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## GLOBAL TRADE UNDER PLANETARY CONSTRAINTS: RECONSIDERING THE "POLLUTION HAVEN" AND "POLLUTION HALO" EFFECTS

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ГЛОБАЛЬНА ТОРГІВЛЯ В УМОВАХ ПЛАНЕТАРНИХ ОБМЕЖЕНЬ: ПЕРЕОСМИСЛЕННЯ  
ЕФЕКТІВ "ЗАБРУДНЮВАЛЬНОГО ПРИТУЛКУ" І "ЗАБРУДНЮВАЛЬНОГО ОРЕОЛУ"

*The aim of the article is to theoretically rethink the effects of "pollution haven" and "pollution halo" in the context of planetary boundaries by substantiating a multidimensional analytical framework in which "global trade" serves as a mechanism for redistributing environmental pressure across planetary boundary dimensions, sectors, and countries. The article argues for a shift in analytical optics from a territorially limited interpretation of "international trade" to a systemic understanding of "global trade," encompassing the functioning of transnational production networks and global value chains, along with the associated flows of resources, energy, materials, and environmental burdens. It is shown that under such conditions, the environmental consequences of production and consumption are formed within a single global economic system, and the key empirical and conceptual problem becomes the gap between the place of production and the place of consumption, between territorial environmental indicators and the actual environmental footprint of final demand.*

*The theoretical core of the study is the integration of the concept of planetary boundaries into trade analysis, thereby moving from a one-dimensional focus on carbon emissions to a multidimensional account of pressure on biophysical processes. The classic dichotomy between the "pollution haven" and the "pollution halo" has been shown to take on a different meaning within planetary constraints: the "pollution haven" manifests itself as a systemic transfer of pressures to particular boundaries, including biogeochemical nitrogen and phosphorus fluxes, land-use change, freshwater resources, biodiversity loss, and the accumulation of "novel entities" in production chains, while the "pollution halo" implies a reduction in the intensity of these pressures through technological and institutional channels associated with the diffusion of cleaner technologies, environmental management standards, certification, and supply chain requirements.*

*It is shown that the positive and negative effects of trade are not mutually exclusive, but coexist within the framework of global production and consumption relations: the technique effect can reduce resource intensity and emissions per unit of output, but the scale effect and composition effect can offset these benefits due to the growth of demand and specialization in environmentally intensive sectors. Three analytical steps of the study are argued: the transition from the national to the global level of environmental performance assessment, the sectoral decomposition of pressure on planetary boundaries, and the combination of technological and institutional dimensions of regulation, which determines the role of standards and trade rules in containing the "pollution haven effect" and strengthening the "halo effect".*

**Мета статті** полягає у теоретичному переосмисленні ефектів "забруднювального притулку" і "забруднювального ореолу" в умовах планетарних обмежень шляхом обґрунтування багатовимірної аналітичної рамки, у межах якої "глобальна торгівля" постає механізмом перерозподілу екологічного тиску між вимірами планетарних меж, секторами та країнами. У статті обґрунтовано необхідність зміщення аналітичної оптики від територіально обмеженого трактування "міжнародної торгівлі" до системного розуміння "глобальної торгівлі", що охоплює функціонування транснаціональних виробничих мереж, глобальних ланцюгів створення вартості та пов'язаних із ними потоків ресурсів, енергії, матеріалів і екологічного навантаження. Показано, що за таких умов екологічні наслідки виробництва і споживання формуються у межах єдиної глобальної економічної системи, а ключовою емпіричною та концептуальною проблемою стає розрив між місцем виробництва і місцем споживання, між територіальними екологічними показниками і фактичним екологічним слідом кінцевого попиту.

Теоретичним ядром дослідження визначено інтеграцію концепції планетарних меж в аналіз торгівлі, що забезпечує перехід від одновимірного підходу, зведеного до вуглецевих викидів, до багатовимірного опису тиску на біофізичні процеси. Доведено, що класична дихотомія між "ефектом притулку" і "ефектом ореолу" набуває іншого змісту у межах планетарних обмежень: "забруднювальний ореол" означає зниження інтенсивності тиску через технологічні та інституційні канали, пов'язані з дифузією чистіших технологій, стандартами екологічного менеджменту, сертифікацією та вимогами до ланцюгів постачання.

Показано, що позитивні і негативні ефекти торгівлі не є взаємовиключними, а співіснують у межах глобальних виробничих і споживчих зв'язків: технологічний ефект може знижувати ресурсомісткість і викиди на одиницю продукції, однак ефект масштабу і структурний ефект здатні нівелювати ці переваги через зростання обсягів попиту і спеціалізацію на екологічно інтенсивних секторах. Запропоновано трьохетапне оцінювання: перехід від національного до глобального рівня оцінювання екологічної результативності, секторальна декомпозиція тиску на планетарні межі та поєднання технологічного й інституційного вимірів регулювання, що визначає роль стандартів і торговельних правил у стримуванні "ефекту притулку" та підсиленні "ефекту ореолу".

Доведено, що в умовах зростання гео економічної конкуренції торгівля дедалі більше виконує функції управління екологічним простором, а торговельна політика трансформується з інструменту лібералізації в механізм екологічного регулювання. У цьому контексті концепт "політики руйнівної кулі" інтерпретується як демонтаж моделі глобалізації, де екологічні витрати залишалися зовнішніми щодо торговельних режимів, і як перехід до конкуренції за можливість перерозподілу тиску в межах планетарних обмежень. Зроблено висновок, що екологічна стійкість не може оцінюватися виключно за територіальними показниками, оскільки національні поліпшення здатні відображати зміну географії і структури тиску, а не його глобальне скорочення. Окреслено, що перспективи подальших досліджень пов'язані з визначенням таких комбінацій стандартів, технологічних режимів і торговельних правил, які забезпечують не лише перерозподіл, а реальне зниження глобального екологічного тиску в межах планетарних обмежень.

*Key words:* global trade, international trade, international markets, imperative, economic development, regulation, modernization, competition, liberalization, relocation, multinational corporations, greening, environmental standards, restrictions, barriers, green trade, energy resources, carbon footprint, trade policy, value chains, international cooperation, wrecking ball policies, pollutant haven effect, pollutant halo effect.

*Ключові слова:* глобальна торгівля, міжнародна торгівля, міжнародні ринки, імператив, економічний розвиток, регулювання, модернізація, конкуренція, лібералізація, релокація, ТНК, екологізація, екологічні стандарти, обмеження, бар'єри, зелена торгівля, енергетичні ресурси, вуглецевий слід, торгова політика, ланцюги вартості, міжнародне співробітництво, політики руйнівної кулі, ефект забруднювального притулку, ефект забруднювального ореолу.

## PROBLEM STATEMENT

The relevance of the study lies in deepening the relationship between trade processes and biophysical constraints on development, thereby extending the

analysis of trade's environmental impact beyond the classical analysis of interstate exchange. In the modern economy, production, consumption, and the movement of

resources are organized in complex transnational production networks, within which the environmental consequences of economic activity are distributed across countries, sectors, and components of the Earth system. Under such conditions, the traditional use of the term "international trade" does not fully reflect the true scale and nature of the processes that drive global environmental pressure. The study uses the concept of "global trade" as an analytical category that covers not only the interstate exchange of goods and services, but also the functioning of global value chains, transnational production networks, and the associated flows of resources, energy, and materials. This approach allows us to consider trade as a component of a single global economic system, within which pressure on planetary boundaries is formed and redistributed. It is in this system that the gap between the place of production and the place of consumption, between territorial environmental indicators and the actual ecological footprint of final demand, arises.

The use of the concept of "global trade" is also driven by the need to reconcile economic analysis with the concept of planetary boundaries, which describes the aggregate biophysical limitations on the functioning of the world economy. Since these boundaries are supranational and do not coincide with state borders, assessing the impact of trade processes on the environment requires moving from a territorially limited approach to a systemic global analysis. In this context, global trade is seen as a mechanism for redistributing environmental pressure between different components of the world economy and different dimensions of planetary limitations.

This approach allows us to rethink the traditional dichotomy of the "pollution haven" and "pollution halo" effects and consider them as interconnected manifestations of a single process of global redistribution of the environmental burden. This determines the study's scientific relevance and necessitates the development of a multidimensional analytical framework that reflects the modern role of trade in the interaction between economic development and planetary environmental constraints. In the following, the term "trade" is used in the sense of "global trade", since the analysis covers not only interstate exchange, but also transnational production networks and the associated flows of resources and environmental pressure. Additional relevance to the study is provided by the shift in the global political economy to the regime of "wrecking-ball politics", within which trade and technological tools are increasingly used to dismantle regimes of interdependence and redistribute access to resources and "ecological space". Under these conditions, the impact of trade on the environment acquires not only a technical and environmental, but also a geoeconomic meaning, which reinforces the need for a multidimensional interpretation of the effects of the "pollution haven" and "pollution halo" across planetary boundaries".

## ANALYSIS OF RESEARCH AND PUBLICATIONS

In modern scientific literature, the relationship between global trade and the environment is increasingly viewed through the prism of the structural restructuring of the world economy amid growing environmental constraints.

Trade is interpreted not only as a mechanism for the exchange of goods and services, but also as a channel for the redistribution of resources, environmental costs, and technological advantages between countries. Attention is paid to the impact of environmental regulation on international competitiveness and the spatial configuration of production, which creates the prerequisites for the relocation of environmentally intensive sectors to jurisdictions with less stringent standards [1]. In this context, the concept of a "green" economy is developing as a systemic response to the limited natural resources and the need to reconcile economic development with environmental limits [2].

Within this evolution, the metaphor of "wrecking-ball politics" is increasingly used, reflecting the transition from the assumption of neutrality or openness to practices in which trade, standards, and market-access rules encode the struggle for control over the flows of resources, technologies, and environmental costs. In this logic, "pollution haven" and "pollution halo" should be interpreted as interrelated modalities of the redistribution of environmental pressure within global value chains. Analysis of global value chains shows that the environmental consequences of production are concentrated in certain segments of production networks, while the main added value may be generated in other regions [3]. Methodological approaches to the analysis of the development of the "green" economy as a socio-ecological-economic system emphasize the need for directed, regular, and irreversible changes in the structure of production, exchange, and consumption. In this logic, international trade is considered a mechanism capable of both accelerating ecological modernization and reproducing global disparities in the use of natural resources, depending on the institutional and technological parameters of economies [4; 5]. At the same time, the digital transformation of the global economy is considered a factor in changing the structure of international exchange and resource use [6]. In works devoted to global risks and the new configuration of the world economy, it is emphasized that environmental constraints are becoming a determining factor in the formation of competitive advantages and development strategies [7; 8]. The issue of global asymmetries of development refers to the uneven distribution of environmental burdens across the world economy [9]. In studies of the environmental imperatives of globalization, the relationship between the transnationalization of production, international trade, and the use of natural resources is emphasized [10; 11]. Understanding modern macroeconomic transformations and crisis processes underscores the growing role of environmental factors in shaping a new model of global development [12]. The greening of global production and trade is considered a systemic process that determines new parameters of international specialization and market access conditions [13; 14; 15]. The generalization of scientific approaches allows us to conclude that global trade under planetary constraints functions as a mechanism for redistributing ecological space and resources [16—20]. Rethinking the effects of the "pollution haven" and "pollution halo" involves moving from analyzing the impact of trade on emissions to studying the struggle for

control over resources, technologies, and environmental standards that shape the new configuration of the world economy.

## FORMULATION OF THE ARTICLE'S OBJECTIVES

The aim of the article is to theoretically rethink the effects of "pollution haven" and "pollution halo" in the context of planetary boundaries by substantiating a multidimensional analytical framework that views global trade as a mechanism for redistributing environmental pressure across the dimensions of planetary boundaries.

## THE PAPER'S MAIN BODY

The impact of global trade on environmental performance is the subject of extensive scientific debate: research focuses on both the positive effects of integration into the global economy and the negative effects of expanding production and trade. Two opposing interpretations have emerged within this discussion. On the one hand, the "pollution haven hypothesis" is substantiated. It is based on the idea that countries with less stringent environmental standards have a comparative advantage in producing environmentally intensive products. Trade liberalization under such conditions can stimulate the relocation of resource-intensive, polluting industries to jurisdictions with softer regulations. The negative effect manifests through scale and composition effects: the total volume of production increases, specialization in raw materials and energy-intensive industries increases, and consumption of water, land, energy, and chemical resources increases. In this logic, global trade appears as a mechanism for redistributing environmental burdens in favor of consumers in developed countries and to the detriment of producers in countries with lower levels of regulation. On the other hand, the hypothesis of the "pollution halo effect" is substantiated. International integration contributes to the diffusion of cleaner technologies, increased productivity, and the introduction of environmental management standards.

The positive effect arises through the technique effect: transnational corporations and global value chains spread more efficient production practices, certification standards, and emission-control systems. Growing export revenues increase the demand for a better environment, and institutional pressure from international markets forces companies to integrate environmental criteria into development strategies. In this interpretation, trade acts as a channel for environmental modernization.

For a long time, the discussion revolved mainly around carbon emissions and other gases, that is, within a one-dimensional approach to environmental impact. However, modern research shows that this is not enough to understand the real scale of the environmental consequences of global trade. This is where the need arises to interpret the hypotheses of the "pollution haven effect" and the "pollution halo effect" through the prism of planetary boundaries. Planetary boundaries describe critical biophysical processes, including biogeochemical fluxes of nitrogen and phosphorus, land-use change, freshwater resources, biodiversity loss, climate change, and the impacts of new synthetic substances, so-called "novel

entities." If we consider global trade through this multidimensional lens, it becomes clear that the "refuge effect" manifests itself not only in the growth of CO<sub>2</sub> emissions, but in the systemic export of pressures to specific boundaries: more intensive fertilizer use and disruption of biogeochemical cycles, expansion of agricultural land and land use change, increased water stress, and the accumulation of chemicals in production chains. At the same time, the "pollution halo" can be reduced through technological innovations, more efficient resource use, and the introduction of standards that limit negative impacts on land, water, and biodiversity. Thus, classical hypotheses acquire a multidimensional character: instead of analyzing a single indicator, a picture of pressure redistribution across the components of the Earth system is formed.

A gradual transition from a unidimensional to a multidimensional analysis allows us to reach a more general conclusion. The positive effects and negative effects of international trade do not exist in isolation. They interact within a single system of global production and consumption relations. Technological improvements can reduce emissions per unit of output, but global demand growth can increase overall environmental pressure. Relocating production can reduce local emissions in the importing country but increase the burden on land and water in the exporting country. Trade creates a complex system of cross-effects, in which benefits and costs are distributed asymmetrically.

In developing this idea, it is appropriate to focus on three analytical steps. The first step is to move from the national to the global level of analysis. A country's environmental performance can no longer be assessed solely based on territorial indicators. Consumption in high-income countries generates pressure on land, water, and biogeochemical cycles in exporting countries. In this way, ecological interdependence is formed, which requires a rethinking of responsibility. The second step is to decompose the pressures into sectors. Different sectors have different impacts on planetary boundaries. Agriculture is a key driver of biogeochemical fluxes and land-use change, energy determines climate pressures, and the chemical industry is associated with the accumulation of new entities. Global trade connects these sectors into global chains, which means that the impact is multiplicative. The third step is to combine the institutional and technological dimensions. If trade is seen as a tool for environmental transformation, then environmental standards, certification, supply chain requirements, and border climate adjustments become elements of global regulation. In this case, the positive halo effect can be enhanced by political mechanisms, while the negative shelter effect is limited by harmonized standards.

In essence, developing the discussion from the dichotomy "does trade harm the environment or not?" to an analysis of the multidimensional redistribution of environmental pressure allows us to establish a new research framework. In this framework, global trade is considered a central node of the interaction of economic interests and planetary constraints, and its regulation becomes a key tool for ensuring the environmental sustainability of global development. We emphasize the

following: in the classical model of the national economy, environmental performance is assessed according to the territorial principle: emissions, resource use, and environmental degradation within the state border are considered. This approach was adequate for economies with relatively closed production cycles. However, the globalization of production has radically changed this logic, as today a significant share of goods undergoes multiple stages of processing across different countries.

The second analytical node concerns the sectoral structure. The impact of global trade on the environment is not homogeneous. Agriculture is a key driver of disruption to biogeochemical flows and of land-use change. Energy determines the climate dimension. Water-intensive industries affect freshwater resources. The chemical industry creates pressure on the frontier of novel entities. If the analysis focuses only on carbon emissions, other dimensions are ignored. However, global trade can reduce carbon intensity in one sector while increasing pressure on land or water in another. Therefore, a multidimensional approach shows that a positive effect in the climate dimension can be accompanied by a negative effect in the biodiversity or water resources dimension. The third analytical node concerns the asymmetry between countries with different income levels. Empirical studies show that high-income countries are key drivers of demand that shape global environmental pressures. At the same time, middle— and low-income countries often act as suppliers of resource-intensive products. This means that global trade shapes a structure of environmental interdependence within which benefits and costs are distributed unevenly.

This conceptualization allows us to proceed to assessing the interaction between positive and negative effects. Technological effects can reduce resource intensity and emissions per unit of output, supporting the "pollution halo" hypothesis. However, simultaneous growth in production scale and global demand can offset these technological advantages. Economies of scale can offset the achievement of increased efficiency. The above shows that the positive and negative effects of global trade are not mutually exclusive. They coexist and interact within the global economic system. This interaction explains why empirical studies yield mixed results. Different effects may dominate in different sectors, regions, and dimensions of planetary boundaries.

If global trade redistributes environmental pressures between countries and planetary boundaries, who is responsible for exceeding these limits? Should responsibility be determined by the territorial principle or by the principle of final consumption? And how does the role of trade policy change in conditions when environmental consequences become a central factor of economic strategy? These are the questions that translate the analysis into the political plane and open the next block of theorizing — about how the global redistribution of environmental pressures changes the content and instruments of modern trade policy. The global redistribution of environmental pressures is gradually changing the functions of trade policy. If in previous decades it was primarily considered an instrument of trade liberalization and barrier reduction, now it is increasingly acquiring the features of an environmental regulatory mechanism. The

inclusion of climate and resource criteria in trade regimes means that access to markets and competitive advantages are increasingly determined not only by price and productivity, but also by the environmental intensity of production.

In this logic, trade policy begins to serve as a mechanism for managing flows of environmental burdens. Countries seek to reduce domestic pressure on the environment while maintaining the stability of resource and intermediate product supply. This creates a new configuration of interests: issues of energy security, access to water, land, critical minerals, and decarbonization technologies are combined with issues of trade competitiveness. It is in this context that we can talk about the emergence of environmentally motivated trade policy. Carbon adjustment mechanisms for imports, requirements for product carbon footprints, environmental certification standards, and rules for traceability of supply chains are shaping a new institutional landscape. They are aimed not only at reducing emissions but also at redistributing global environmental pressure. Countries with high standards seek to avoid importing environmentally intensive products without compensation mechanisms, while exporting countries face the need to adapt production to new requirements.

This means that the classic discussion about the positive and negative effects of global trade takes on a new dimension. The positive effect can manifest itself in stimulating technological modernization and increasing the environmental efficiency of production. The negative effect can be amplified by increasing barriers to exports for countries that lack sufficient resources for rapid environmental transformation. As a result, environmental policy becomes a factor in the structural differentiation of the world economy. At the same time, global value chains remain a key channel of interdependence. Even under conditions of increased regulation, countries cannot completely abandon mutual trade in resources, energy, and technology. This creates a situation of double dependence: economies seek to reduce external environmental risks, but at the same time remain dependent on imports of resources and components. In such conditions, strategic decisions on trade policy are increasingly linked to assessments of environmental consequences and of access to planetary boundaries.

The transition to a regime of "wrecking-ball politics" means that environmental criteria cease to be external to trade regimes and become an element of competition for access to resources, decarbonization technologies, and "ecological space". Under such conditions, the analysis of the effects of "pollution haven" and "pollution halo" requires simultaneous consideration of technological, institutional, and geoeconomic channels of redistribution of pressure on planetary boundaries. It is this transformation that allows us to move on to a broader conceptual conclusion.

Global trade is becoming a mechanism for managing not only flows of goods and capital but also environmental pressures. Its regulation is increasingly determined by states' desire to optimize their positions within the global system of environmental constraints. In this sense, trade policy becomes part of a broader geoeconomic strategy

aimed at ensuring access to resources, technologies, and ecological space. This allows us to pose the following question of the lecture: if global trade creates a system of ecological interdependence and stratification, can individual countries achieve environmental sustainability without changing the structure of global trade flows? The answer to this question opens the next logical block: the limits of national environmental strategies in a globally integrated economy.

Rethinking the effects of the "polluting haven" and "polluting halo" in conditions of planetary constraints inevitably leads the study to the question of the limits of national strategies of environmental sustainability. If global trade is seen as a system of redistribution of environmental pressures, then the environmental performance of individual countries cannot be assessed in isolation from their position in global production and consumption relations. In the classical model of economic policy, environmental sustainability is interpreted as the result of domestic regulatory decisions. The state sets emission standards, limits resource use, and stimulates the introduction of cleaner technologies, thereby shaping its own trajectory of environmental transformation. However, in the context of global trade, which operates within planetary constraints, such logic proves insufficient.

Global production networks create a situation in which the environmental consequences of economic activity are distributed across countries and sectors. Domestic reductions in emissions or resource consumption may be accompanied by increased imports of products with high environmental intensity. In this case, the "pollution haven" effect manifests as a spatial shift in pressure on planetary boundaries, while the "pollution halo" effect may manifest as the spread of technologies and standards that reduce the intensity of this pressure. Both effects coexist and interact within the global system, determining the real outcomes of environmental policies. This means that environmental sustainability can no longer be considered solely as a function of national regulation. It becomes a derivative of the configuration of global trade and the distribution of environmental burdens within the world economy. A country can improve its own territorial performance, but remain integrated into global chains that generate high levels of pressure on biogeochemical cycles, water resources, or biodiversity in other regions. In this case, achieving local stabilization does not mean reducing the global burden on planetary boundaries.

That is why rethinking the effects of "pollution haven" and "pollution halo" requires a shift from a territorially limited analysis to a systemic consideration of global trade as an institutional mechanism for managing environmental pressure. Within this framework, national strategies for environmental transformation should be assessed, taking into account the structure of exports and imports, the position in global value chains, and the nature of external demand. In turn, this changes the content of trade policy. It ceases to be a neutral instrument for liberalizing exchange and increasingly serves to regulate access to ecological space. Carbon footprint requirements, supply chain traceability standards, and restrictions on the use of resource-intensive technologies are shaping a new architecture of global regulation. Within this architecture,

states seek to reduce domestic environmental pressures without losing access to resources and markets, which reinforces the interdependence between trade and environmental policies.

## CONCLUSIONS

The theoretical contribution of the article is to substantiate the multidimensional interpretation of the effects of the "pollution haven" and "pollution halo" through the concept of planetary boundaries. It is shown that the classical dichotomy of these effects is analytically insufficient when the assessment is narrowed to emissions, whereas the transition to planetary boundaries allows us to describe the redistribution of pressure across different biophysical dimensions and the channels of its spatial and sectoral movement. This shifts the discussion from the question of trade's sign on the environment to the configuration and channels of its redistribution of environmental pressure. We have established that the theoretical rethinking of the effects of the "pollution haven" and "pollution halo" within the concept of planetary boundaries demonstrates the limitations of traditional one-dimensional optics reduced to emissions alone. The proposed multidimensional framework shifts the focus of the discussion from the sign of the environmental impact of trade to the configuration of pressures on different planetary boundaries and the mechanisms of their spatial and sectoral redistribution.

The conditions of planetary constraints change the content of the effects themselves. The "pollution haven" manifests itself as the transfer of pressures to individual boundaries, including biogeochemical flows, land use, freshwater, and "novel entities," while the "pollution halo" manifests itself as the reduction of the intensity of these pressures through technological and institutional channels. Both effects are interpreted not as mutually exclusive alternatives, but as interrelated modalities of global trade within the same system of limited biophysical resources.

In this framework, global trade appears not as a neutral mechanism of exchange but as an institutional mechanism for managing environmental pressures. This creates grounds for revising standard notions of environmental performance and sustainability, since national achievements may reflect changes in the geography and structure of pressures rather than their real reduction at the global level. The imperativeization of environmental factors in trade regulation is shaping a new political economy in which market access rules increasingly encode access to "ecological space." In this context, "wrecking-ball politics" is interpreted as the dismantling of the previous model of globalization, in which environmental costs remained external to trade regimes, and as a shift toward competition over the possibility of redistributing pressures within planetary boundaries. This means that further research should focus on what combinations of standards, technological regimes, and trade rules ensure not only redistribution, but also a reduction in global environmental pressures. Within planetary constraints, global trade appears not as a source of unambiguously positive or negative consequences, but as a mechanism for the distribution and redistribution of environmental space among actors in the global economy.

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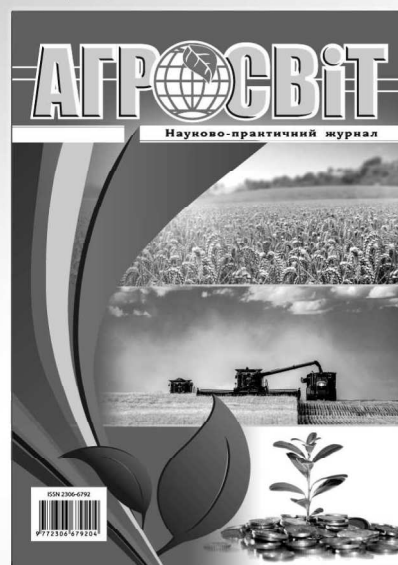
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