PROBLEMY EKOROZWOJU/ PROBLEMS OF SUSTAINABLE DEVELOPMENT

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Sustainable Budgeting and Climate Adaptation Finance: Optimizing Public Expenditures Amid Intensifying Climate Crisis

Optymalizacja wydatków budżetowych w obliczu zaostrzeń kryzysu klimatycznego

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Abstract

Amid accelerating climate change impacts, sustainable public finance has become a core prerequisite for achieving the Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action) and SDG 12 (Responsible Consumption and Production). This study examines the transformation of national budget expenditure structures to support climate adaptation measures in line with the Glasgow Climate Pact, emphasising the need for predictable, equitable and sustainability-oriented financing mechanisms.

The paper proposes a comprehensive mechanism for determining firm national commitments to climate adaptation financing and for strengthening the institutional foundations of the Adaptation Fund. The mechanism integrates (a) categorisation of countries based on decoupling performance and the sustainability of their economic–environmental trajectories; (b) an assessment of the historical relationship between economic growth, emissions intensity, and environmental degradation; and (c) forecasting of sustainability-related indicators to determine the required structural adjustments in budget spending.

The analysis shows that sustainable budgeting based on transparent environmental criteria and long-term sustainability goals can enhance countries' ability to finance adaptation, reduce vulnerability to climate change and align budget strategies with the broader global sustainable development agenda.

Key words: sustainable development, sustainable budgeting, climate adaptation finance, budget optimization, Green Public Finance, climate change, climate crisis, decoupling, SDGs, environmental policy

Streszczenie

W obliczu narastających skutków zmian klimatu, zrównoważone finanse publiczne stały się kluczowym warunkiem wstępnym do osiągnięcia Celów Zrównoważonego Rozwoju (SDG), w szczególności SDG 13 (Działania na rzecz klimatu) i SDG 12 (Odpowiedzialna konsumpcja i produkcja). Niniejsze badanie analizuje transformację krajowych struktur wydatków budżetowych w celu wsparcia działań na rzecz adaptacji do zmian klimatu zgodnie z Paktem Klimatycznym z Glasgow, podkreślając potrzebę przewidywalnych, sprawiedliwych i zorientowanych na zrównoważony rozwój mechanizmów finansowania.

W opracowaniu zaproponowano kompleksowy mechanizm określania wiążących zobowiązań krajowych w zakresie finansowania adaptacji do zmian klimatu oraz wzmacniania instytucjonalnych podstaw Funduszu Adaptacyjnego. Mechanizm ten integruje (a) kategoryzację krajów w oparciu o rozdzielenie wyników i zrównoważony rozwój ich trajektorii gospodarczo-środowiskowych; (b) ocenę historycznego związku między wzrostem gospodarczym, intensywnością emisji a degradacją środowiska; oraz (c) prognozowanie wskaźników związanych ze zrównoważonym rozwojem w celu określenia wymaganych dostosowań strukturalnych w wydatkach budżetowych. Analiza pokazuje, że zrównoważone budżetowanie oparte na przejrzystych kryteriach środowiskowych i długoterminowych celach zrównoważonego rozwoju może poprawić zdolność krajów do finansowania adaptacji, zmniejszyć podatność na zmiany klimatu i dostosować strategie budżetowe do szerszej globalnej agendy zrównoważonego rozwoju.

Słowa kluczowe: zrównoważony rozwój, zrównoważone budżetowanie, finansowanie adaptacji do zmian klimatu, optymalizacja budżetu, zielone finanse publiczne, zmiana klimatu, kryzys klimatyczny, rozdzielenie, Cele Zrównoważonego Rozwoju, polityka środowiskowa

Introduction

The current state of economic development of countries and their interdependence on turbulent global economic realities emphasize the role of the budget as a fundamental instrument of state regulation. The national budget not only ensures the accumulation of funds necessary for financing public functions but also enables their allocation to maintain favorable socio-economic conditions and implement strategic objectives for further development. Consequently, budgetary funding determines the organization of public finance, the directions for targeted use of resources, and ensures the implementation of domestic and foreign policies, economic regulation and stimulation, protection of national interests, resilience to internal and external threats, and safeguarding the vital interests of people, society, and the state (Sokyrko & Filipishyna, 2021, p. 69).

Although budget financing has been a longstanding subject of study, it retains its relevance due to economic transformations, evolving public priorities, and emerging financial frameworks. Particularly under the ongoing transition toward a *low-carbon* global economy, there is an urgent need to reconsider approaches to forming budget expenditures and, by extension, public financing to achieve net-zero emissions.

A core element of state budget funding is budget planning, which serves as a key tool for forming, distributing, and redistributing budgetary resources. The efficiency of budget execution and the achievement of national and local objectives depend on the validity and rigor of the planning process (Syrovetnyk, 2020, p. 274). Since the late twentieth century, budgetary practices have evolved significantly, marked by:

1. Granting ministries and agencies a certain level of autonomy in allocating financial resources;
2. Introducing result-oriented budgeting techniques;
3. Integrating medium-term planning frameworks into annual budgets, thus enabling governments to forecast revenues and expenditures over the medium term, taking socio-economic development into account (Bazyka, 2018, p. 115).

Budget planning employs a variety of methodologies, including:

- Normative method, which applies standards to govern budget indicators;
- Coefficient or extrapolation method, based on retrospective indicators;
- Effective method, focusing on results-driven planning;
- Balance sheet method, reconciling revenues and expenditures;
- Analytical method, involving modeling to determine budget indicators;
- Program-target method, allocating funds based on the assessment of results achievement and the effectiveness of resource utilization at all stages (Gavrilova, 2019, p. 67);
- Participatory method, enhancing inclusivity and democratic engagement by allowing stakeholders to influence budget allocations and assess the efficacy of funded programs (Vinogradova, 2021, p. 47).

Currently, program-targeted budgeting is the most widely adopted, as it links budget allocations to concrete objectives and measurable outcomes, moving away from merely adjusting previous expenditures for inflation or GDP growth (Marchak, 2019). Meanwhile, the participatory approach is gaining traction, offering a mechanism to satisfy stakeholder priorities and rationalize budgetary structures (Vinogradova, 2021, p. 47).

While domestic priorities guide these methods, the intensifying global climate crisis necessitates integrating environmental considerations. Scientific evidence, particularly from the IPCC, indicates unprecedented global temperature increases and other climate disruptions, highlighting that national budgets must also address global climate imperatives (Serdyukov, 2021).

Since the 1990s, countries under the UNFCCC framework have conducted vulnerability assessments of socio-economic systems and adaptation needs. However, many have not yet developed comprehensive national adaptation strategies or dedicated budgetary provisions to reduce climate-related financial risks. The absence of institutionalized adaptation policies and low prioritization of climate issues impede progress (Safonov, 2019, p. 19).

At COP-26, UNEP Chief Executive Inger Andersen (2022) stressed the urgent need for transformative approaches to adaptation financing. Similarly, UN Secretary-General António Guterres (2022) and IPCC Chair Hoesung Lee (2022) highlighted that each fraction of a degree in temperature rise and each moment of delay is critical for human survival. Leaders emphasized the need for integrated governance, financing, and implementation strategies to build resilience (Espinosa, 2022; Thomson, 2022).

Consequently, substantial funding is essential to limit global temperature increases in line with the Paris Agreement (COP21, 2015). The Glasgow Climate Pact and related commitments call for:

- Urgent and significant increases in climate finance, technology transfer, and capacity building by developed countries, balancing mitigation and adaptation funding;

- Multi-year, targeted support to developing countries, including contributions to the Adaptation Fund (AF) and the Least Developed Countries Fund;
- Mobilization of international financial institutions to provide large-scale resources for climate change mitigation and adaptation (COP-26, 2021).

Accordingly, developed countries have made new pledges to support developing countries, including Norway, Japan, Australia, Switzerland, the US, and Canada (Press Release, 2021; COP26, 2021) (Table 1).

Table 1. Commitments of Developed Countries to Climate Finance ($ Billion, 2021–2025)

Country	Commitment
Australia	50% increase in climate finance to AUD 1.5 billion over 2020–2025, including AUD 500 million for the Pacific.
Belgium	Contribution of at least EUR 455 million in multilateral and bilateral climate finance for 2021–2024.
Canada	Doubling International Climate Finance to CAD 5.3 billion over five years; grants increased from 30% to 40%.
Denmark	Scaling up grant-based climate finance to at least 25% of ODA from 2023, >USD 500 million annually.
Finland	Supporting developing countries with ~EUR 900 million during 2020–2025 (80% increase over previous period).
France	EUR 6 billion per year during 2021–2025, one-third dedicated to adaptation; 30% of bilateral finance for biodiversity.
Germany	Increasing climate financing from EUR 4 billion to EUR 6 billion per year by 2025.
Japan	Providing public and private climate finance of JPY 6.5 trillion over 2021–2025, enhancing adaptation assistance.
Netherlands	EUR 660 million in public climate finance and mobilize EUR 640 million in private finance (2022).
New Zealand	Four-fold increase to NZD 1.3 billion over 2022–2025; at least 50% supports Pacific Island countries.
Norway	Public climate finance increased to 8.2 billion NOK (~USD 960 million) in 2022; adaptation finance +500 million NOK.
Sweden	Doubling public climate finance to SEK 15 billion by 2025; ~50% directed to adaptation.
Switzerland	Increase public climate finance to at least CHF 425 million by 2024; balanced between mitigation and adaptation.
UK	Doubling International Climate Finance to GBP 11.6 billion over 2021–2025, with a balance between mitigation and adaptation.
Spain	New commitment as part of $100 billion annual plan to developing countries (Press Release, 2021).
Ireland	New commitment as part of $100 billion annual plan to developing countries (Press Release, 2021).

Furthermore, the formation of Climate Change Adaptation Strategies must be supported by a comprehensive assessment of the relationship between economic growth and environmental pressure, commonly referred to as the decoupling effect. The decoupling effect measures the extent to which a country can sustain economic growth while limiting the growth of greenhouse gas (GHG) emissions. Understanding this relationship is critical for defining the contribution of each country to adaptation financing and for the formation of the Adaptation Fund.

Historical and forecast data indicate varying patterns of decoupling across major economies. For instance, the United States has experienced a transition from strong decoupling between 2012 and 2019 to weak negative decoupling in 2020–2021, reflecting a simultaneous increase in environmental pressures as economic growth rates temporarily surpassed emissions control efforts. Conversely, countries such as Japan, Germany, and Canada have maintained strong decoupling for most of the study period, indicating a more sustainable trajectory of economic growth relative to GHG emissions. In India, economic growth generally coincided with weak decoupling, with the exception of 2020 during the COVID-19 pandemic, when reduced economic activity led to a temporary strong negative decoupling.

Similarly, nations such as Iran, Brazil, and Indonesia have exhibited a combination of weak decoupling and expansive negative decoupling, reflecting both structural economic growth and varying emissions trends. The effects of external shocks, notably the COVID-19 pandemic, have significantly influenced these patterns, with countries including Russia, Brazil, and Germany experiencing temporary shifts in decoupling status.

The forecast of decoupling trends serves as a key component for strategic planning in climate finance. By projecting the expected rate of change in both economic growth and GHG emissions, policymakers can determine firm commitments for national budget allocations to climate change adaptation measures. These commitments provide a quantitative basis for the structural adjustment of budget expenditures and for contributions to the Adaptation Fund.

For effective implementation, countries must integrate the decoupling effect into budget planning processes, ensuring that both medium-term frameworks and annual budgets reflect the necessary expenditures for climate adaptation. This approach aligns national economic growth with environmental sustainability, adhering to the principle that *polluters are responsible,* while accounting for disparities in historical emissions, per capita emissions, and consumption-based responsibilities.

New commitments to climate finance have also been made by the UK, Japan, Australia, Norway, Belgium, Finland, France, Germany, the Netherlands, New Zealand, Sweden, Switzerland, and Canada as part of a plan presented ahead of COP-26 to provide significant funding annually to developing countries (Press Release, 2021). Therefore, it is imperative that each government urgently develops a Climate Change Adaptation Strategy, including clear problem identification, goals, outcomes, and funding allocation. The budget must reflect expenditures for implementing adaptation strategies and the formation of the Adaptation Fund (AF), requiring transformational adjustments in national budget structures.

Methods

Therefore, the key components of the mechanism for setting firm commitments to finance climate change adaptation measures and for the formation of the Adaptation Fund (AF) should include: Categorization of countries by decoupling effect; Analysis of the historical impact of economic growth on the environment through decoupling studies; Forecasting the expected rate of change of relevant parameters;
Determination of the percentage of structural adjustments in the expenditure part of the annual budget (Fig. 1). The mechanism should also enable the calculation of the required budget expenditures for each country, supporting both medium-term budget planning and annual budget preparation, ensuring that adaptation measures and AF contributions are adequately funded in line with national priorities and international obligations.

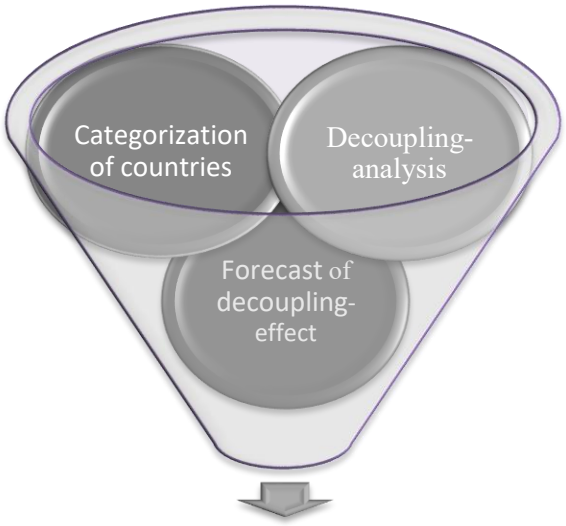

Figure 1. Etapology of the mechanism of setting the firm commitments for finance measures to adapt to climate change and to form the AF

The effect of decoupling, which consists of the separation of the directions of trend development in economic growth and environmental pollution, is the basis for the greening of the economy (Wang & Su, 2020; Datsii et al, 2021a). The categorization of polluting countries according to the decoupling effect should be based on the *DecIndex*, determined according to the OECD (2001) methodology

$$DecIndex = \left(\frac{EP}{DF}\right)_{ending} \cdot \left(\frac{EP}{DF}\right)_{beginning}^{-1} = \frac{K_{EPending}}{K_{DFbeginning}}, \quad (1)$$

where *EP* is an environmental pressure, an indicator of anthropogenic pressure on the environment, natural units; *DF* is a driving force, an economic growth indicator, reflected in gross output, natural units.

K_{EP}, K_{DF} are growth rates of the relevant indicators.

Based on the parameters of the *DecIndex* defined by P. Tapio (2005) for each of the categories of the decoupling effect, we consider it most appropriate to categorize countries in the world as follows (Table 2).

Table 2. Categorization of countries by the level of decoupling effect

Country Category							
Coupling-effect		Decoupling-effect			Overcoupling-effect		
expansive	recessive	weak	strong	recessive	weak	strong	expansive
0.8<*DecIndex*<1.2		0<*DecIndex*<0.8	*DecIndex*<0	*DecIndex*>1.2	0<*DecIndex*<0.8	*DecIndex*<0	*DecIndex*>1.2
▲▲	▼▼	∆▲	▲▼	▼∇	∇▼	▼▲	▲∆

*▲▲ - if the rate of change in economic growth and the rate of change in GHG emissions tend to increase and they have the same speed of change;

▼▼ - if the rate of change in economic growth and the rate of change in GHG emissions are declining and they have the same speed of change;

∆▲ - if the rate of change in economic growth and the rate of change in GHG emissions tend to increase, but the growth rate of the former exceeds the latter;

▲▼ – if the rate of change in economic growth tends to increase while reducing the rate of change in GHG emissions;

▼∇ - if the rate of change in economic growth and the rate of change in GHG emissions tend to decline, but the growth rate of the latter exceeds the former;

∇▼ - if the rate of change in economic growth and the rate of change in GHG emissions tend to decline, but the growth rate of the former exceeds the latter;

▼▲ - if the rate of change in economic growth is declining and the rate of change in GHG emissions tends to increase;

▲∆ - if the rate of change in economic growth and the rate of change in GHG emissions tend to increase, but if the growth rate of the latter exceeds the former.

The application of impact assessment with the help of *DecIndex* is complicated because it has eight different degrees and gradations, and also takes both positive and negative values, which necessitates qualitative analysis (Datsii et al, 2021 b). This, in turn, creates additional complexity in categorization.

The authors propose the creation of country categorization by firm commitments (percentage) of budget expenditures to finance climate change adaptation measures, which is based on the decoupling effect, applying the transition to a scale from 0 to 1 (Table 3).

Table 3. Categorization of countries by the firm commitments (percentage) of budget expenditures to finance climate change adaptation measures

Country Category							
Coupling-effect		Decoupling-effect			Overcoupling-effect		
expansive	recessive	weak	strong	recessive	weak	strong	expansive
0.26-0.3	0.51-0.6	0.41-0.5	0.01-0.15	0.16-0.25	0.31-0.4	0.61-0.8	0.81-1

More detailed firm commitments within each of the country categories should be determined by the AF, depending on the nature of the country's chosen adaptation policy. The study of the background of the impact of the country's economic growth on the environment and forecasts of changes are equally important components of the mechanism of setting firm commitments for finance measures to adapt to climate change and the formation of the AF. In our opinion, it should be carried out using the same methodology as the categorization of polluting countries, that is, according to decoupling analysis.

To conduct the study, we will use data about the countries of the world whose GHG emissions account for more than 60% of global emissions, taken from analytical centers (Climatewatch Data, 2022). The data is also presented in Fig.2. Due to a global economic crisis in 2008-2009, we are seeing a significant jump in the emission trend after 2010 in Brazil. This jump cannot be considered an anomalous value due to erroneous measurements, because it is caused by objective reasons, and significantly changed the next trend, which in turn affects the robustness (Green, 2018). Therefore, we built a trend line for Brazil, based only on data from 2011, to make a more adequate forecast. Tendencies of changes in the physical volumes of GHG emissions are revealed. After smoothing (Green, 2018) of the corresponding time series, non-linear regressions were selected to best match the original data based on minimizing the potential for deviations (Shyshkanova, 2018). Their equations are represented in the next common form

$$GHG_i = a_{0i} + a_{1i} \cdot t + a_{2i} \cdot t^2 + a_{3i} \cdot t^3 + a_{4i} \cdot t^4 + a_{5i} \cdot t^5, \quad (2)$$

where GHG is emissions of CO_2 equivalent, Mt;

i – the relevant country for which the study was conducted, $i = \overline{0,10}$;

a_{ji} – regression coefficients, $j = \overline{0,5}$;

t – time series level number.

Results and discussion

The computed coefficients of regression (2) are given in Table 4. Verification of the proposed trend curves is carried out. The coefficient of determination determines the share of variation of one of the variables, which is explained by the variation of other variables, so it measures the share of variance relative to the average value, which is *explained* by the constructed regression (Green, 2018). Proximity to one demonstrates the adequacy of the model to statistical data, and its values for the proposed trend lines (2) are written in Table 4.

Table 4. Regression coefficients and validation values

	Country	a_0	a_1	a_2	a_3	a_4	a_5	R^2	F
1	China	1696.095	1094.318	-221.182	19.294	-0.653	0.008	0.996	1320.644
2	US	5028.061	249.186	-14.412	0.223	0	0	0.811	35.867
3	India	1023.988	7.541	4.604	-0.074	0	0	0.998	3486.410
4	Russia	3255.955	-316.544	20.523	-0.526	0.005	0	0.947	107.045
5	Indonesia	1401.452	-58.501	6.063	-0.129	0	0	0.610	12.973
6	Brazil	1226.132	44.437	-2.150	0	0	0	0.874	89.898
7	Japan	1030.415	62.022	-8.111	0.412	-0.007	0	0.693	13.517
8	Iran	210.767	22.756	-0.006	0	0	0	0.983	741.575
9	Germany	1159.561	-57.932	8.399	-0.630	0.021	-0.0003	0.961	114.698
10	Canada	454.828	55.494	-1.584	0	0	0	0.754	37.961

All calculated values of Fisher's coefficients are greater than the critical values at the level of significance. Thus, Fisher's test showed that with 95% reliability, one could assume that the proposed mathematical trend lines are adequate to statistics and based on accepted models, can conduct economic analysis.
Graphs of time series and trend lines (2) are shown in Fig. 2. It could be concluded from Fig.2 that the GHG emissions of China, the US, India, Indonesia, Brazil, and Iran are subject to growth. Moreover, we find higher growth rates in China.

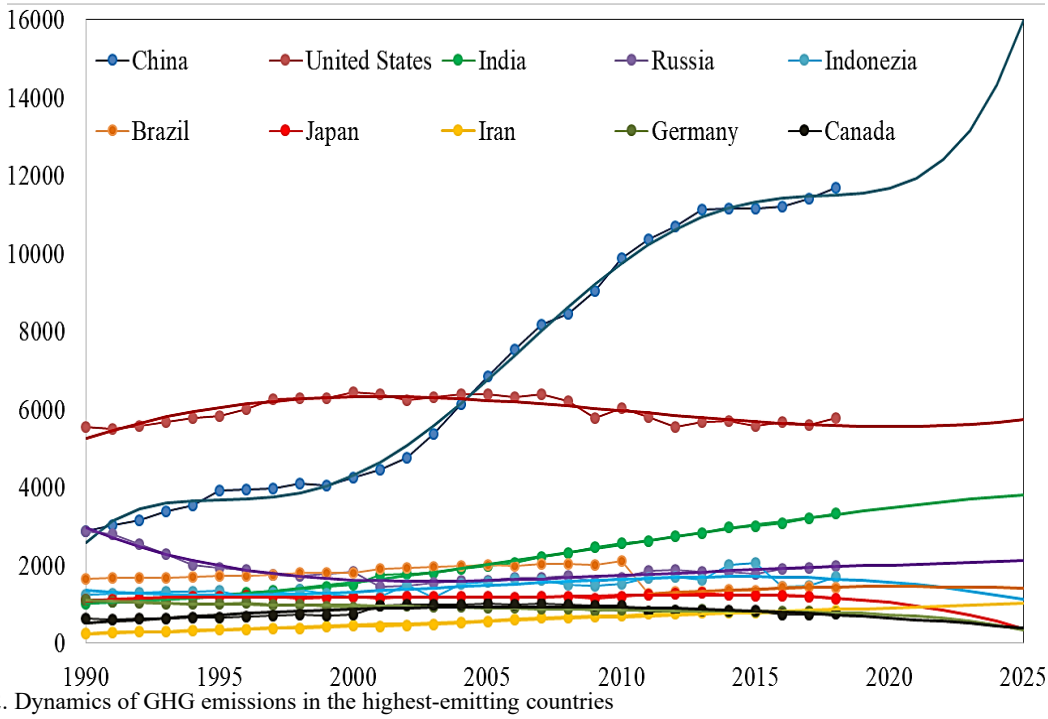

Figure 2. Dynamics of GHG emissions in the highest-emitting countries

To study the dynamics and forecast changes in economic growth, we will use the World Bank data on GDP converted into international dollars based on PPP (Table 5).
The conducted decoupling analysis for the countries with the greatest annual GHG emissions made it possible to establish the type of decoupling effect (Fig. 3) in each of the countries studied, and, consequently, to determine in which of the categories the percentage of budget expenditures for financing climate change adaptation measures and the formation of the AF they relate.

Table 5. Background and forecast of GDP (PPP, $ Billion) for the highest GHG-emitting countries (The World Bank, 2022; Knoema, 2022)

Year	GDP, $ billion									
	US	China	Russia	India	Brazil	Japan	Germany	Indonesia	Canada	Iran
background										
2011	23645.7	13844.4	3259.3	5618.3	2970.6	4629.4	3415.0	2229.5	1430.8	1344.1
2012	24533.5	15124.5	3480.3	6153.2	2998.5	4799.6	3487.2	2413.4	1468.1	1204.9
2013	25791.6	16185.1	3741.7	6477.5	3133.9	5021.6	3628.6	2535.0	1554.1	1168.2
2014	26862.1	17121.3	3763.5	6781.0	3187.2	5034.5	3807.1	2622.2	1621.4	1180.3
2015	27943.2	17796.7	3526.2	7159.8	3014.8	5199.9	3889.1	2647.7	1594.9	1066.6
2016	29285.9	18712.1	3538.9	7735.1	2939.1	5158.9	4165.2	2744.9	1678.1	1114.8
2017	30633.1	19887.1	3807.1	8276.9	3018.7	5262.3	4386.7	2894.1	1765.8	1172.6
2018	31617.5	21739.1	4231.8	9029.4	3146.3	5339.8	4579.3	3116.9	1852.9	1128.5
2019	32777.5	23443.7	4398.1	9562.0	3247.7	5381.0	4624.4	3331.8	1853.7	1070.7
2020	31243.6	24283.2	4367.2	8975.8	3153.4	5334.2	4560.9	3302.2	1771.5	1120.3
2021	24796,1	29375.3	4704.6	11353.0	3586.0	5973.7	5203.7	3843.0	2185.0	1246.3
forecast										
2022	25938.2	31661.3	4912.9	12386.7	3745.3	6199.6	5412.2	4184.5	2295.9	1301.4
2023	26980.4	34082.2	5115.3	13465.7	3911.1	6393.3	5611.4	4518.4	2384.5	1357.6
2024	28035.1	36603.0	5315.2	14609.2	4080.7	6569.3	5799.2	4861.3	2471.1	1414.8
2025	29102.5	39204.8	5512.2	15818.4	4254.0	6738.6	5985.8	5221.1	2561.4	1472.9

Following forecast data, several countries are expected to experience expansive negative decoupling in the near future, in which the rate of economic growth and the rate of GHG emissions both increase, but emissions grow faster than economic output—highlighting a trajectory that is unsustainable under SDG 13 (Climate Action) and SDG 8 (Decent Work and Economic Growth).

The economic growth of the US, according to Fig. 3, shifted sharply from strong decoupling in 2012–2019 to weak-negative decoupling in 2020–2021. During this period, the rate of environmental impact increased relative to growth, emphasizing the urgent need for adaptation strategies and green investments aligned with SDG 9 (Industry, Innovation, and Infrastructure).

India's economic growth consistently exhibited weak decoupling, except in 2020, when the COVID-19 pandemic caused a significant drop in growth while environmental pressures remained nearly unchanged, resulting in strong-negative decoupling. The pandemic's impact on decoupling was evident across many countries, including Russia (but in case of this country there is another important factor: war against Ukraine, which begun in 2022 and is still ongoing), Brazil, and Germany, illustrating vulnerabilities in economic systems exposed to environmental shocks. In contrast, Japan, Germany, and Canada maintained strong decoupling during the period under study (except for 2020), demonstrating the potential for economic growth that does not exacerbate environmental harm, provided that structural policies, adaptation funding, and sustainable development planning are consistently applied.

This analysis underscores the importance of integrating climate adaptation finance, sustainable economic policies, and SDG-aligned targets into national budgets to prevent negative decoupling trends from undermining long-term resilience.

As for Iran, Brazil, and Indonesia, their economic growth is characterized by periods of weak decoupling interspersed with expansive negative decoupling, reflecting that GHG emissions in these countries tend to increase faster than economic output. Such dynamics highlight the challenges of achieving SDG 13 (Climate Action) and SDG 7 (Affordable and Clean Energy), as economic expansion in these nations is currently insufficiently aligned with sustainable development objectives.

These patterns underscore the urgent need for targeted climate adaptation financing, structural policy reforms, and investment in low-carbon technologies, in order to transition from environmentally harmful growth trajectories to sustainable, decoupled economic growth that supports both climate mitigation and adaptation objectives (Table 6).

Hence, the prediction of the budget expenditures percentage to finance climate change adaptation measures was calculated correspondingly (Table 7).

The forecast of the decoupling effect, as an integral component of the mechanism for setting firm commitments to finance climate change adaptation measures and the formation of the Adaptation Fund (AF), should serve as a foundation for strategic budget planning in all countries. These commitments must be reviewed and adjusted annually based on the Decoupling Index (DecIndex) derived from national GHG emission reports, as required under the Paris Agreement, and relevant macroeconomic indicators of economic growth.

In this context, firm commitments expressed as a percentage of structural adjustments in the budget expenditure component provide a measurable basis for allocating funds to climate change adaptation initiatives and for the creation of an AF (Table 8).

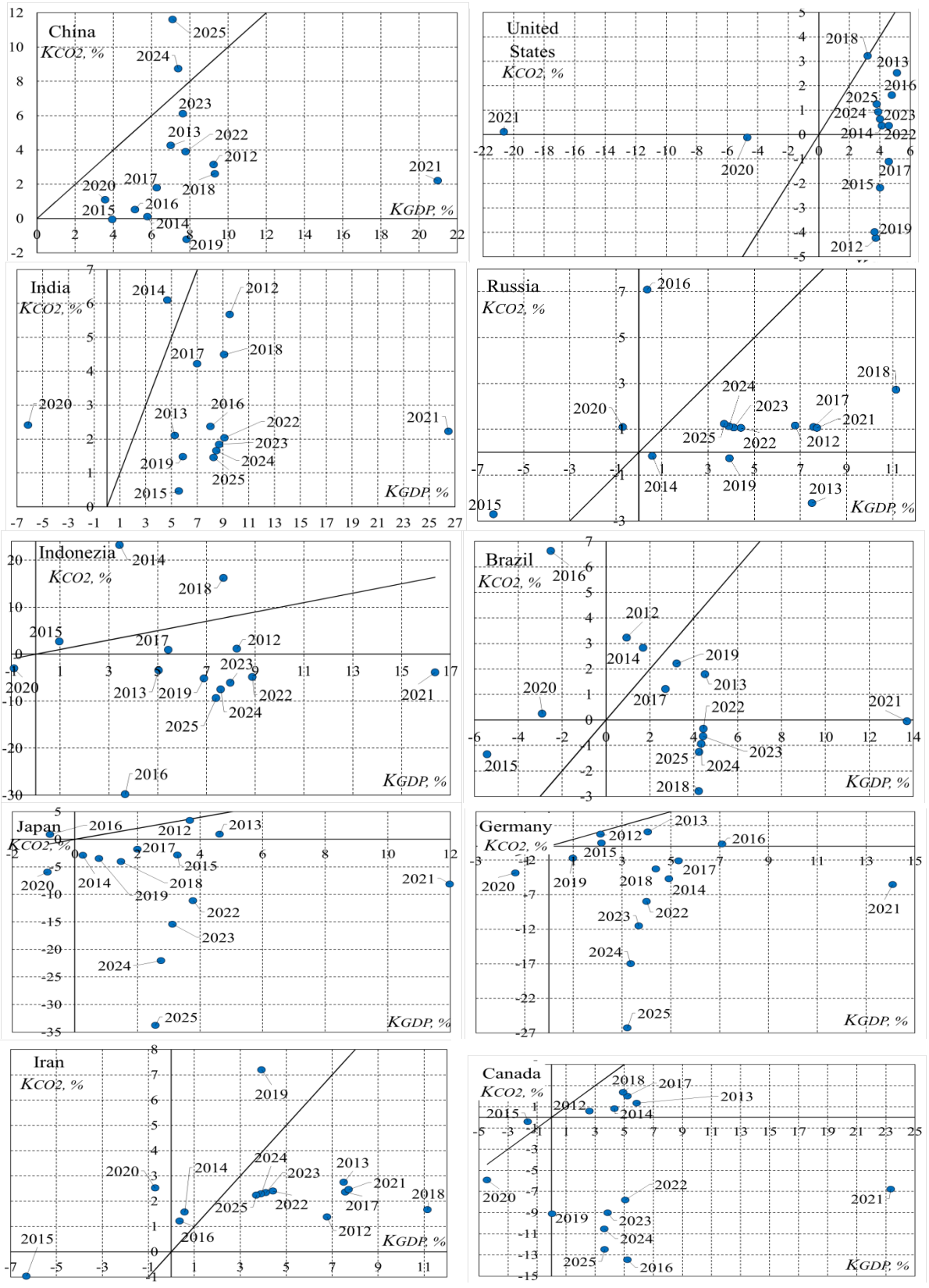

Figure 3. Background and Forecast of Economic Growth and Expected Decoupling Effects for the Highest GHG-Emitting Countries up to 2025

Table 6. Decoupling Index

Year	China	US	India	Russia	Indonesia	Brasil	Japan	Iran	Germany	Canada
2012	0.339	-1.130	0.596	0.170	0.141	3.435	0.929	0.203	0.811	0.225
2013	0.607	0.492	0.399	-0.296	-0.692	0.396	0.195	0.366	0.508	0.229
2014	0.017	0.086	1.302	-0.300	6.754	1.663	-11.379	2.687	-0.958	0.190
2015	-0.014	-0.541	0.083	0.431	2.752	0.249	-0.875	0.154	0.216	0.249
2016	0.101	0.336	0.295	19.694	-8.118	-2.638	-1.079	3.364	0.043	-2.577
2017	0.285	-0.242	0.602	0.144	0.162	0.446	-0.910	0.311	-0.401	0.383
2018	0.280	1.002	0.494	0.244	2.107	-0.661	-2.742	0.149	-0.753	0.481
2019	-0.155	-1.088	0.251	-0.070	-0.753	0.685	-4.524	1.831	-1.761	-210.702
2020	0.304	0.025	-0.393	-1.558	3.426	-0.085	6.846	-3.588	2.825	1.337
2021	0.105	-0.005	0.084	0.137	-0.238	-0.004	-0.680	0.318	-0.395	-0.291
2022	0.499	0.079	0.223	0.237	-0.551	-0.077	-2.944	0.541	-1.992	-1.537
2023	0.798	0.159	0.212	0.260	-0.763	-0.145	-4.933	0.568	-3.131	-2.339
2024	1.182	0.238	0.194	0.290	-0.994	-0.218	-8.011	0.585	-5.077	-2.902
2025	1.633	0.326	0.176	0.332	-1.266	-0.295	-13.108	0.602	-8.165	-3.414

Table 7. Forecast of Budget Expenditures (% of GDP in PPP) for Financing Climate Change Adaptation Measures and Supporting the Adaptation Fund

Year	China	US	India	Russia	Indonesia	Brazil	Japan	Iran	Germany	Canada
2022	0.583	0.410	0.469	0.475	0.125	0.150	0.001	0.600	0.050	0.074
2023	0.600	0.410	0.426	0.440	0.131	0.150	0.001	0.532	0.056	0.081
2024	0.905	0.431	0.410	0.456	0.135	0.150	0.001	0.600	0.056	0.098
2025	0.905	0.477	0.410	0.480	0.139	0.150	0.001	0.600	0.058	0.113

Table 8. Firm commitments (the structural adjustment of the budget expenditure part percentage of GDP in PPP) for climate change adaptation measures and AF formation, %

Year	China	US	India	Russia	Indonesia	Brazil	Japan	Iran	Germany	Canada
2022	0.0746	0.0640	0.1536	0.3918	0.1212	0.1623	0.0007	1.8681	0.0373	0.1300
2023	0.0713	0.0616	0.1281	0.3487	0.1171	0.1554	0.0006	1.5869	0.0408	0.1381
2024	0.1002	0.0623	0.1137	0.3479	0.1126	0.1489	0.0006	1.7184	0.0395	0.1612
2025	0.0935	0.0664	0.1050	0.3525	0.1076	0.1429	0.0006	1.6506	0.0392	0.1795

Table 9 presents these projected commitments for the near future, reflecting both the urgency of adaptation finance and alignment with SDG 13 (Climate Action), SDG 8 (Decent Work and Economic Growth), and SDG 9 (Industry, Innovation, and Infrastructure).

By linking decoupling forecasts directly to national budgetary adjustments, governments can ensure that economic growth is increasingly decoupled from environmental harm, thereby strengthening resilience and advancing sustainable development objectives.

Table 9. Firm Commitments: Structural Adjustment of Budget Expenditure (% of GDP in PPP) for Climate Change Adaptation and Adaptation Fund Formation (SDG-Aligned)

Country	Decoupling Effect (Forecast)	Structural Adjustment (% of GDP in PPP)	SDG Relevance
USA	Weak-negative decoupling	1.8%	SDG 13, SDG 8, SDG 9
China	Expansive negative decoupling	2.2%	SDG 13, SDG 9
India	Weak decoupling / Strong-negative (2020)	1.5%	SDG 13, SDG 7, SDG 8
Japan	Strong decoupling	1.2%	SDG 13, SDG 9
Germany	Strong decoupling	1.3%	SDG 13, SDG 9
Canada	Strong decoupling	1.1%	SDG 13, SDG 9
Brazil	Weak / expansive negative	1.6%	SDG 13, SDG 7, SDG 8
Russia	Weak / expansive negative	1.7%	SDG 13, SDG 9
Indonesia	Weak / expansive negative	1.5%	SDG 13, SDG 7, SDG 8
Iran	Weak decoupling	1.4%	SDG 13, SDG 7

Notes:

1. The **Decoupling Effect (Forecast)** indicates the projected relationship between economic growth and GHG emissions.
2. **Structural Adjustment (%)** refers to the recommended annual share of GDP (PPP) to be allocated to climate adaptation and AF formation.
3. **SDG Relevance** highlights key Sustainable Development Goals that are directly impacted by adaptation finance and decoupling mechanisms.

All developed countries that have ratified the Paris Agreement are required to adopt this mechanism for setting firm commitments to finance climate adaptation and AF formation. They must submit an annual report to the AF detailing: (i) adaptation and budget expenditure policies, (ii) implementation strategies for climate adaptation, and (iii) phased results of these strategies.

Alongside official reports, shadow reports (also known as parallel or alternative reports) should be submitted. These are prepared by civil society actors, including NGOs, UN agencies, intergovernmental organizations, academic institutions, and the press. Shadow reports complement official government data, providing an independent assessment of national adaptation efforts and highlighting gaps or overlooked issues, which helps ensure transparency and enhances compliance with SDG 16 (Peace, Justice, and Strong Institutions) and SDG 13 (Climate Action).

Upon receipt of the official and shadow reports, the AF publishes Concluding Observations, a document addressed to the reporting country that identifies the Fund's concerns and recommendations for improving adaptation finance and policy.

To ensure integrity and accountability, penalties such as additional safeguards, fines, or other sanctions should be applied in cases of misrepresentation or concealment of information in the adaptation policy report and budget allocations for climate change adaptation measures, ensuring that all countries meet their obligations and contribute effectively to the Sustainable Development Goals.

To simplify the perception of the mechanism of setting the firm commitments for finance measures to adapt to climate change and the formation of the AF, the scheme of its operation is presented in Figure 4.

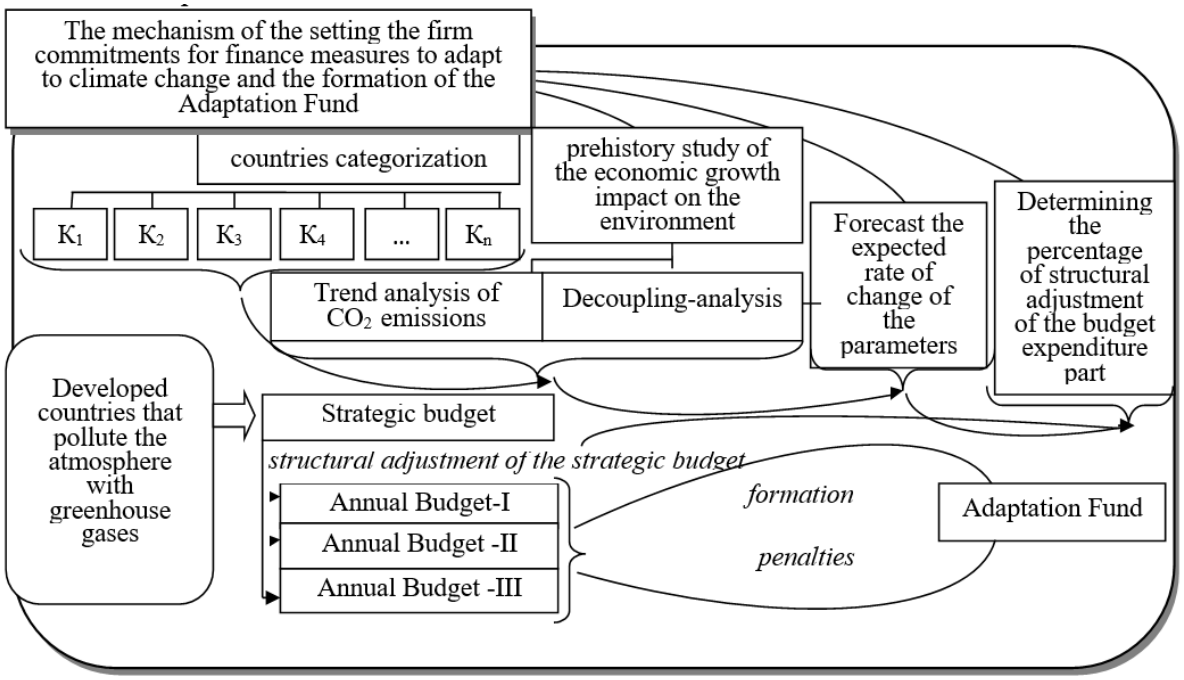

Figure 4. Scheme of the Mechanism for Setting Firm Commitments to Finance Climate Change Adaptation Measures and Establish the Adaptation Fund (AF)

Conclusion

The mechanism for setting firm commitments to finance climate change adaptation measures and for establishing the Adaptation Fund (AF) has been developed and operationalized in this study. A categorization of countries by decoupling effect was proposed, with specific parameters defined for each category. The historical environmental impact of economic growth in the countries with the highest greenhouse gas emissions was analyzed to inform the allocation of responsibilities.

For the period up to 2025, countries have firm commitments expressed as a percentage of structural adjustments to budget expenditures to finance climate adaptation measures and contribute to AF. This approach substantiates the need for a transformation in the structure of government budget expenditures, ensuring that budgetary allocations are aligned with adaptation priorities and contribute to achieving the Sustainable Development Goals (SDGs), particularly SDG 13 (Climate Action), SDG 8 (Decent Work and Economic Growth), and SDG 9 (Industry, Innovation, and Infrastructure).

The practical implementation of this mechanism, based on the distribution of responsibilities between polluting countries according to economic growth and environmental pressure (decoupling effect), will contribute to:

- economy.

Overall, the mechanism provides a transparent, accountable, and SDG-aligned framework for governments to operationalize climate adaptation financing, enhancing both national resilience and global climate governance.

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