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EUROPEAN UNION'S CARBON BORDER ADJUSTMENT MECHANISM AS A GLOBAL GOVERNANCE TOOL

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Abstract. This paper considers a greenhouse gas (GHG) emissions management system with an international component and taxation of the imported carbon-intensive goods. As an example, we discuss European Union's Carbon Border Adjustment Mechanism (CBAM). CBAM is expected to be introduced in 2023. It will have global coverage by countries and companies. We overview the available scientific literature on mathematical methods for analysis and assessment of CBAM for socio-economic development. As noted, carbon border adjustment provides ample opportunities for mathematical analysis, calculations, and modeling. We outline some classes of models to investigate CBAM: DSGE models, Inter-Country Input-Output Tables, game-theoretic models, and others. Their capabilities for conducting economic analysis are described. Special attention is paid to the analysis models of Global Value Chains. We compile the block diagram of the CBAM management system based on the EU regulatory documents. Its main blocks, participants, and connections are studied. We present and analyze the generic formulas for determining GHG emissions in the European Union. As concluded, CBAM introduction will form a new and broad area of studies on fundamental and applied economics, including management of international carbon border trading markets.

Keywords: Carbon Border Adjustment Mechanism, greenhouse gas (GHG) emissions, European Union, global governance, models, mathematical methods.

INTRODUCTION

The economic policy on carbon adjustment and management of greenhouse gas (GHG) emissions has been forming in the world under the auspices of the UN since the 1970s; see the Declaration of the United Nations Conference on the Human Environment (1972) and the Convention on Long-range Transboundary Air Pollution (1979). Over the past decades, there were breakthroughs in solving the climate problem and achievements, particularly in energy saving, energy effectiveness, and reducing specific GHG emissions per capita and per unit of world gross domestic product. Also, there were failures, primarily related to the unrealized Rome Club's forecasts for solving global problems of humanity and *carbon leakage*, understood as two interrelated processes. The first process was production shift to other countries with less stringent limits on emissions, caused by stringent climate policies in the original countries. The second process was an increase in cheaper goods import because of the low carbon taxes in foreign, mainly developing countries [1, *p. 89*].

In the 2000s, the concept of adjusting economic relations with GHG emissions was further developed in emissions monetization and forming greenhouse gas markets. The European Union (EU) became the global pioneer in implementing an emissions trading system. It happened in 2005, when a system of payments for GHG emissions, called the European Union Emissions Trading System (EU ETS), was introduced. Thus, the formation of the greenhouse gas market in the European space was initiated. Subsequently, Norway, Iceland, and Liechtenstein joined the system based on intergovernmental agreements [2, *p. 18*].

Currently, the EU ETS covers about 36% of greenhouse gas emissions in the member countries [3, *p. 5*]. A powerful system of management, monitoring, and control was developed, which includes public authorities, divisions of producers responsible for participation in the EU ETS, brokers, intermediaries, auditors, and other companies.

The EU ETS, tested for over 15 years, is expected to track the GHG emissions in production processes, including the extraction of raw materials, the use of energy, materials, semi-finished, and other intermediate products in the goods imported into the EU (carbon footprint) in the form of the *Carbon Border Adjustment Mechanism* (CBAM). The European Commission sent the corresponding proposal for approval to other EU governing bodies and the member countries on July 14, 2021; see [1], hereinafter referred to as the basic document. The implementation of this proposal will start in 2023.

CBAM has global coverage by countries and companies. In the first stage (from 2023), it will affect the exporters of "dirty" industries products to the EU from almost the whole world: iron and steel are supplied to the EU by 160 countries; aluminum, by 175 countries; cement, by 86 countries; fertilizers, by 98 countries. (The data were provided by the Trade Map portal [4].)

This paper is devoted to studying CBAM as the first global management system for greenhouse gas emissions, unique in international practice. In particular, we justify the global character of CBAM and construct the flowchart of its management system with the characteristics of the main elements and links between them. Next, we generalize modern approaches to modeling the adjustment of carbon border emissions as well as overview the mathematical methods and models used to assess the economic effect of CBAM introduction. Finally, we analyze the mathematical model of determining emissions within CBAM.

1. THEORETICAL FUNDAMENTALS

The concept of using a GHG emissions market was proposed and developed in the 1960s by American economist Thomas Crocker and Canadian expert John Dales [5]. According to their approach, the government grants permissions to companies of "dirty" industries and production processes for a certain amount of emissions. J. Dales suggested an accurate term, from our point of view, to characterize the new instrument of emissions adjustment, "markets in pollution rights." This term is much more correct and appropriate to reality than the concept of emissions trading currently used in the Russian literature for one simple reason: emissions are not goods and, accordingly, they cannot be traded. The Crocker–Dales concept became one of the important branches in the theory of social costs, formulated also in the early 1960s by Ronald Coase. (In 1991, R. Coase received the Nobel Prize in Economic Sciences for "for his discovery and clarification of the significance of transaction costs and property rights for the institutional structure and functioning of the economy.")

However, can the market rights-based approach be applied to improve the effectiveness of environmental management? This issue is still open. It has not yet been proven whether direct government taxation of polluting companies is less or more effective compared to the emissions market.

CBAM, as the idea of emission management in international trade or border monitoring and control of greenhouse gases in imported goods, has been discussed in the EU and around the world for more than ten years, since the 2008–2009 crises. But it was formally announced in 2019, as part of *the EU Green Deal* [6], and immediately sparked a lively discussion about the possibilities and legitimacy of carbon border adjustment. The main topic of discussion was establishing the EU's actual control over enterprises in third countries with GHG emissions, i.e., outside the jurisdiction of Brussels.

Emissions trading is based on *cap and trade* (CAT), a principle widely used in the market economy [2, *p.* 5]. Following CAT, the government sets an upper limit of permissible GHG emissions in quotas, which are provided free of charge or for money to companies that emit GHGs into the atmosphere. If a company produces emissions below the allocated quota, it can sell the surplus in the market; in the case of exceeding the quota, it must purchase the corresponding certificates (permissions) at market prices. In theory, this mechanism shall reduce emissions by motivating the optimal and most cost-effective investment policy of companies.

Thus, CAT implementation and the introduction of an emissions management system in international practice provide ample opportunities for fundamental and applied research using mathematical and numerical methods of carbon market modeling, simulation, optimization, and forecasting. Such models may have various objectives, from assessing the effectiveness of state economic policy in carbon adjustment to reducing the factual payments of businesses on carbon border tax. Companies interested in additional profit can develop optimal market strategies for carbon payments to minimize the costs and even earn from emissions trading.

The prerequisites for the wide use of mathematical tools in carbon border adjustment are obvious at the conceptual level of emissions trading. In theory, the goals of the international emissions market are, first of all, to reduce GHG emissions cost-effectively through international competition and, in addition, to stimulate the investments of production companies in modern technologies reducing GHG emissions.

CAT predetermines a thorough analysis of various game-theoretic, simulation, and optimization situations and the wide use of the corresponding models in investment decision-making by companies. In addition to producers participating in the EU ETS, mathematical methods and tools are actively applied by other participants in the emissions market (brokers, financial players, consulting firms, and numerous intermediaries, which appeared during the emissions monetization in the EU).

In recent years, publications on carbon border adjustment have been increasing exponentially. They include articles in peer-reviewed periodicals, reports of research institutes and centers, as well as studies commissioned by governments, producers, and banks. At the same time, global governance problems due to CBAM introduction are not paid proper attention to, both abroad and in Russia. However, they reflect the fundamental difference between the international trade control mechanisms before and after CBAM introduction.

This paper analyzes the EU's CBAM, the unique global-scale system of carbon border adjustment and control of production processes in foreign countries.

2. THE CURRENT STATUS OF RESEARCH

Many aspects of CBAM were studied in detail in the economic literature. Among the foreign publications, we note large surveys on border adjustment of GHG emissions (including hundreds of sources and dozens of analyzed models) [7, 8], taxes in modeling of border supply chains (more than 70 sources) [9], and other problems.

Russian researchers focus on a qualitative analysis of carbon border adjustment and its content; for example, see [10]. The CBAM debates in the EU were considered in detail in the paper [11]. Implications and risks for Russian companies exporting their goods to the EU were also actively studied; for example, see [12, 13].

Leading European research and consulting centers derive their assessments primarily from quantitative analysis using a wide range of mathematical and instrumental tools: from complex multi-parameter computational systems (inter-country input-output tables and stochastic equations) to relatively simple game-theoretic, graphical, and other models. According to the Ifo's report on CBAM, "Given the importance of the proposal currently being prepared in Brussels, it is clear that costs and benefits should be carefully assessed and, where possible, pinned down quantitatively based on the best available methods." See [14, *p. 23*].

International GHG emissions adjustment in imported goods, as well as national control systems, provides ample opportunities for applying mathematical methods of analysis, calculation, and modeling. Complex dynamic stochastic general equilibrium (DSGE) models [15–17] were constructed to assess the effect of foreign trade policy changes on the environment, production, consumption, investments, economic structure, and other economic indicators.

The class of DSGE models based on inter-country input-output tables of large dimensions has become most widespread due to its cross-sector character. They relate national input-output tables to export-import flows in bilateral trade in goods and services. Such models allow simulating and predicting the effect of carbon payments in one country on foreign trade, economic situation, and industries in other countries. For example, the authors [15] constructed a DSGE model for the United States and demonstrated that carbon border adjustment is a more effective mechanism for reducing "carbon leakage" than other branches of the US climate policy.

In [16], an extended DSGE model and the GTAP input-output tables[1] [18] were used to assess the effects of CBAM application and possible trade partner responses. Simulation results were presented for four scenarios causing overall changes in world energy trade by countries. The model provides estimates for many production and trade variables.

The United Nations Conference on Trade and Development (UNCTAD) study [17] involved the DSGE model and the GTAP database to examine the impact of CBAM on international trade, carbon dioxide (CO_2) emissions, income, and employment, with a focus on developing countries. As was shown, introducing a tax on emissions jointly with CBAM helps to reduce GHG emissions inside and outside the EU [17, *p. 13*].

Several researchers [19–21] modeled the risks to developing countries from CBAM introduction.

In terms of global governance, the most important problem under study is the CBAM's compliance with the WTO regulations and rules; for example, see [22].

[1] The Global Trade Analysis Project (GTAP) database is developed and supported by the Center for Global Trade Analysis, Department of Agricultural Economics, Purdue University (USA). Its latest version (2017) contains bilateral trade information for 140 countries in 57 commodity groups and industries.

Proposals to adjust the carbon footprint with the participation of international community institutions within international climate agreements were formulated in [23].

When studying the problems of global governance, DSGE models are the main quantitative analysis tool as well. The paper [24] employed such a model to quantitatively assess the economic and environmental consequences of implementing different CBAM modifications to resolve the dilemma between compliance with WTO rules and the acceptability of the new adjustment mechanism. Within a DSGE model containing imperfect competition, Global Value Chains, greenhouse gas emissions, and the endogenous price of emission quotas, the authors showed that CBAM shall reduce "carbon leakage." However, it shall simultaneously increase the price of emission quotas in the EU ETS market.

The political aspects of CBAM are also widely examined using mathematical models. For example, the paper [25] considered which countries are most likely to politically oppose this mechanism. As an analysis tool, the authors proposed a multidimensional CBAM opposition index based on several indicators (the volume of trade with the EU, carbon intensity, litigation and disputes in the WTO, domestic public opinion on climate change, and the ability to innovate).

Research on Global Supply Chains [9, 26, 27] plays a significant role in the publications on CBAM problems.

The paper [26] presented a Global Supply Chains model with a separate block of GHG emissions. A particular example of a retailer in an importing country with adjusted emissions and a supplier in an exporting country with unadjusted emissions was modeled, equilibrium solutions were obtained, and the impact of the carbon tariff on global emissions adjustment was investigated. Based on the analytical study and mathematical calculations, the authors concluded that a carbon tariff does not necessarily reduce global emissions under certain circumstances.

Game-theoretic models are widespread in CBAM analysis. For example, such a model was used to assess CBAM's potential effect on China [28]. The paper [27] described an incentive model for companies to reduce CO_2 emissions in a two-link supply chain with trade regulation (one seller and one buyer). Four emission reduction incentive strategies were proposed therein. The equilibrium solutions for all the strategies were obtained using game-theoretic models. Through comparisons and analysis, the authors concluded that high consumer awareness of low carbon emissions can stimulate the producer to reduce carbon emissions, thereby increasing profits for both supply chain members.

3. CBAM MANAGEMENT SYSTEM

Emissions management in the modern economy is a complex system of tools: normative legal (laws, regulations, strategies, programs, and other statutory acts) as well as organizational and institutional (management bodies, committees, and commissions at the national and sectoral levels). It includes a wide set of tools to regulate the economic activities of all industries and production processes. Its main goals are to reduce GHG emissions, develop renewable energy sources (RES), and improve energy effectiveness.

EU's Carbon Border Adjustment Mechanism is a new and unique tool for global governance, monitoring, and control of production processes in companies located in countries out of the EU's jurisdiction. (The international legitimacy of management and control of producer emissions in third countries by the EU is not considered here; details can be found, e.g., in the paper [23].)

The CBAM management system is cumbersome and complex but generally logical. Its flowchart is shown in the figure below. The main elements are as follows:

– the European Commission,

– the CBAM Committee of the European Commission,

– the governments of EU member states,

– the competent authorities in the governments of EU member states,

– Customs authorities,

– importing companies and their authorized declarants,

– accredited verifiers,

– the non-EU producer/exporter companies (operators of installations according to CBAM).

The European Commission is the *Central administrator* of CBAM. It is responsible for the CBAM support, coordination of the activities of the relevant competent national authorities, development and maintenance of a public central CBAM database, management of a transaction log for the purchase of CBAM certificates, etc. In particular, the central CBAM database shall contain the names, addresses, and contacts of the companies producing the imported goods as well as the location of their production facilities.

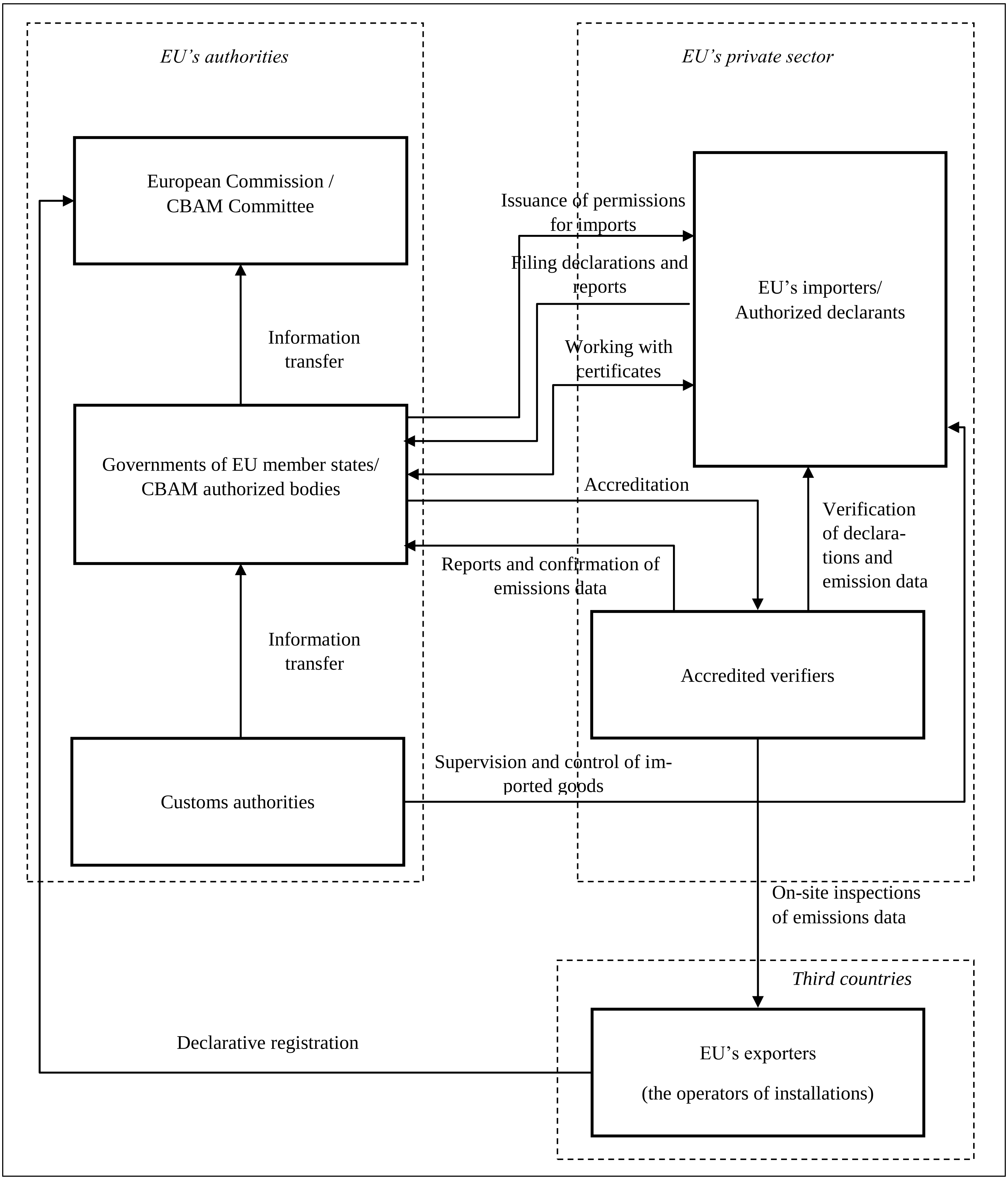

Fig. The flowchart of the CBAM management system.

European Commission's CBAM Committee is established to carry out practical CBAM work under the general guidance of the European Commission.

The governments of EU member states will directly organize CBAM on their territories. They will also be responsible for CBAM control and supervision. They will have the right to impose penalties on importing companies and decide on administrative or criminal sentences for non-compliance with CBAM legislation.

Competent authorities are organized by the governments of EU member states. They have the following responsibilities: the development and maintenance of national CBAM databases; maintenance of various CBAM registers, their accounts, and decisions concerning import permissions; the issuance and withdrawal of such permissions; implementation of the life cycle of CBAM certificates; accreditation of verifiers; reception and handling of CBAM declarations; transfer of relevant information to the CBAM Committee.

Customs authorities supervise and control imported goods, check declarants and documents for the import of goods into the EU territory, and transmit information on the goods declared for import to the competent authority of an EU member state. They ban the import of goods if the declarant is not authorized by the competent authority. Also, they periodically transfer detailed information about the goods declared for import to the competent authority.

An authorized declarant is a person authorized by a company importing goods in the EU to conduct all activities under CBAM. A declarant works with the competent and customs authorities; it must be registered and authorized by the competent authority to conduct import operations for the declared group of goods. A declarant bears the transaction costs of applying for authorization to import goods, drawing up annual CBAM declarations, ensuring emission inspections by accredited verifiers, drawing up reports, etc. It must make CBAM payments on behalf of the importing company and monitor the EU ETS market to purchase CBAM certificates at a low price. This price is linked to the bidding results on the EU ETS. Data on the emissions of goods produced abroad and imported into the EU must be confirmed by accredited verifiers. On a quarterly basis, a declarant is obliged to provide the competent authority with a CBAM report. All these activities place an additional burden on importers of goods in the EU and their authorized declarants.

The operators of installations are any persons in third (non-EU) countries who operate or control installations; see [1], *Art. 3.* In essence, they are foreign companies outside the EU or persons authorized by them to export CBAM-covered goods to the EU.

One of the key CBAM provisions is the declaratory registration of the operators of installations with the European Commission. According to Article 10 of the CBAM basic document, such registration shall be performed through submitting an application form where an operator of installations specifies information on itself, including business activities and the capacity of installations (facilities, equipment, technical units, etc.) to produce the goods covered by CBAM. Paragraph 1 of this article states: "The Commission shall, upon request by an operator of an installation located in a third country, register the information on that operator and on its installation in a central database" [1, *p. 32*]. Registration is voluntary, being a right (not an obligation) of a foreign producer. At any time, following the operator's request, this information must be removed from the EU database.

At the same time, paragraph 5 of the same article obliges the operator to:

(a) determine the embedded emissions calculated in accordance with the methods set out in Annex III, by type of goods produced at the installation referred to in paragraph 1;

(b) ensure that the embedded emissions referred to in point (a) are verified in accordance with the verification principles set out in Annex V by a verifier accredited pursuant to Article 18;

(c) keep a copy of the verifier's report as well as records of the information required to calculate the embedded emissions in goods as laid down in Annex IV for a period of four years after the verification has been performed.

Note that the declarant, not the operator, is responsible to the European Commission for the CBAM issues. This is quite understandable because the EU jurisdiction does not apply to companies in third countries. But, on the other hand, the declarant does not have complete and reliable information, supported by technical documentation, on the operator's production capacity, facilities, and emissions. Such information can only be received from the producer of the goods imported by the declarant (not only received but also verified by an accredited verifier). However, suppose that an operator is not registered with the European Commission (it is his right to decide). In this case, how shall the declarant receive information on the production facilities of third-country companies and the emissions produced by them? This issue is unclear and not regulated in the CBAM basic document.

Accredited verifiers (hereinafter, referred to as verifiers). EU-accredited verifiers have wide powers within CBAM, particularly for the foreign operators of installations. They verify and certify the emissions data provided by the declarants. But, most importantly, they are obliged to carry out annual inspections on the emissions of third-country producers. According to paragraph 1 (c) of Annex V of the basic document, "installation visits by the verifier shall be mandatory except where specific criteria for waiving the installation visit are met."

A verification report shall include, at least, the following information [1, *Annex V*, *2*]:

(a) identification of the installation where the goods were produced;

(b) contact information of the operator of the installation where the goods were produced;

(c) the applicable reporting period;

(d) name and contact information of the verifier:

(e) ID of accreditation, name of the Accreditation Body;

(f) the date of the installation visit, if applicable, or the reasons for not carrying out an installation visit;

(g) quantities of each type of declared goods produced in the reporting period;

(h) direct emissions of the installation during the reporting period;

(i) a description on how the installation's emissions are attributed to different types of goods;

(j) quantitative information on the goods, emissions and energy flows not associated with those goods;

(k) in case of complex goods:

i. quantities of input materials (precursors) used;

ii. the specific embedded emissions;

iii. in case actual emissions are used: the identification of the installation where the input material has been produced and the actual emissions from the production on that material.

(l) the verification opinion statement;

(m) information on material misstatements found and not corrected, where applicable;

(n) information of non-conformities with calculation rules set out in Annex III, where applicable.

Finally, it is unclear how efficient this cumbersome CBAM management system will be, and what will happen to the "carbon leakage" from the EU. The expected profits of the competent authorities of member states and the EU from the ETS, presented in numerous studies commissioned by the EU and on an initiative basis, do not confirm anything since the effectiveness for the economy as a whole and the integral costs of companies have not been calculated or assessed.

4. THE MODEL

Despite all the complexity of the institutional management structure and paperwork, the model for calculating emissions is simple, linear, and involves only a few algebraic equations depending on the type of goods.

The basic category is the emissions of carbon dioxide (CO_2) or other GHG in CO_2 equivalent. Emissions are divided into direct and indirect. *Direct emissions* mean emissions from the production processes of goods over which the producer has direct control. *Indirect emissions* mean emissions from the production of electricity, heating and cooling, which is consumed during the production processes of goods. First of all, the calculation includes electricity, heating, and cooling costs, which are consumed during the production of goods and have the largest specific emissions in comparison with the other intermediate products. Until 2026, indirect emissions will not be adjusted.

Also, an important category is *embedded emissions* in imported goods (see [13, *p. 104*]). These emissions mean direct emissions released during the production of goods, calculated pursuant to the methods set out in Annex III [1]. Embedded emissions are determined by the technical specifications in the certificates of production facilities.

Specific embedded emissions mean the embedded emissions of one tonne of goods, expressed as tonnes of CO2e emissions per tonne of goods.

Actual emissions mean the emissions calculated based on primary data from the production processes of goods [1, *p. 27*].

For emissions accounting, goods are divided into simple and complex. Simple goods are most widespread. They fall under CBAM in the initial stage.

Simple goods mean goods produced in a production process requiring exclusively input materials and fuels having zero embedded emissions. The document [1] specified five goods of this type: cement, fertilizers, iron and steel, aluminum, and electricity.

Complex goods mean goods requiring the input of other simple goods in its production process. They will be covered by the CBAM mechanism in the following stages.

Only direct emissions are considered for determining the specific embedded emissions of simple goods. They are calculated as

$$SEE_g = \frac{AttrEm_g}{AL_g}$$

with the following notations: SEE_g is the specific embedded GHG emissions in CO_2 equivalent per one tonne of simple goods g; $AttrEm_g$ is the direct GHG emissions released during the production of simple goods g in tonnes of CO_2 equivalent; finally, AL_g is the output of goods g in tonnes. (In this paper, we preserve the original notations of the source document [1].)

By analogy, the factual embedded emissions SEE_g per one tonne of complex goods g are determined through the direct emissions only. They are obtained from the equation

$$SEE_g = \frac{AttrEm_g + EE_{InpMat}}{AL_g},$$

where EE_{InpMat} is *the embedded emissions of the input materials* consumed in the production process. These emissions are given by

$$EE_{InpMat} = \sum_{i=1}^{n} M_i \cdot SSE_i$$

with the following notations: M_i is the mass of input material i used in the production process; SEE_i is the specific embedded emissions in the production of input material i; finally, n is the number of input materials.

The exporting company (the operator of installation) must specify in the declaration the emission value from the installation where the input material was produced. (Under the condition that the data for the installation can be properly measured.)

Thus, the general formula for determining the embedded emissions EE_P of product p in the upstream value chain can be written as

$$EE_p = EM_p + IE_p + \sum_{i=1}^{n} MC_i \; (EM_i + IE_i)$$

with the following notations: EM_p and IE_p are the direct and indirect emissions, respectively, in the production process of goods p; MC_i is the mass of input material i used for goods p; EM_i and IE_i are the direct and indirect emissions for producing one tonne of input material i; finally, n is the number of input materials.

CONCLUSIONS

Generally speaking, with introducing carbon border adjustment, theoretical and application-oriented economics will have a new and broad area of studies, including the management of border GHG markets.

The CBAM management system is operable and reasonable. It serves the international climate policy adopted by the UN. The model for calculating emissions for various goods is correct as well. This system seems to contain no control links with insufficient or redundant functionality. Its analog—the EU ETS—has been operating for 15 years and has been tested in practice.

However, implementing the CBAM management system may face several serious challenges due to the international legal character of the emerging economic relations:

- The introduction of tariffs (certificates) on GHG emissions in the goods imported into the EU directly affects foreign producers and is a political step. CBAM application will be the first case of taking tough fiscal measures by one subject of international relations (the European Union) to other participants (companies from third countries). Therefore, CBAM represents a global governance tool for almost all countries as the object of relations.
- Since CBAM is the first attempt to monitor and control (regulate) production processes in exporting countries, there will be a problem of allowing verifiers into the territory of third countries to carry out their inspections. What are the grounds for the EU verifiers to carry out such inspections? The answer is unclear so far.
- The EU verifiers, responsible for the correctness of the emissions data declared and submitted to the competent authorities, are not a whim of the EU bureaucracy but a necessary and inevitable link in the management system: someone shall perform expert verification and certify the correctness of the calculated emissions. But it requires an international mandate and an international organization under the UN instead of the private initiative of one of the international entities. A good example is the International Atomic Energy Agency (IAEA), which was established under the UN to verify national nuclear power facilities.

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