



Carbon-Tax Benchmark as a Complement to Emissions Trading: An Empirical Calibration Based on Slovak EU ETS Data

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Abstract

This article examines whether a carbon-tax benchmark calibrated on EU ETS data can complement emissions trading in the Slovak Republic. Using Slovak EU ETS installation-level data on allocated allowances, verified emissions and EUA prices for 2015–2024, it develops an illustrative calibration methodology and compares the resulting tax yield with a modelled above-allocation ETS compliance-cost proxy. The comparison is intentionally limited: it cannot establish fiscal superiority over the EU ETS, because auction revenues, private compliance costs and potential tax revenues are conceptually different. The results show that, when the minimum tax floor is not binding, the tax yield is mechanically linked to the ETS proxy through the calibration coefficient. The estimated revenue difference should therefore be interpreted as a consequence of the benchmark design. The article also discusses distributional implications and CBAM compatibility, emphasising product-level embedded-emissions data and coordination to avoid double charging.

Keywords

Carbon Tax, EU ETS, Carbon Pricing, Emission Allowances, CBAM

I. Introduction

The EU Emissions Trading System (EU ETS) is the EU's key instrument for reducing greenhouse gas emissions (European Commission, 2026a). It creates a price signal through allowance allocation, auctioning and trading, but it also raises questions about allocation efficiency, price volatility and the fiscal distinction between public auction revenues and

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private compliance costs. These issues explain why carbon taxation has repeatedly been discussed as a complementary carbon-pricing instrument.

The theoretical rationale for carbon taxation is rooted in the Pigouvian logic of internalising negative externalities through corrective taxation (Pigou, 1920). In this article, however, the proposed tax rate is not derived as a welfare-optimal Pigouvian tax. It is constructed as an empirical benchmark calibrated on observable EU ETS variables.

The aim of this article is to propose and analytically illustrate a carbon-tax benchmark for the Slovak Republic, calibrated on EU ETS data. The article does not claim that such a tax should replace the EU ETS. Instead, it examines whether verified emissions, allocated allowances and European Union Allowance (EUA) prices can be used to construct a transparent complementary benchmark and to compare it with a modelled above-allocation ETS compliance-cost proxy.

The article thus contributes to the discussion on carbon-pricing design from the perspective of economic regulation, fiscal transparency and regulatory compatibility. Its contribution is methodological rather than prescriptive: it demonstrates how national installation-level ETS data can be translated into a benchmark tax rate while explicitly separating public auction revenues, private compliance costs and potential tax revenues. The novelty is therefore not a claim that a carbon tax is fiscally superior to the EU ETS, but a transparent calibration framework for a small open EU economy operating under the constraints of the EU ETS and the Carbon Border Adjustment Mechanism (CBAM).

The empirical basis, data sources and variable definitions are presented in Section III, where the distinction between Slovak installation-level data, EU-wide allowance prices and the modelled ETS compliance-cost proxy is explained in detail.

The remainder of the article reviews the relevant literature, presents the data and methodology, discusses the empirical results and sensitivity tests, and concludes with implications and limitations.

II. Literature Review

By distinguishing between private benefit and social benefit, Pigou (1920) pointed out the need to internalise external costs through corrective taxes. This theoretical foundation remains relevant, but current carbon-pricing literature no longer relies only on the Pigouvian benchmark. Recent work emphasises institutional design, rate updating, revenue recycling, interaction with emissions trading and border-adjustment rules (OECD, 2019). Aldy (2020) and Metcalf (2021) argue that carbon taxes require predictable adjustment mechanisms and institutional arrangements that allow the tax rate to respond to new information. The World Bank (2026) documents that direct carbon pricing now covers almost one third of global greenhouse gas emissions and mobilised more than USD 107 billion for public budgets in 2025. The OECD (2025) also stresses that recent carbon-pricing developments combine emissions trading, explicit carbon taxes and energy taxation rather than relying on a single instrument.

In contemporary climate-policy research, the literature focuses mainly on the comparison of quantitative instruments, represented by emissions trading systems, and price instruments in the form of carbon taxes. Metcalf and Weisbach (2009) analyse the design of the carbon

tax and point out its ability to provide broad coverage of emissions at relatively low administrative costs. More recent literature has refined this argument by stressing hybrid design, tax-rate updating and environmental assurance mechanisms (Aldy, 2020; Metcalf, 2020, 2021). Evidence on the EU ETS has also become more robust. Colmer et al. (2025), using firm-level evidence, find that the EU ETS reduced regulated firms' emissions without detectable negative effects on output or employment, which reinforces the need to treat emissions trading as a functioning instrument rather than as a policy to be mechanically replaced. These findings support the relevance of complementary tax benchmarks, but they also show that effectiveness depends on sectoral coverage, exemptions, energy structure, firm behaviour and the credibility of the price path.

Determining the optimal carbon tax rate is associated with significant uncertainty. Economic theory assumes that the rate should correspond to the marginal social damage caused by emissions, often operationalised through the social cost of carbon. Nordhaus (2008, 2017) points out that optimal rates tend to rise over time, with their dynamics depending on technological progress, economic growth and discount rates. However, current policy practice often uses pragmatic carbon-price benchmarks rather than a single theoretically optimal rate. The High-Level Commission on Carbon Prices (Stiglitz et al., 2017), OECD effective carbon-rate studies and World Bank carbon-pricing reports show that carbon prices differ substantially across countries, sectors and instruments. This implies that the rate calculated in this article should be interpreted as an empirical calibration linked to EU ETS data, not as a welfare-optimal Pigouvian tax.

Recent policy practice in comparable European countries confirms that carbon taxation has developed mainly as a complement to emissions trading rather than as a full substitute. Sweden illustrates the credibility of a predictable long-term carbon-tax path, Finland shows the coexistence of carbon-related energy taxation with EU ETS participation, France demonstrates the importance of exemptions and sectoral design, and Ireland highlights the role of a legislated upward rate path. These examples suggest that predictable adjustment rules, sectoral exemptions and interaction with the EU ETS are as important as the nominal tax rate itself (Government Offices of Sweden, 2026; OECD, 2023, 2025; Revenue Commissioners, 2026; SDES, 2024).

A specific issue for the European Union is the Carbon Border Adjustment Mechanism (CBAM). Regulation (EU) 2023/956 established CBAM to align the carbon cost of selected imported goods with the carbon cost borne by EU producers (Regulation (EU) 2023/956, 2023). According to the European Commission (2026c), CBAM entered a transitional phase for 2023–2025 and applies under its definitive regime from 2026. Recent research indicates that CBAM is already relevant at the level of specific products and firms, not only at the country or sector level. Vríz et al. (2026) show early evidence that the CBAM reporting phase is reshaping EU-India steel trade by affecting high- and low-emission exporters differently. This is directly relevant for the present article because any national border component must be product-specific and must not duplicate CBAM obligations for covered goods. This need to avoid regulatory overlap also reflects the broader multi-level structure of climate regulation, in which national policy instruments, supranational EU

rules and international climate obligations interact with emerging debates on corporate accountability for climate change (Avbelj, 2026).

It follows that a carbon tax can be an effective climate policy pricing instrument, but its practical effectiveness depends on its specific design: the definition of the tax base, the calibration of the rate under uncertainty, the rules for adjusting it over time, the treatment of free allocation and auctioning under the EU ETS, and compatibility with CBAM. The recent literature therefore supports a cautious interpretation: a carbon tax may improve predictability and fiscal transparency, but it cannot be assessed without considering existing EU instruments and the risk of double regulation.

This focus on Slovakia is relevant because the country's trade specialisation remains strongly linked to medium-tech activities, while long-term convergence depends on structural transformation towards more knowledge-intensive and innovation-driven sectors (Fifeková and Nežinský, 2025). The research gap therefore lies in the design of a transparent and practically applicable carbon-tax benchmark for a small open EU economy that is already integrated into the EU ETS and, from 2026, operates in an environment shaped by CBAM. The novelty criteria are refined accordingly: the article contributes by linking Slovak installation-level ETS data with a tax-rate benchmark, by distinguishing public auction revenues from private compliance-cost proxies, by implementing a simple smoothing rule, and by critically identifying the limits of the resulting fiscal interpretation.

A calibration coefficient can be used as a modelling parameter rather than as a normatively optimal tax rate. In this article, $k = 1.25$ is treated as an illustrative benchmark for comparing carbon taxation with emissions trading and is tested through sensitivity scenarios in Section IV (Parry et al., 2022; Shen and Zhao, 2022; Timilsina, 2022; Köppl and Schratzenstaller, 2023). Total potential tax revenue is calculated as the product of the tax rate and covered verified emissions, in line with the standard logic of carbon-pricing instruments (Metcalf and Stock, 2023; OECD, 2023, 2025).

III. Data and Methodology

Data sources

The analysis is based on publicly available EU ETS data for 2015–2024. The empirical period is limited to 2015–2024 because the study uses only complete verified installation-level observations available at the time of dataset closure; 2025 estimated values are therefore not included. The Slovak component of the dataset is not derived from aggregate EU-level totals. It is identified using data from the Slovak National Emission Allowance Administrator, which reports installation-level data for operators administered in the Slovak Republic (National Emission Allowance Administrator of the Slovak Republic, 2026). For each year, the installation-level values are aggregated to the Slovak national level. Allowance-price data are then added from the annual series of EU emission allowance prices (Kurzy.cz, 2025). This procedure ensures that emissions and allocation variables refer to Slovak EU ETS installations, while the allowance price variable reflects the common EU carbon market price.

For each reporting year t , the following variables are used:

- (i) A_t – allocated allowances for Slovak EU ETS installations in year t ;
- (ii) E_t – actual verified emissions of Slovak EU ETS installations in year t ;
- (iii) $P_{t,m}$ – monthly EU allowance price in month m of year t , used to calculate the annual average price $P_{bar,t}$.

The above-allocation volume is denoted by X_t and is defined as the positive difference between verified emissions and allocated allowances. This variable is used only to construct a modelled above-allocation ETS compliance-cost proxy. It is not interpreted as official EU ETS fiscal revenue, because official ETS revenues depend on auctioning, free allocation rules, banking and compliance behaviour.

The empirical procedure has four steps: aggregation of Slovak installation-level data, conversion of monthly EUA prices into annual averages, calculation of above-allocation emissions for the ETS compliance-cost proxy, and derivation of the carbon-tax benchmark from verified emissions, allocations, EUA prices and the calibration coefficient.

For geographical interpretation, the study distinguishes Slovak installation-level emissions and allocations from the EU-wide allowance price. Official national auction-revenue data are not used in the benchmark calculation, so the results should not be interpreted as direct Slovak budget revenues. If future research incorporates official auction revenues, the comparison should be re-estimated using those public-revenue data rather than the private compliance-cost proxy used here.

Construction of the above-allocation volume

The baseline calculation uses observed historical data. The above-allocation volume used in the ETS compliance-cost proxy is defined as follows:

$$X_t = \max(E_t - A_t, 0) \quad (1)$$

where X_t is the above-allocation volume in year t , E_t denotes actual verified emissions of Slovak EU ETS installations, and A_t denotes allocated allowances for those installations. The max operator ensures that the proxy is zero when verified emissions do not exceed allocations.

This construction maintains internal consistency with Slovak EU ETS data and avoids presenting forecasted observations as if they were empirical results.

Calculation of the ETS compliance-cost proxy

The annual allowance-price variable is calculated from monthly EU allowance prices. The monthly value denotes the monthly price of an emission allowance, not a monthly emissions volume. The annual average allowance price $P_{bar,t}$ is then applied to X_t , the volume of emissions above allocation, to obtain a modelled above-allocation ETS compliance-cost proxy.

$$\bar{P}_t = \frac{1}{12} \times \sum_{m=1}^{12} P_{t,m}; \quad R_{ETSproxy,t} = X_t \times \bar{P}_t \quad (2)$$

where $P_{t,m}$ is the monthly EU allowance price in month m of year t , $P_{bar,t}$ is the annual average allowance price, $X_t = \max(E_t - A_t, 0)$ is the volume of verified emissions above allocated allowances, and $R_{ETSproxy,t}$ is the modelled above-allocation ETS compliance-cost proxy. This proxy is deliberately narrower than official auction revenue.

This proxy captures the private compliance-cost logic of emissions above allocation. It is not interpreted as official ETS auction revenue, because auctioning, free allocation, banking and secondary-market transactions are different mechanisms within the EU ETS design (European Commission, 2026b). The proxy comparison can therefore show how the benchmark formula behaves relative to a compliance-cost measure, but it cannot establish whether a carbon tax would generate more public revenue than the EU ETS as a whole.

Setting the carbon tax rate

The proposed carbon tax is designed as a tax applied to each unit of emissions generated. The carbon tax rate is derived from the empirical relationship between actual emissions, allocation of allowances and the market price of carbon under the ETS. Specifically, the tax rate is determined as a function of:

- (i) the share of emissions exceeding allocated allowances in total emissions,
- (ii) the average emission allowance price,
- (iii) a calibration factor reflecting the extent to which emissions exceed allocated allowances:

$$T_t = \max \left(T_{\min}, k \times \bar{P}_t \times \frac{X_t}{E_t} \right); \quad R_{tax,t} = T_t \times E_t \quad (3)$$

where T_t is the carbon-tax rate in EUR per tonne of CO₂ in year t , $T_{\min}$ is the minimum policy floor used to avoid a zero-price signal, k is the calibration coefficient, $P_{bar,t}$ is the annual average EUA price, X_t is the above-allocation volume, E_t is actual verified emissions, and $R_{tax,t}$ is the potential carbon-tax revenue.

The benchmark calibration uses $k = 1.25$. The 25 percent uplift is not an estimated structural parameter and is not interpreted as a welfare-optimal Pigouvian tax rate. It anchors the benchmark between a neutral scenario ($k = 1.00$), in which the tax revenue equals the ETS compliance-cost proxy when the floor is not binding, and a stricter scenario ($k = 1.50$), which represents a stronger regulatory wedge. Economically, the 25 percent uplift is used as a moderate risk-premium adjustment for allowance-price volatility, possible over-allocation and the policy objective of maintaining a non-zero incentive signal.

Because k is a modelling assumption, the results are evaluated as a benchmark scenario rather than as a final statutory proposal. Section IV therefore re-applies the formula for $k = 1.00$, $k = 1.10$, $k = 1.25$ and $k = 1.50$, keeping the minimum floor fixed where it binds.

The total potential carbon-tax revenue is calculated as $R_{tax,t} = T_t \times E_t$, where E_t represents verified emissions covered by the tax. When the minimum floor is not binding, Equation (3) implies $R_{tax,t} = k \times P_{bar,t} \times X_t$, which is k times the ETS compliance-cost proxy. The resulting revenue difference is therefore primarily a consequence of the calibration choice, not an independent empirical finding from two unrelated revenue streams.

The formula should be read as a calibration device, not as an annual statutory rule. Because it uses EUA prices and the above-allocation share, the raw calculated rate inherits part of the ETS volatility. Fiscal predictability would therefore have to come from a broader taxable base and from policy design elements such as a moving average, a rate corridor, a minimum floor and a maximum annual adjustment rule, rather than from the unsmoothed formula itself. Section IV implements a three-year moving average to illustrate one such smoothing rule.

Border tax adjustment

To limit the risk of carbon leakage, the methodology retains an illustrative border-adjustment component. After the introduction of CBAM, however, such a component cannot be interpreted as an independent national charge on the same embedded emissions in CBAM-covered goods. It is therefore treated only as a conceptual benchmark or as a possible complement outside the CBAM scope.

$$B_{j,t} = EI_{j,t} \times \max(0, k_B \times T_t - C_{j,t}) \quad (4)$$

where $B_{j,t}$ is the illustrative border-adjustment amount for imported product j in year t , $EI_{j,t}$ is the embedded-emissions intensity of product j , k_B is the border-adjustment calibration coefficient, T_t is the domestic carbon-tax benchmark, and $C_{j,t}$ represents the carbon price already paid through CBAM or an equivalent foreign carbon-pricing system. The coefficient $k_B = 1.25$ is not interpreted as a uniform import levy. It is an illustrative risk-premium parameter applied to the domestic benchmark before product-specific embedded emissions and carbon prices already paid are considered. A practical CBAM-compatible design would require product-level embedded-emissions data, recognition of carbon prices already paid, avoidance of overlap with EU certificates and coordination with the phase-out of free allocation under the EU ETS. A flat charge on all imported goods would therefore not be practically or legally suitable.

Assumptions and limitations of the methodology

The methodology is based on several simplifying assumptions. The ETS comparison uses an above-allocation compliance-cost proxy rather than official auction revenues. The calibration coefficient $k = 1.25$ is a benchmark parameter and must be interpreted together with the sensitivity tests. The border-adjustment component is illustrative because CBAM already creates an EU-level mechanism for covered imports. The *ceteris paribus* assumption may also overstate long-term revenues: if a carbon tax successfully changes behaviour, firms may reduce emissions, substitute technologies, alter production or pass costs through to consumers. The proposed benchmark should therefore be interpreted as a static calibration exercise and decision-support tool, not as a guarantee of permanently stable budget revenue.

IV. Results and Discussion

Development of EUA prices and calibration of the carbon-tax rate

EUA prices provide the market-price input for the carbon-tax benchmark. During 2015 to 2017, allowance prices remained relatively low, mainly due to over-allocation and weaker demand. Since 2018, prices have increased substantially, reflecting tighter EU climate targets and ETS reforms, including the Market Stability Reserve.

Based on the methodology presented in Section III, the raw carbon-tax rate was calculated for each year and then smoothed using a three-year moving average (Table 1). The moving average is included to respond directly to the volatility of the raw formula and to illustrate how a practical policy rule could dampen annual fluctuations without severing the link to observable ETS variables.

Table 1: Raw and smoothed carbon-tax rate compared with the average EUA price (€)

Year	Raw carbon-tax rate	Three-year moving average	Average emission allowance price
2015	4.04	4.04	8.03
2016	3.99	4.02	5.33
2017	5.71	4.58	5.93
2018	15.60	8.43	16.48
2019	40.03	20.45	24.75
2020	51.31	35.65	25.05
2021	1.00	30.78	55.02
2022	24.56	25.62	82.04
2023	50.38	25.31	89.58
2024	44.79	39.91	67.25

Source: Own elaboration based on Slovak installation-level EU ETS data (National Emission Allowance Administrator of the Slovak Republic, 2026) and EUA price data (Kurzy.cz, 2025)

The 2021 result requires specific interpretation. The calculated carbon-tax rate reaches the minimum value because verified emissions did not exceed, or only marginally exceeded, allocated allowances in the Slovak dataset. The value of €1 is therefore a minimum policy floor, not a market-based carbon price. Without such a floor, the mechanical formula would generate a zero or near-zero signal in that year.

The phrase “clear price signal” does not mean that the rate is stable or uniform. It means that the rate is linked to observable variables: the EUA price and the above-allocation share. The variation from €1 to €51.31 confirms that the raw annual calibration should not be transposed directly into legislation. The smoothed series in Table 1 reduces the abrupt 2021 drop by averaging it with adjacent years, illustrating how a moving-average rule can make the benchmark more predictable while preserving the link to ETS data.

Fiscal revenues and compliance-cost proxies: comparing the ETS and the carbon tax

A key outcome of the analysis is a comparison of the modelled above-allocation ETS compliance-cost proxy and the hypothetical public yield of a carbon tax, under a *ceteris paribus* assumption (Table 2). The comparison must be read narrowly. The ETS column is not the official auction revenue of the EU ETS and it is not a direct revenue item of the Slovak state budget. It is a simplified proxy based on excess emissions above allocation and EUA prices, which approximates private compliance costs rather than public receipts.

The proxy comparison can establish only the mechanical relationship between a broader tax base, the calibration coefficient and an above-allocation compliance-cost benchmark. It cannot establish that a national carbon tax would be fiscally superior to the EU ETS, because that would require official auction-revenue data, behavioural modelling and a complete treatment of free allocation, banking and secondary-market transactions. In years when the minimum floor is not binding, the potential tax yield is approximately the ETS proxy multiplied by k ; the revenue difference is therefore a calibrated benchmark result rather than an independent empirical revenue discovery.

Table 2: Modelled above-allocation ETS compliance-cost proxy versus potential carbon-tax yield, 2015–2024 (€ million)

Year	Modelled above-allocation ETS compliance-cost proxy	Modelled potential carbon-tax yield	Difference
2015	342.4	428.0	85.6
2016	340.0	425.0	85.0
2017	504.5	630.6	126.1
2018	1,386.1	1,732.6	346.5
2019	3,187.8	3,984.8	797.0
2020	3,729.0	4,661.3	932.3
2021	0.0	20.9	20.9
2022	1,712.5	2,140.6	428.1
2023	3,426.6	4,283.3	856.7
2024	3,218.4	4,023.0	804.6
Total difference			4,482.8

Source: Own elaboration based on Slovak installation-level EU ETS data (National Emission Allowance Administrator of the Slovak Republic, 2026) and EUA price data (Kurzy.cz, 2025)

Note: The ETS column is a modelled compliance-cost proxy, not official auction revenue. The tax-yield column is recalculated from Equation (3); when the floor does not bind, it equals k times the ETS proxy.

The results in Table 2 show that the positive difference is a consequence of the calibration structure. In years when the minimum floor is not binding, the tax yield equals the above-allocation ETS proxy multiplied by $k = 1.25$. The apparent advantage is therefore not evidence that the carbon tax is empirically more revenue-productive than the EU ETS; it is the arithmetic effect of applying a 25 percent benchmark uplift to the compliance-cost proxy.

This finding limits the strength of the fiscal conclusion. The model is useful for showing how a tax benchmark can be derived from ETS variables, but the €4.48 billion cumulative difference over 2015–2024 should be interpreted as the result of the calibration rule. A genuine fiscal comparison would require official auction-revenue data and behavioural responses. Fiscal stability is therefore understood as improved transparency and a broader statutory base, not as guaranteed higher public revenue.

To assess the role of the calibration coefficient, Table 3 re-applies Equation (3) for $k = 1.00$, $k = 1.10$, $k = 1.25$ and $k = 1.50$ while keeping the €1 minimum floor fixed in years where it binds.

Table 3: Sensitivity of cumulative fiscal comparison to the calibration coefficient k , 2015–2024 (€ billion)

Calibration coefficient k	Cumulative tax revenue, 2015–2024	Difference versus ETS proxy	Difference excluding 2019–2020
1.00	17.87	+0.02	+0.02
1.10	19.65	+1.81	+1.11
1.25 (benchmark)	22.33	+4.48	+2.75
1.50	26.79	+8.94	+5.49

Source: Own calculation based on Table 2

Note: Scenarios re-apply Equation (3) for each value of k . The €1 minimum floor remains fixed when it binds, so the 2021 tax yield is not proportionally scaled by k .

Table 3 shows that the sensitivity exercise does more than restate that a higher k produces a higher revenue figure. It identifies the role of the minimum floor and the calibration coefficient separately. When $k = 1.00$, the cumulative difference is almost zero and arises only from the floor year. As k increases, the difference grows mechanically. The table therefore clarifies that the benchmark's fiscal advantage is not an independent empirical result, but a direct consequence of the chosen regulatory uplift.

Illustrative distributional and sectoral implications

Table 4 summarises the main channels through which a complementary carbon-tax benchmark could affect sectors and groups.

Table 4: Qualitative distributional implications of a complementary carbon-tax benchmark

Channel or sector	Expected incidence	Policy implication
EU ETS stationary industry	Direct exposure through verified emissions and interaction with free allocation.	Avoid double regulation; coordinate any tax benchmark with EU ETS obligations.
Energy-intensive trade-exposed sectors	Higher sensitivity to carbon-cost pass-through and competitiveness effects.	Use CBAM-compatible crediting and monitor leakage risks.
Transport and buildings outside the current EU ETS	Potentially broader pass-through to households and small firms under fuel-price channels.	Revenue recycling or targeted compensation may be needed to protect vulnerable users.
Households and consumers	Indirect burden through energy, transport and product prices.	Distributional effects should be assessed before any statutory implementation.
CBAM-covered imports	Exposure depends on product-level embedded emissions and carbon prices already paid.	A flat border charge is unsuitable; product-specific embedded-emissions data are required.

Source: Own synthesis based on the methodology and CBAM

Border adjustment in the CBAM context

The border-adjustment component is retained only as a conceptual extension of the carbon-tax benchmark. From 2026, CBAM requires authorised declarants to purchase CBAM certificates for covered imports, with the objective of aligning the carbon price of selected imported goods with the carbon price borne by EU producers. Recent evidence also suggests that CBAM effects can differ across firms and product categories (Vriz et al., 2026). Therefore, a national border tax could not be designed as a separate charge on the same embedded emissions in CBAM-covered goods.

Its realistic role would be limited to non-CBAM goods, to a supplementary analytical benchmark, or to a mechanism that deducts carbon prices already paid under CBAM or in third countries. A practical CBAM-compatible design would require product-level embedded-emissions data, deduction of carbon prices already paid abroad or through CBAM, and sector-specific rules. For this reason, the border component is not treated as an empirical revenue result in this article, but only as a competitiveness-related design issue.

Discussion, limitations and implications

The results should be interpreted cautiously and only within the scope of the empirical comparison. The model does not compare the full EU ETS with a complete carbon-tax system, but a Slovak above-allocation ETS compliance-cost proxy with a hypothetical carbon-tax benchmark. It shows that a carbon tax can create a transparent price benchmark and a broader statutory base, while the EU ETS provides a market-based scarcity signal through

the cap, auctioning and trading. However, because Equation (3) mechanically links the tax yield to the ETS proxy through k when the floor does not bind, the revenue comparison is best understood as a calibration exercise, not as evidence of fiscal superiority.

Several limitations affect the interpretation. The raw tax rate varies from €1 to €51.31, which means that the formula does not itself guarantee policy predictability. The three-year moving average in Table 1 illustrates a simple smoothing rule, but other rules, such as corridors or maximum annual changes, should be tested. Table 3 confirms that the fiscal comparison is sensitive to k and to the minimum floor. The model also abstracts from official auction revenues, allowance banking, secondary-market transactions, behavioural responses, production shifts and CBAM compliance rules. If the tax reduces emissions, the taxable base may decline over time and lower long-term revenue. The benchmark should therefore be read as a decision-support framework, not as a ready-made statutory proposal.

V. Conclusion

This article proposed and empirically illustrated a carbon-tax benchmark for the Slovak Republic calibrated on EU ETS data. The contribution of the article lies primarily in its methodological framework: it shows how verified emissions, allocated allowances and EUA prices can be used to construct a transparent calibration approach, while explicitly distinguishing between public auction revenues, private compliance costs and potential tax revenues.

The results indicate that the benchmark can create a broader statutory base than a Slovak above-allocation ETS compliance-cost proxy, but they do not prove fiscal superiority over the EU ETS. When the minimum floor is not binding, the potential tax yield follows mechanically from the ETS proxy and the calibration coefficient. The fiscal interpretation is therefore conditional on the chosen value of k , the smoothing rule, behavioural responses and the use of official auction-revenue data in future work.

The border-adjustment component must be interpreted in the context of CBAM. It cannot be treated as a parallel national import charge for goods already covered by the EU mechanism, because this would risk double charging and regulatory overlap. Further research should use official auction-revenue data, test alternative smoothing rules, model behavioural responses, incorporate the most recent verified installation-level data and analyse interaction with the EU ETS and CBAM.

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