwiększenie stopnia zanieczyszczenia jeziora sprzyja powiększaniu proporcji odłowów gatunków dających mniejsze korzyści ekonomiczne, a hamuje wzrost frakcji połowów gatunków cenniejszych gospodarczo. Tym samym działalność ograniczająca zanieczyszczenia

jeziora sprzyja zwiększeniu udziału gatunków zdecydowanie bardziej efektywnych ekonomicznie. Tego typu zmiany strukturalne świadczą więc o swoistej konkurencji między gatunkami ryb o odmiennych wymaganiach środowiskowych, chociaż rezultaty empiryczne modelowania ekonometrycznego sugerują istnienie tego rodzaju konkurencji również w grupie ryb o zbliżonych potrzebach dotyczących jakości siedliska. Sytuacja taka determinuje zatem charakter skutków w gospodarce rybackiej J. Charzykowskiego. Z punktu widzenia zmian struktury populacji ryb w Jeziorze Charzykowskim w obserwowanym przedziale zmienności zmiennych modelu istnieją też czynniki neutralne, które potencjalnie uznawano za aktywnie uczestniczące w zmianach wskaźników struktury odłowów ryb. Zaproponowane procedury optymalizacji mogą być instrumentem programowania efektywności gospodarki rybackiej w celu utrzymania równowagi ekologicznej.

Słowa kluczowe: model ekonometryczny, zanieczyszczenie wód, gospodarka rybacka