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SELF-ORGANIZATION EFFECTS IN REGIONAL ENVIRONMENTAL MONITORING SYSTEMS – AN ASSESSMENT AND GOVERNANCE IMPLICATIONS

Khodyko Dmitrii Igorevich
Candidate of Economic Sc., Assoc. Prof. of Dept. of Economy of Ukraine
Ivan Franko National University of Lviv, Ukraine

A heuristic concept of institutional self-organization in regional environmental monitoring systems is proposed and tested with a cross-country example. The effect of pollutants' health and environmental impact upon their coverage in annual monitoring programs is modeled using logistic regression with random effects, controlling for central government budget allocations. Statistical estimations show the varying degree of self-organizing systems' capability of efficiently mediating macro policy signals. A regular assessment of this kind may provide the screening criteria for efficiency audit, as well as design, of environmental monitoring systems, and assist in establishing co-financing amounts and structures for environmental administration.

Keywords: *institutional self-organization, environmental monitoring, environmental governance, socio-ecological systems, fiscal decentralization, Ukraine, Poland.*

Introduction. Development of scientific methodology, as well as policy instruments, for sustainable governance of socio-ecological systems remains a practical and intellectual challenge. As Hryniv (2009) has stressed, the existing policy approaches to sustainability are clearly inadequate to the complex ontology of spatially determined territorial systems constituting the biosphere [1].

Given the spatial heterogeneity of socio-ecological landscapes, the regional governance systems are required to become the key policy instrument for transition towards sustainability. The desired degree of decentralization of sustainable governance functions is, however, still an open question. This issue is particularly important for environmental monitoring subsystems, as monitoring comprehensiveness and sensitivity determines the predictability of ecosystems dynamics, including global ecological change processes. Full decentralization in scoping and scaling of monitoring systems, as well as in their financial supply, would arguably disrupt the interregional coordination of governance efforts, which is

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necessary on national, cross-border and supranational levels.

An empirical approach to this issue would take into account the specific nature of socio-ecological landscapes as complex open systems governed by biophysical laws [1] [6]. Dynamics of these systems are, according to this methodology, constituted by exogenous impact of external environment (in both ecological and institutional sense) on the one hand, and by endogenous feedbacks on the other. The parameters of regional environmental monitoring systems, such as monitoring comprehensiveness, spatial and temporal density, detection sensitivity etc., may be determined exogenously or endogenously to various extents, possibly differing across regions. It is worth noting that the presence of diverse monitoring subjects with their own subordination and particular instruments disallows an a priori evaluation of modeling approaches, while at the same time leaving the possibility for detection of both groups of effects. Each of the possible outcomes may have far-reaching governance implications.

Analysis of recent research and publications. The applicability of non-equilibrium thermodynamic concepts to description and analysis of social and economic processes is hotly debated in the theoretical literature. Luhmann's (2012) evolutionary systems-theoretical approach [2] to the emergence of social structures is increasingly supported with development of a class of formal conflictological models, e.g. by Elsner and Heinrich (2011) [3]. Samet (2012) comes closer to transdisciplinary thought by considering institutional emergence as the process of investment capital dissipation [4], which presents a direct analogy to dissipation of energy in self-organized non-equilibrium systems studied by Ilya Prigogine. On the other hand, Bateira (2007) argues for only an heuristic value of transdisciplinary transitions of this kind, denying methodological applicability of biological or biophysical concepts to institutional evolution processes [5].

The ongoing discussion may suggest the high context sensitivity of arguments concerning the economic meaning of open systems theory applications. The fundamental role of photosynthetic production in biospheric emergence undoubtedly provides solid scientific foundation for the recent transdisciplinary developments in ecological economics treating regions as complex natural, social and environmental systems shaped by processes of self-organization and entropy production [6]. While institutions in this context may be treated as subsystems subject to the same evolutionary processes in biospheric environment, the specific nature of negentropic and entropic processes in economies and governance structures remains unknown. For this reason, we might presently only suggest a heuristic concept of institutional self-organization to describe the variety of exogenous and endogenous impacts upon parameters of regional environmental monitoring systems.

Previously unsettled constituent problem. While the mainstream discussion

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over open systems theory in economics focuses primarily on methodological issues, the research directed towards empirical assessment of the systems parameters, as well as policy implications of the methodology is more scarce. A brief review of contemporary governance principles further justified by the transdisciplinary approach, including target-based programming, action analysis planning, and resolution of conflicts between environmental perspectives on various territorial levels, is provided in [6]. However, further policy-oriented research informed by the methodology and grounded in quantitative empirical estimations is required. On the other hand, measurement problems can easily be identified as one of the major factors hindering progress in this direction.

The main purpose of the article is to develop an instrument for statistical estimation of self-organization effects in regional environmental monitoring systems and thus provide an empirical guideline for their design and financial supply. The paper concludes by a brief discussion of environmental and economic policy implications of the proposed concept of institutional self-organization.

Results and discussion. According to the heuristic concept, regional environmental monitoring systems may be expected to respond to exogenous changes in macro policy environment, such as in financial allocations, by endogenously adjusting their functions and structures in processes which could be described as dissipation of external financial supply.

The proposed design of statistical models was governed by the possibility of using conventional and readily available economic and environmental data. Air and ground pollution monitoring was chosen as an example due to clarity of monitoring aims and functioning in this case. The degree of health and environmental safety of polluting substances are expected to influence the parameters of monitoring system, such as coverage of the pollutant, observations density, and detection methodology. This effect may be mediated or moderated by exogenous and/or endogenous factors, which the presented models aim to capture and differentiate. One of the possible general designs can include the pollutant safety variable to estimate its effect independently of region-specific conditions, as well as the effect of its interaction with the regional factors. Self-organization processes could then be captured by comparably high statistical significance of both effect groups. While financial supply of the monitoring system may include the nation-level or region-level budget allocations, the considered issue of centralized financing justifies the inclusion of nation-level budget allocations as an external environment factor of monitoring functioning.

The model of logistic regression, treating pollutant coverage as a probabilistic indicator, was chosen for testing. Coverage of a particular pollutant by a regional monitoring program in a given year was chosen as the binary dependent variable. The

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safety of polluting substances was represented by their safety class according to Ukrainian State Standard 12.1.007, the indicator ranging from 1 for the most harmful substances to 4 for the least harmful. The treatments of the variable as a factor or as a covariate, each requiring its own model specification, are essential for capturing the mechanism of its impact. As a factor, it represents the spatially independent effect of pollutant safety on monitoring system parameters. When included as a covariate, it moderates the effect of region-specific factors. This framework thus contrasts the modeling approaches treating the impact of a pollutant's class on monitoring coverage as exogenous or endogenous.

Two logistic regression specifications with random effects were built with the dependent binary response Observation variable. Both models included categorical factors, Nation and Region, to capture the corresponding level effects, as well as the monitoring agencies' central government budget figures, used to approximate the financial supply of monitoring activities. The latter Budget variable was included as a continuous covariate. In the first model, the exogenous impact of pollutants' safety class was modeled by inclusion of categorical Class factor as a main effect. In the second model, the endogenous impact was modeled by inclusion of ordinal Class covariate, and the Region-Class interaction effect was estimated.

The data set consisted of regional environmental monitoring metadata compiled from the 2008-2012 monitoring programs for two regions of Ukraine, namely Lvivska [7] and Zakarpatska [8] regions, as well as two voivodships of Republic of Poland, namely Podkarpackie and Malopolskie voivodships [9]. The polluting substances included the following six air pollutants: carbon oxide (4), formaldehyde (2), ammonia (4), phenol (2), chlorine (2), lead (1); as well as two ground pollutants: cadmium (1), oil products (4). The values in brackets show the pollutants' safety class. The central government budget figures for the actual monitoring agencies, the Ukrainian State Sanitary Control budgetary program (the program expenditure code 2301250) and the Polish Chief Inspectorate of Environmental Protection (expenditure partition 90014), were obtained from the respective legislative sources [10] [11]. The central budget allocation figures for Poland were extracted on voivodship levels, while for Ukraine the general allocation figures were included. While these heterogeneities in the data disallow direct comparisons of the budget main effects, the estimated interaction effects still remain informative. All figures were converted to UAH thousands using the average 2008-2012 PLN/UAH exchange rate.

The generalized linear model estimation method was used for actual calculations, performed using SPSS 16.0 software. The selected estimation results, adapted from the software output, are provided below in Table 1. The table shows size and significance of variable effects for both models, as well as some parameter estimates for the second model.

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Table 1

Estimation of logistic regression models with random effects

	Wald Chi-Square	df	Sig.
Class	16.104	2	.000
Nation * Budget	10.325	2	.006
Region * Nation * Budget	1.443	1	.230

Dependent Variable: Observation
Model: (Intercept), Class, Nation * Budget, Region * Nation * Budget

	Wald Chi-Square	df	Sig.
Region * Class	17.870	4	.001
Nation * Budget	5.947	2	.051
Region * Nation * Budget	7.819	2	.020

Dependent Variable: Observation
Model: (Intercept), Region*Class, Nation*Budget, Region*Nation*Budget

Parameter	B	Std. Error	Wald χ^2	df	Sig.
[Reg=Lviv] * Class	1.356	.4859	7.788	1	.005
[Reg=Malopol] * Class	-.559	.2991	3.493	1	.062
[Reg=Podkarp] * Class	-.708	.2964	5.705	1	.017
[Reg=L]*[Nat=UA]*Budg	-2.933E-6	1.1001E-6	7.107	1	.008

Source: adapted from SPSS 16.0 output

We find that, for both specifications, the model effects are generally significant with $p<0.001$. In the first model, no significant region-level effects remain after controlling for the exogenous effect of pollutants' class and central government budget allocation. The second model captures various within-region interaction effects of pollutants' class upon their monitoring coverage, as well as national and regional sensitivities towards central budgeting changes. The reverse sign of Region-Nation-Budget interaction effect for Lviv region of Ukraine may seem unexpected; however, this may be practically interpreted as a weaker impact of financial allocation increase upon pollutants coverage compared to other regions. Similarly, the reverse sign of Region-Class interaction effect, with a positive impact expected, indicates that due to absence of direct need, some of the more harmful pollutants are not being monitored in the region. This means that the region-level adaptation of the monitoring system has a potentially negative impact, tending to ignore some of the ecological and health exposures associated with lower event probabilities.

Conclusion and further research directions. The obtained results confirm that the ability of regional environmental monitoring systems to adapt for changes in the external environment, as well as potentially positive or negative environmental

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impact of such adaptation, are subject to cross-regional and cross-country statistical estimation. The comparable statistical significance of model and variable effects for both specifications shows a degree of equivalence of endogenous and exogenous approaches to modeling of factors shaping the regional monitoring systems, which may be interpreted as a result testifying for validity of the proposed institutional self-organization concept. This implies practical significance of the developed framework and suggests a number of policy implications.

The design of an open, in a financial and informational sense, regional environmental monitoring system should possess the key capability of efficiently mediating macro policy signals to economic subjects. In a fiscally decentralized regional governance network, the informational function of central government budget allocation becomes more prominent. With the regional environmental governance systems in place possessing self-organization properties, the level of central budget allocation signals the degree of acceptable regulation or deregulation of nature use relations. The empirical validity of the latter statement, which may be termed the environmental rights allocation hypothesis, requires comprehensive testing in itself. However, it can be theoretically derived from various institutional self-organization concepts. If true, the statement suggests a new perspective for discussion of centralization and decentralization of environmental administration and finance. Decentralization of financial sources signals for centralized environmental deregulation and does not (as the above discussed results for Lviv region may suggest) guarantee the ecological efficiency of the system. The centralized financing, on the other hand, while implying the more effective regulation, increases the risk of exogenous disruption of regional governance systems due to short-term budget fluctuations. Similar considerations apply on cross-border, supranational or global levels of environmental policy and administration.

The institutional self-organization effects estimated within a statistical framework may therefore inform the cross-regional environmental governance in two ways. First, an assessment of self-organization capability and impact can be used as screening of the governance system to identify best practices and deficiencies in regional monitoring systems for their audit and improvement. Second, a regular assessment, within institutional monitoring and target-based programming frameworks, may be used to establish the amounts and structure of environmental administration co-financing from various centralized and decentralized sources, which would facilitate management of the above mentioned perverse incentives and budget shocks risks.

As one of the possible directions for further policy-oriented research, the empirical investigation of institutional self-organization, and particularly within the context of the above expressed environmental rights allocation hypothesis, may be

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emphasized. Elaboration and testing of this hypothesis would require application of spatial econometric instruments, as well as explicit modeling of institutional emergence.

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ЕФЕКТИ САМООРГАНІЗАЦІЇ У СИСТЕМАХ РЕГІОНАЛЬНОГО ЕКОЛОГІЧНОГО МОНІТОРИНГУ — ОЦІНКА ТА ВИСНОВКИ ДЛЯ УПРАВЛІННЯ

Ходико Дмитро Ігорович
кандидат економічних наук, доцент кафедри економіки України
Львівський національний університет ім. І. Франка, Україна

Запропоновано евристичну концепцію інституційної самоорганізації у регіональних системах екологічного моніторингу. Запропоновану концепцію протестовано на прикладі регіонів двох країн. За допомогою логістичної регресії з випадковими ефектами змодельовано статистичний зв'язок санітарно-екологічного впливу забруднювачів із їх включенням у щорічні програми моніторингу, з урахуванням розподілу відповідних видатків з державного бюджету. Оцінки свідчать про наявність відмінностей у здатності самоорганізуючих систем до ефективної передачі управляючих сигналів макрорівня. Проведення регулярного оцінювання подібного типу здатне виявити попередні критерії для проектування та аудиту ефективності систем екологічного моніторингу, а також надати інформацію для визначення обсягів та структури співфінансування екологічної адміністрації.

Ключові слова: інституційна самоорганізація, екологічний моніторинг, екологічне управління, соціоекологічні системи, фіскальна децентралізація, Україна, Польща.

ЭФФЕКТЫ САМООРГАНИЗАЦИИ В СИСТЕМАХ РЕГИОНАЛЬНОГО ЭКОЛОГИЧЕСКОГО МОНИТОРИНГА — ОЦЕНКА И ВЫВОДЫ ДЛЯ УПРАВЛЕНИЯ

Ходыко Дмитрий Игоревич
кандидат экономических наук, доцент кафедры экономики Украины
Львовский национальный университет им. И.Франко, Украина

Предложена эвристическая концепция институциональной самоорганизации в региональных системах экологического мониторинга. Предложенная концепция протестирована на примере регионов двух стран. С помощью логистической регрессии со случайными эффектами смоделирована статистическая связь между санитарно-экологическим влиянием загрязняющих веществ и их включением в ежегодные программы мониторинга, с учетом распределения соответствующих расходов государственного бюджета. Оценки свидетельствуют о различиях в способности самоорганизующихся систем к эффективной передаче управляющих сигналов макроуровня. Проведение регулярного оценивания подобного типа способно выявить предварительные критерии для проектирования и аудита эффективности систем экологического мониторинга, а также предоставить информацию для определения объемов и структуры софинансирования экологической администрации.

Ключевые слова: институциональная самоорганизация, экологический мониторинг, экологическое управление, социоэкологические системы, фискальная децентрализация, Украина, Польша.