Original Article

ENERGY & ENVIRONMENT

Energy & Environment
1–23

DOI: 10.1177/0958305X231151679
journals.sagepub.com/home/eae
SAGE

Green development of the country: Role of macroeconomic stability

Yang Chen[1], Oleksii Lyulyov[2,3], Tetyana Pimonenko[2,3] and Aleksy Kwilinski[2,3,4]

Abstract

The intensification of ecological issues provokes to search for the appropriate mechanism and resources to solve them without declining the economic growth. This requires moving from resources oriented to green economic development. It could be realised through two goals: achieving macroeconomic stability – core driver of economic growth; declining environmental degradation and increasing efficiency of resources using – core requirements for green development. The paper aims to check the hypothesis on macroeconomic stability's impact on the green development of the countries. The object of investigation is European Union countries from 2000 to 2020. The study applied the following methods: the Global Malmquist-Luenberger productivity index – to estimate the green development of the countries; Macroeconomic Stabilisation Pentagon model – to estimate macroeconomic stability; Kernel density estimation and Tobit model – to check the macroeconomic stability impact on the green development of the countries. The empirical findings show that Malta from the 'Green Group' and Estonia from the 'Yellow group' have the highest value of green development, and Sweden and Greece have the highest value of macroeconomic stability. Besides, the findings allow confirming the research hypothesis. Thus, the growth of external dimensions of macroeconomic stability by 1 point led to the growth of green economic development by 0.085 (among 'Green group') and 0.195 (among 'Yellow group'). It confirms that harmonising macroeconomic stability among all EU members allows for achieving the synergy effect.

[1]School of Economics, Fujian Normal University, Fuzhou, P. R. China
[2]Department of Management, Faculty of Applied Sciences, WSB University, Dabrowa Gornicza, Poland
[3]Department of Marketing, Sumy State University, Sumy, Ukraine
[4]The London Academy of Science and Business, London, UK

Corresponding authors:
Oleksii Lyulyov, Department of Management, Faculty of Applied Sciences, WSB University, 41-300 Dabrowa Gornicza, Poland; Department of Marketing, Sumy State University, Sumy, Ukraine.
Email: alex_lyulev@econ.sumdu.edu.ua

Tetyana Pimonenko, Department of Management, Faculty of Applied Sciences, WSB University, 41-300 Dabrowa Gornicza, Poland; Department of Marketing, Sumy State University, Sumy, Ukraine.
Email: tetyana_pimonenko@econ.sumdu.edu.ua

Keywords
Macroeconomic stabilisation Pentagon model, green economic growth, renewable energy, carbon dioxide emissions, economic openness, economic globalisation, foreign direct investment, quality of institutions

Introduction

The scholars[1–3] justified that transitioning from traditional to sustainable development requires changing the economic growth paradigm into green growth. It allows for harmonising the country's social, economic and ecological development.[4] Besides, it leads to decline in the negative impact on the environment while simultaneously saving the tendency of the economic growth rate. It should be noted that it requires implementing relevant mechanisms and instruments at all levels (multinational, national, regional, and local) and sectors (economic, social, finance, etc.). Besides, considering the studies,[5–8] developing and developed countries have cardinally different capabilities to transit into the policy of green development. Developed countries have enough financial capabilities and an attractive climate for green investment in research and development for extending green technologies.[5,7,9–13] At the same time, developing countries do not have enough financial capabilities and mostly have worse macroeconomic stability, which negatively effects on investment climate of the country for attracting green investors.[6–8] Thus, it provokes gaps in green development between countries, which contradicts the principles of sustainable development.[5,7] It should be noted that European experts established the Macroeconomic Imbalance Procedure (MIP)[14] in 2011 to detect the imbalances at the early stage among EU countries after the world financial recession. Considering the analytical report,[15] in 2021, compared to 2015, all countries declined the level of macroeconomic stability. The consequences of COVID-19 could explain it. The past study[16] empirically confirmed that COVID-19 had negative effect on economic growth. In addition, COVID-19 could provoke the declining of CO_2 in short term. However, in long term such impact did not prove in case for China.[16]

It should be noted that Denmark, Sweden, Finland, and Luxembourg have stable macroeconomic stability compared to other EU countries.[15] At the same time, the following countries meet with macroeconomic imbalances: Croatia, Cyprus, France, Germany, and Greece. Besides, Cyprus, Greece, and Italy meet the over macroeconomic imbalances. It should be underlined that the MIP procedure does not allow comparing countries between each other by the level of macroeconomic stability. At the same time, considering the report of the Solability Agency in 2021 among European Union countries (EU) the TOP-10 countries (Figure 1) on the Global Sustainable Competitiveness Index (GSCI) (scoreboard of the country on green growth from 2012, based on 131 quantitative indicators) are Sweden (61.2), Finland (60.7), Switzerland (60.4), Denmark (60.2) and Norway (59.8).[17]

In 2021, the following countries had the lowest level of GSCI: Greece (49.6), Bulgaria (49.6), Cyprus (47.5), Montenegro (46.8) and Moldova (46.0). It should be noted that GSCI consists of five dimensions: nature capital, social capital, intellectual capital, governance and resource intensity. Thus, the findings confirmed that among TOP-10 countries on GSCI, all dimensions are balanced and do not have big gaps between each other. At the same time, the countries with low values of GSCI have big gaps between dimensions.[17] Past studies[18,19] confirmed that the transition into green development does not depend on the macroeconomic stability of the country in the short term. However, this impact was confirmed in the long term.[19] Furthermore, scholars[20] proved that economic growth did not provoke the accumulating footprint and did not affect green growth. Besides,

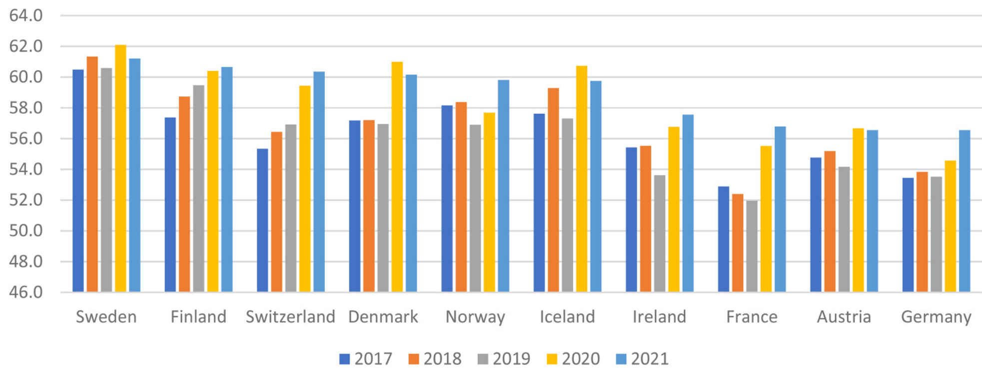

Figure 1. Global sustainable competitiveness index under the core dimensions for TOP-10 highest value among EU countries (based on[17]).

the researchers[21,22] underlined two opposite views: (1) green growth could not be achieved without the restriction of economic growth; (2) green growth would not be due to economic growth, which requires increasing production and consumption. The findings[21] confirmed that green innovation technologies are conducive to green development, consequently leading to economic growth.

Thus, considering those mentioned above, it is necessary to check the relation between macroeconomic stability and the green development of the country. In this case, the paper aims to: estimate the green development of the countries; estimate macroeconomic stability based on an approach which allows comparing countries to each other; check the impact of macroeconomic stability on the green development of the countries.

The paper contributes to theoretical framework of green economic development (Ged) by the advanced approach for assessment of: (1) Ged which based on Global Malmquist-Luenberger (GML) productivity index, which allows simultaneously considering two goals ensuring economic growth (desired outputs) and declining the eco-destructive impact on nature; (2) macroeconomic stability of the country based on macroeconomic stabilisation Pentagon model which consider internal and external factors of country's economic development. Furthermore, the study fills the gap in the deciding role of macroeconomic stability impact in Ged based on Tobit model with the following control variables economic openness, economic globalisation, foreign direct investment and quality of institutions.

Considering the above-mentioned aspects, the paper has the following structure: 'Literature review' – analysis of the theoretical framework for the assessment of macroeconomic stability and green development and checks the relation between them; 'Methodology' – explains the applied methods to measure macroeconomic stability and green development and checks the relation between them; 'Results' – explanation of the core empirical results of the investigation; 'Conclusion & discussion' – conclusion and discussions of the obtained results under the investigation.

Literature review

Green economic development: Approach for assessment

The analysis showed that scientists mostly used a vast range of approaches to estimate the country's green development, which depends on the core dimensions of the analysis. Scholars[23] proposed to use the green GDP to measure the green development of the country. They analysed the following indicators: resource consumption, harmful effect on the environment, and environmental protection and restoration initiatives. A similar approach was used by Turkish scientists[24] for the assessment of green growth in Turkey. They calculated green growth as GDP and education expenditure sum after deducting the value of exhausting coal, crude oil, natural gas and forest and the damage value due to carbon dioxide emissions. The study[25] applied the DPSIR method and TOPSIS-coupling coordination degree evaluation model to measure the green growth of the region in China. DPSIR method is based on the compilation of economic and social drivers, environmental damage (energy consumption, emissions and waste), environmental regulation and innovation (research and development). Another scientific group[18,26–28] applied the Global Malmquist–Luenberger index to measure green development. Thus, the study[28] suggested that economic growth could not be analysed without relevant indicators revealing its harmful effects on the environment. The scholars[28] applied Global Malmquist–Luenberger index and proposed to consider undesirable outputs of air pollution to measure Ged. The researchers[26] used a similar approach to estimate Chinese environmental productivity. They used energy consumption as the input data. Air pollution, wastewater and industrial waste were undesirable outputs. The study[18] chose the following indicators to estimate the Ged for Chinese provinces: labour, capital, GDP, gas emission from the industry, wastewater from the industry, and solid waste from the industry. The paper[27] proposed to measure Ged through the Green Innovation Efficiency Index, which is based on the slacks-based measure and Global Malmquist–Luenberger index. Besides, the core indicators were the following: input – human resources investment, capital investment, energy investment; desirable output – scientific research level, achievement transformation level; undesirable output – wastewater emissions, exhaust emissions and CO_2.

Macroeconomic stability: Approach for assessment

The analysis of the theoretical framework of macroeconomic stability showed that the experts had not accepted the unified approach to defining it. Consequently, the experts applied various approaches and models to estimate it. Thus, the studies[29,30] used the following measures of macroeconomic stability for OECD countries: GDP growth rate, investment, and consumption. Bleaney[31] analysed the macroeconomic stability of developing countries 1980–1990. He applied the regression functions with the variables: GDP per capita, labour, capital and shocks which provoked the instability. Martinez-Vazquez and McNab[32] defined macroeconomic stability through the function of labour, capital and fiscal decentralisation. Besides, inflation and unemployment were used as the core determinates. Thus, they confirmed that fiscal decentralisation indirectly impacted economic growth through macroeconomic stability. The studies[33–35] confirmed that macroeconomic stability depends on external and internal social, economic, ecological and financial shocks. Iqbal and Nawaz[36] highlighted that most investigations used inflation as the indicator of macroeconomic stability. In this case, they applied Misery Index to measure Pakistan's macroeconomic stability. Besides, they suggested that macroeconomic stability depends on fiscal decentralisation. Thus, the scholars used three models to define macroeconomic stability: (1) decentralisation of income, money supply (growth rate), investment and openness; (2) decentralisation of expenditure, money supply (growth rate), investment and openness; (3) decentralisation of income and expenditure, money supply (growth rate), investment and openness. Roszko-Wójtowicz and Grzelak[37] analysed the macroeconomic stability and competitiveness among EU countries. Thus, macroeconomic stability was estimated by the macroeconomic stabilisation pentagon. It should be noted that Kolodko[38] developed the macroeconomic stabilisation pentagon approach, which focused on five goals of the country's development: economic growth (measure growth rate of GDP), unemployment, inflation rate, budget balance and current account balance. Besides, reseachers[39] based the investigation on[38] approach to measure macroeconomic stability through the relation between indicators: unemployment and inflation, unemployment and rate of economic growth, inflation and budget, account balance and budget, account balance and rate of economic growth. Under the analysing of the impact of macroeconomic stability on the sustainable development of the companies in Central and Eastern European Countries, scholars[40] defined macroeconomic stability as the appropriate combination of political, institutional and structural conditions which provide the convergent price mechanism and effective using of available economic resources.

Macroeconomic stability and green economic development

Past study[39] concluded that policy on macroeconomic stability should be synchronised with the ecological policy of the country. The study[41] confirmed that big ecological scandals influenced on country's brand, declining its reputation and macroeconomic imbalances. The researchers[39] applied the OLS and SUR methodologies to confirm the statistically significant impact of macroeconomic stability on economic decarbonisation for the largest polluters in EU countries (France, Germany, Italy, Poland and Spain) in 1990–2020. Saydaliev and Chin[42] applied temporal analysis to empirically justify the positive impact of green investment for environmental policy on macroeconomic stability for ASEAN countries. Thus, increasing green investment by 1% allowed declining energy pollution through innovation and clean technologies. Consequently, it led to the strengthening of the macroeconomic stability of the country. The study[43] applied the OLS methodology to confirm the statistically significant impact of economic recession on the achievement of sustainable development goals in Nigeria. Besides, they proved the necessity of modernisation policy to improve macroeconomic indicators through declining corruption and structural reforms. The scholars[44] applied GMM for 90 countries from 2010–2015 to justify the positive impact of green growth on financial stability. Thus, considering findings, they concluded that green growth had a positive, statistically significant impact on long-term and short-term financial stability. However, they highlighted that the social dimensions of green growth did not affect financial stability. Similar conclusions were obtained by study.[45] The findings confirmed the relationship between green growth and fiscal imbalances for E-7 economies. However, Xia and Xu[18] did not confirm the link between green development and the high-quality growth of Chinese provinces. The priory study[46] empirically justified the bidirectional Granger causal relationship between carbon dioxide emissions and economic growth for 147 countries from 1990 till 2015. Besides, economic growth and increasing of energy intensity enhance carbon dioxide emissions. At the same time, the growth of consumption from renewable energies conducive to declining carbon dioxide emissions.

Based on an analysis of the theoretical framework, Jänicke[1] concluded that consensus between traditional economic and green growth could be achieved through the relevant policy to avoid de-growth and imbalances among all EU countries. Barbier[47] underlined that green growth could not be realised without stable economic development. Thus, green growth should catalyse the overall world economic transformation and decline the geographical poverty gaps. It could be realised through sharing knowledge, innovations and technologies. Besides, Barbier[47] highlighted that the investment policy was a core trigger of green growth. Considering Draft,[48] green growth allows increasing GDP, revenue from ecosystem services, extending innovations and so on. Besides, Draft[48] highlighted that green growth is conducive the declining inequality and poverty gaps. At the same time, Braunstein and Houston[49] underlined the role of macroeconomic stability in sustainability and green growth. Thus, considering findings, they justify the macroeconomic stability impact on green growth of the developing countries. Thus, considering the analysis mentioned above showed that scientists obtained vice versa findings on the linking between macroeconomic stability impacted and green growth of the county. Considering it, the following hypothesis was checked:

Hypothesis 1: The macroeconomic stability affected on Ged of the country.

Methodology

Index selection and data sources

Green economic development. Based on the methodology of the studies,[18,26–28]in general way the production technologies for county with the hypothesis to decline the undesirable outputs with asymmetrically of the desirable and undesirable outputs could be written as formula 1:

$$PT\ (x) = \{(y, b)|x\ could\ produce\ (y, b) \tag{1}$$

Besides, the following axioms should be considered:

$$\text{if } (0, 0)\ \epsilon\, \text{PT (x) for all x } \in\ R_{+}^{N}\ \ (N\, \text{desirable outputs}) \tag{2}$$

$$\text{if}\, x' \geq x,\ \text{then}\, PT\left(x'\right) \supseteq PT(x) \tag{3}$$

$$\text{if}\, (y, b)\ \in\ PT(x)\, \text{and}\, 0 \leq \theta \leq 1,\ \text{then}\, (\theta y, \theta b)\ \in PT(x) \tag{4}$$

$$\text{if}\, (y, b)\ \in\ PT(x)\, \text{and}\, y' \geq y,\ \text{then}\, (y', b) \in PT(x) \tag{5}$$

$$\text{if}\, (y, b)\ \in\ PT(x)\, \text{and}\, b = 0,\ \text{then}\, y = 0 \tag{6}$$

It should be noted that the distance function of the decision-making units (DMUs) allows simplifying the calculation and interpretation of the data. Thus, if $g = (g_y, g_b)$ is a direction vector and $g \in\ R_{+}^{N} \times\ R_{+}^{J}$, the distance function of the DMUs should be:

$$\overrightarrow{D_0}\, (x, y, b; g_y, g_b) = \max\{\beta{:}(y + \beta g_y,\ \ y - \beta g_b \in PT(x)\} \tag{7}$$

GML productivity index consider two options for contemporaneous production technology sets contemporaneous (formula X) and global production technology sets (merged of all contemporaneous technology sets).

$$Ged^t\ (x^t) = \{(y^t, b^t)|x^t\ could\ produce\ (y^t, b^t),\ \ t\ =\ 1\ldots T \tag{8}$$

Based on the studies,[18,26–28] this investigation applies the GML productivity index to estimate the Ged. It allows considering the postulates of sustainable development: declining the eco-destructive impact (undesired outputs) while simultaneously ensuring economic growth (desired outputs). Besides, based on the directional distance function, the GML productivity index directs to maximising desired outputs while simultaneously declining undesired outputs.

$$Ged_t^{t+1} = \left[\frac{1 + D_i^G(x^t, y^t, \ b^t)}{1 + D_i^t(x^t, y^t, \ b^t)} \times \frac{1 + D_i^{t+1}(x^{t+1}, y^{t+1}, \ b^{t+1})}{1 + D_i^G(x^{t+1}, y^{t+1}, \ b^{t+1})}\right] \times \frac{1 + D_i^t(x^t, y^t, \ b^t)}{1 + D_i^{t+1}(x^{t+1}, y^{t+1}, \ b^{t+1})}$$
$$= GedTECH_t^{t+1} \times GedEFFCH_t^{t+1} \quad (9)$$

$$Ged_t^{t+1} = GedTECH_t^{t+1} \times GedEFFCH_t^{t+1} \quad (10)$$

where $x^t, y^t, \ b^t$ – the set of input and output indicators of the model (M input resources $x = (x_1, \ x_2, \ \ldots, \ x_M) \epsilon R_+^M$ produce the N desirable outputs $y = (y_1, \ y_2, \ \ldots, \ y_N) \ \epsilon \ R_+^N$, and J undesirable outputs $b = (b_1, \ b_2, \ \ldots, \ b_J) \epsilon R_+^J$); $D_i^t(x^t, y^t, \ b^t)$, $D_i^{t+1}(x^{t+1}, y^{t+1}, \ b^{t+1})$ – the distance function of the DMUs in t and $t+1$ time, relevant; $GedTECH_t^{t+1}$, $GedEFFCH_t^{t+1}$ – the green technical (TECH) and efficiency change ($EFFCH$) in t and $t+1$ time.

Calculation and decomposition of Ged is estimated by searching the equitation's optimisation (11) and (12):

$$\begin{cases} D_0^S(x^s, y^s, \ b^s; \ y^s, \ - \ b^s) = max\beta \\ \sum_{k=1}^{K} z_k^s y_{km}^s \geq (1 + \beta) y_m^s, \quad m = 1, .., M \\ \sum_{k=1}^{K} z_k^s b_{kj}^s = (1 - \beta) b_j^s, \quad j = 1, .., J \\ \sum_{k=1}^{K} z_k^s x_{kn}^s \leq x_n^s, \quad n = 1, .., N \\ z_k^s \geq 0, \ k = 1, \ \ldots, K \end{cases} \quad (11)$$

or

$$\begin{cases} D_0^G(x^s, y^s, \ b^s; \ y^s, \ - \ b^s) = max\beta \\ \sum_{t=1}^{T} \sum_{k=1}^{K} z_k^t y_{km}^t \geq (1 + \beta) y_m^s, \quad m = 1, .., M \\ \sum_{t=1}^{T} \sum_{k=1}^{K} z_k^t b_{kj}^t = (1 - \beta) b_j^s, \quad j = 1, .., J \\ \sum_{t=1}^{T} \sum_{k=1}^{K} z_k^t x_{kn}^t \leq x_n^s, \quad n = 1, .., N \\ z_k^t \geq 0, \ k = 1, \ \ldots, K \end{cases} \quad (12)$$

where $s = t, \ t+1$; z_k^S – the intensity variables.

In the studies,[3,50] the core production factors were capital, labour and energy. Thus, the desired outputs are product production and service, measured by Gross Domestic Product (GDP). Rapid transition into an economy with a low carbon-free economy is the basic requirement for achievements of energy and climate goals EU to 2030 and long-term preceptive.[51–56] At the same time, the energy sector is a core force to decarbonise the economy of EU countries. It is provoked by snowballing growth and development of renewable energy, allowing declining carbon emissions.[57–59] Considering it, Ged requires the expected economic growth due to the extending innovation technologies for renewable energy and declining carbon emissions. Thus, the study includes the energy from a renewable source to the model (1) – input of production, CO_2 emissions are undesirable

Table 1. Variables of the analysis of Ged.

Symbol	Meaning	Sources
Inputs		
L	Labour force, total	World Data Bank[61]
K	Gross capital formation (current US$)	
E	Use of renewables for electricity (gigawatt-hour)	Eurostat[62]
Desirable output		
GDP	Gross domestic product	World Data Bank[61]
Undesirable outputs		
Em	CO_2 emissions	Eurostat[62]

production outputs.[26,60] The variable's type (Input, Desirable and Undesirable outputs) and explanations are shown in Table 1.

Macroeconomic stability

The macroeconomic stability assessment is based on the macroeconomic stabilisation pentagon model proposed by Kolodko[38] and improved in the studies.[32,36,37,39] Considering that model, macroeconomic stability is estimated by synthetic indicator MSP, which measures the pentagon's surface. The vertices of the pentagon are the basic macroeconomic indicators (GDP growth rate, unemployment rate, inflation rate, fiscal balance and current account balance). The relation between those indicators showed the assessment of core directions for providing macroeconomic stability in the country: the real sector of the economy (defined as the multiplication of the GDP growth rate and the unemployment); stagflation (which depends on unemployment and inflation rates); budget and inflation rate (defined as the multiplication of the inflation and the state budget balance); financial balance (calculated as the multiplication of the state budget and the current turnover to GDP); external sector of the economy (reflects the multiplication of the current turnover to GDP and GDP growth rate):

$$MSP_{i,t} = [(GDP_{i,t} \times Un_{i,t}) + (Un_{i,t} \times ICP_{i,t}) + (ICP_{i,t} \times SB_{i,t}) + (SB_{i,t} \times CA_{i,t}) + (CA_{i,t} \times GDP_{i,t})] \times k \quad (13)$$

where $MSP_{i,t}$ – macroeconomic stability of the i-country in t-time; $GDP_{i,t}$, $Un_{i,t}$, $ICP_{i,t}$,$SB_{i,t}$, $CA_{i,t}$ – normalised indicators of GDP growth rate (%), unemployment rate (%), inflation rate (%), fiscal balance as a percentage of GDP, current account balance as a percentage of GDP of the i-country in t-time; $k = 1/2 \sin 72\ (^\circ) = 0.475$.

The indicators from formula (13) are normalised (distancing from the pentagon's centre means a better development value of the selected variables), taking into account the following assumption: the value of MSP should not exceed 1, relevant to the square area of the triangle is 0.200 ($5 \times 0.200 = 1$), and the maximum length of the side of the triangle is 0.6485:

for stimulant (*GDP*, *SB*, *CA)*:

$$X^{+}_{norm,\ it} = \frac{X_{j,\ it} - X_{\min}}{X_{\max} - X_{\min}} \quad (14)$$

for destimulant (*Un*, *HICP*):

$$X^{-}_{norm,\ it} = \frac{X_{\max} - X_j}{X_{\max} - X_{\min}} \tag{15}$$

where $X^{+}_{norm,\,it}$, $X^{-}_{norm,\ it}$ – normalised indicators GDP, Un, ICP, SB, CA of the *i*-country in *t*-time; X_j – the actual value of GDP, Un, ICP, SB, CA of the *i*-country in *t*-time; X_{max}, X_{min} – maximum and minimum values of GDP, Un, ICP, SB, CA.

Considering the theory, the macroeconomic stability of the country is directly proportional to the square area of the pentagon. At the same time, the balance of the pentagon's form confirms the coordination between vectors of regulatory policies of the country. The formula (16) provides the analysis of the impact of internal and external dimensions on macroeconomic stability in detail.

$$MSP_{i,t} = MSP_{1,\,it} + MSP_{2,\,it} \tag{16}$$

where $MSP_{1,\,it}$ – an indicator which reveals the impact of internal dimensions on macroeconomic stability of the *i*-country in *t*-time; $MSP_{2,\,it}$ – an indicator which reveals the impact of external dimensions on macroeconomic stability of the *i*-country in *t*-time.

Thus, $MSP_{1,\,it}$ and $MSP_{2,\,it}$ are calculated by the formulas (17) and (18):

$$MSP_{1,\,it} = [(GDP_{i,t} \times Un_{i,t}) + (Un_{i,t} \times ICP_{i,t}) + (ICP_{i,t} \times SB_{i,t})] \times k \tag{17}$$

$$MSP_{2,\,it} = [(SB_{i,t} \times CA_{i,t}) + (CA_{i,t} \times GDP_{i,t})] \times k \tag{18}$$

The results of MSP and its components allow indicating the spheres which define the progressive process of stabilisation or destabilisation of the country and the impact of state policy. Comparison analysis of macroeconomic stability pentagon areas allows detecting the best experience to overcome macroeconomic imbalances (under the unemployment rate, inflation, etc).

Research methods

To check the hypothesis, at the first stage, the study analysed the level of harmonisation of economic growth with the simultaneously declining environmental pollution. The ratio between average values (from 2005 to 2019) of green economic growth and global Malmquist productivity growth (19) reveals the effectiveness of government reforms and programs considering the sustainable development goals[63]:

$$\mathrm{GM}_t^{t+1}(x^t, y^t,\ x^{t+1}, y^{t+1}) = \frac{D_i^{t+1}(x^{t+1}, y^{t+1})}{D_i^t(x^t, y^t)} \tag{19}$$

where x^t, y^t – the set of input and output indicators of the model (*M* input resources $x = (x_1,\ x_2,\ \ldots,\ x_M)\epsilon R_+^M$ produce the *N* desirable outputs $y = (y_1,\ y_2,\ \ldots,\ y_N)\epsilon R_+^N$, $D_i^t(x^t, y^t)$, $D_i^{t+1}(x^{t+1}, y^{t+1},)$ – the distance function of the DMUs in *t* and $t + 1$ time, relevant.

If the ratio between Ged_t^{t+1} and GM_t^{t+1} is less than 1, it is considered that the countries pay less attention to environmental pollution than economic growth. Considering this, all countries are divided into two groups: the first – 'Green group' (Ged_t^{t+1} / $\mathrm{GM}_t^{t+1} \geq 1$); the second – 'Yellow group' (Ged_t^{t+1} / $\mathrm{GM}_t^{t+1} \leq 0.99$).

Kernel density estimation allows analysing of the spatial differences in Ged and macroeconomic stability for the ‘Green group’ and ‘Yellow group’ among the EU:

$$f(x) = \frac{1}{Nh}\sum_{i=1}^{N} K\left(\frac{X_i - x}{h}\right) \tag{20}$$

where N – the number of observations, X_i – independent, x – equally distributed observations, representing the average of the observed values, $K(\cdot)$ – a kernel density function and a bandwidth.

This research applies the following Gaussian kernel density function, which is mostly used among other functions,[64,65] to estimate the dynamic distribution evolution of the country’s Ged and macroeconomic stability:

$$K(x) = \frac{1}{\sqrt{2\pi}}\exp\left(-\frac{x^2}{2}\right) \tag{21}$$

The Ged has a right-censoring direction. In this case, it is necessary to apply the panel Tobit model which allows to consider it. It should be noted that in statistics, Tobit model is any of a class of regression models in which the observed range of the dependent variable is censored in some way.[66] Thus, the equitation could be written as follows:

$$Ged^{*}_{i,t}{=}\beta_0 + \beta_1 MS_{i,t} + e_{i,t}, \quad Ged_{i,t} = Ged^{*}_{i,t}, \text{ if } Ged^{*}_{i,t} > 0 \text{ a}nd\ Ged_{i,t} = 0, \quad \text{if } Ged^{*}_{i,t} \le 0 \tag{22}$$

where $Ged_{i,t}$ – the value of the Ged of i county in t time; $MS_{i,t}$ – the value of the macroeconomic stability of i county in t time; $\mathrm{WGI}_{i,t}$ – integrated index of the quality of institutions of i county in t time; $\beta_0,\ \beta_1$ – searching parameters of the model; $e_{i,t}$ denotes the i-th residual.

Under the estimation of macroeconomic stability impact on the Ged, the endogenous issue (due to the assumption of explanation variables impact on the findings) is eliminated by the adding of the control variables to the model (23), which impacted on green economic growth:

$$Ged_{i,t} = \beta_0 + \beta_1 MS_{i,t} + \rho \mathrm{Contr}_{i,t} + e_{i,t} \tag{23}$$

where $Ged_{i,t}$ – the value of the green economic growth of i county in t time; $MS_{i,t}$ – the value of the macroeconomic stability of i county in t time; $\mathrm{Contr}_{i,t}$ – series of control variables that affect the $Ged_{i,t}$; $\mathrm{X}_{i,t}$ – is a vector of control variables; $\beta_0, \beta_1,\ \rho$ – searching parameters of the model; $e_{i,t}$ denotes the i-th residual.

Based on the studies,[3,4] the following control variables were chosen: economic openness (TO), economic globalisation (KOF), foreign direct investment (FDI), quality of institutions (WGI). Globalisation is conducive to the free movement of capital, labour and recourses which allow providing the stable economic growth of the country. Besides, it allows implementing of new innovative and effective environmental management instruments.[67] At the same time, in developing countries, globalisation could provoke increasing social inequality and growing disparities between countries, deepening ecological issues.[68] The study used economic openness (TO) and economic globalisation (KOF) as indicators to measure the globalisation impact.[68,69]

The studies[27,70] confirmed that ecological modernisation and green innovations require the attractiveness of foreign direct investment and additional capital, which, consequently, lead to a declining negative impact on the environment. Thus, extending energy efficiency technologies and spreading renewable energy allows for declining use of natural resources and pollution of the environment.[71,72] At the same time, the inflow of foreign capital without relevant regulatory policy could provoke uncontrol energy consumption and pollution, increasing the eco-destructive impact on the environment.[73]

In this case, effective government institutions are the core dimension of green economic growth. On one side, institutional restriction blocks the opportunism in the redistribution of resources. On the other side, countries with an inefficient judicial system, political instability, a high level of corruption, and regulatory mechanisms for limiting the access of political elites to resources could not provide effective mechanisms for overcoming environmental issues.[74–78] Based on the papers,[50,69,77,79] the Worldwide Governance Indicators and the principal components analysis are used to measure the integrated index of quality of institutions:

$$\mathrm{WGI}_i = \alpha_1 WGI_{ViA} + \alpha_2 WGI_{PS} + \alpha_3 WGI_{GE} + \alpha_4 WGI_{RL} + \alpha_5 WGI_{CC} + \alpha_6 WGI_{RQ} \quad (24)$$

where WGI_i – integrated indicators for assessment of the quality of institution; $\mathrm{WGI}_{\mathrm{ViA}}$ – voice and accountability; $\mathrm{WGI}_{\mathrm{PS}}$ – political stability and absence of violence/terrorism; $\mathrm{WGI}_{\mathrm{GE}}$ – government effectiveness; $\mathrm{WGI}_{\mathrm{RL}}$ – rule of law; $\mathrm{WGI}_{\mathrm{CC}}$ – control of corruption; $\mathrm{WGI}_{\mathrm{RQ}}$ – regulatory quality; $\alpha_1 \ldots \alpha_6$ – weigh factors.

The weight coefficients of the Worldwide Governance Indicators for assessment of the quality of institutions are shown in Table 2.

Explanations and descriptive statistics of the control variables are shown in Table 3.

Considering the aspects mentioned above, the framework of the study is shown in Figure 2.

Results

The list of countries on the ratio between Ged_t^{t+1} and GM_t^{t+1} are shown in Table 4. The findings allow allocating of 12 'Green group' among 27 analysed countries: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Luxembourg, Malta, Netherlands and Sweden.

In general, EU countries have a large spread between the ratio of Ged_t^{t+1} and GM_t^{t+1}. In 2006–2019 years, Greece had the highest gap between the average value of green development (estimated by the GML productivity index) *Ged* – 0.1% and the average value of economic growth (estimated by global Malmquist productivity index) *GM* – 5.2%. At the same time, in the analysed time in Sweden (*Ged* – 0.2%; GM – −1.6%), Belgium (*Ged* – 0.1%; GM – −1.3%), and Austria (*Ged* –

Table 2. The finding of principal components (eigenvectors) outputs for WGI.

Indicators	Weigh factors
$\mathrm{WGI}_{\mathrm{ViA}}$	0.4243
$\mathrm{WGI}_{\mathrm{PS}}$	0.3197
$\mathrm{WGI}_{\mathrm{GE}}$	0.4242
$\mathrm{WGI}_{\mathrm{RL}}$	0.4302
$\mathrm{WGI}_{\mathrm{CC}}$	0.4219
$\mathrm{WGI}_{\mathrm{RQ}}$	0.418
Equation (15):	
$\mathrm{WGI}_i = 0.4243WGI_{ViA} + 0.3197WGI_{PS} + 0.4242WGI_{GE} + 0.4302WGI_{RL} + 0.4219WGI_{CC} + 0.4180WGI_{RQ}$	

Note: WGI_i: integrated indicators for assessment of the quality of institution; $\mathrm{WGI}_{\mathrm{ViA}}$: voice and accountability; $\mathrm{WGI}_{\mathrm{PS}}$: political stability and absence of violence/terrorism; $\mathrm{WGI}_{\mathrm{GE}}$: government effectiveness; $\mathrm{WGI}_{\mathrm{RL}}$: rule of law; $\mathrm{WGI}_{\mathrm{CC}}$: control of corruption; $\mathrm{WGI}_{\mathrm{RQ}}$: regulatory quality.

Table 3. Explanations and descriptive statistics of the control variables.

Symbol	Meaning	Sources	Mean	Std. Dev.
TO	Economic openness	World Data Bank (2022)	125.475	65.168
KOF	Economic globalisation	KOF Globalisation Index (2022)	79.263	6.598
FDI	Foreign direct investment	World Data Bank (2022)	2.36×10^{10}	6.58×10^{10}
WGI	Quality of institutions	World Data Bank (2022)	2.563	1.217

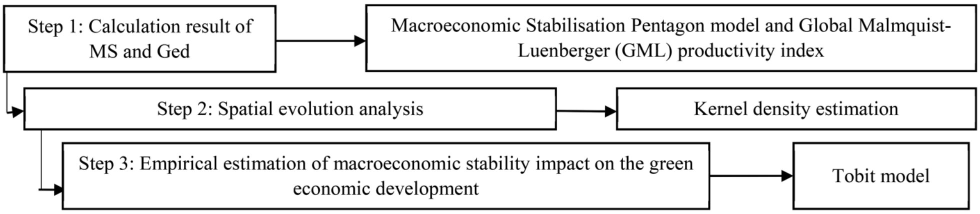

Figure 2. The core steps of the investigation.

0.1%; GM – −1.1%) the value of Ged significantly exceeds the economic development by 1.8, 1.4 and 1.2%, respectively. Among 'Green group', Czech Republic (0.3%), Hungary (0.5%), Luxembourg (0.6%), Netherlands (0.6%) have the minimum gap between Ged_t^{t+1} and GM_t^{t+1}. Furthermore, Sweden (1.8%), Belgium (1.4%), Austria (1.2%), France (1.1%), Finland (1.0%) have the highest gap. Among the 'Yellow group', the minimum gap is in Poland (−0,4%) and Italy (−0,4%), and the maximum – is in Greece (−5.2%), Latvia (−3.8%) and Bulgaria (−3.4%).

The tendency of dynamic evolution *Ged* for EU countries has upward dynamics (Figure 3). Compared to 2006, in 2019, the maximum value of *Ged* increases by 0.0177 points, and the minimum value of *Ged* declines by 0.0373 points. This tendency is explained by the EU convergent policy to decarbonise economic growth by providing a carbon-free economic development model. In addition, EU countries provide the incentive and prevention mechanisms to mitigate climate change in the relevant sectors. Thus, the EU mostly pay attention to energy sectors as it provokes more than 75% of total greenhouse gas emissions in EU countries.[80]

On average, for the analysis time, Malta (0.9%) has the highest value of Ged among the 'Green group'. It shows that, on average, the GDP of Malta grew by 0.9% per year, and CO_2 decline by 0.09% per year with fixed resources. The findings of the GM index allow concluding the growth rate of productivity is high – 0.8%. The average annual growth rate of efficiency changes (EFFCH) in Malta is 0.9% to the Malmquist-Luenberger productivity index. It shows that efficiency increases by 0.9% per year for analysed time. In addition, Malta occupies first place on the Malmquist-Luenberger productivity index among EU countries, and Cyprus (1.9%) is second. However, Cyprus has the highest efficiency decline rate – −0.8%. The findings prove that outsider countries are moving to the modern technological border, confirming the 'catching-up' effect for analysed years. Considering GedTECH, Cyprus and Estonia have the highest value of the average annual growth rate of technical changes in Ged – 0.03%. It confirms the existence of technical progress on average. Although most countries show technical progress, 11 ('Green group' – 6 countries, 'Yellow group' – 5 countries) have a deterioration in technical development. The core reason for such gaps is the existence of heterogeneity in attracting investments in technical progress and the lack of the effect of technical leadership during the study period. Fluctuation in the growth

Table 4. The distribution of countries by ratio level between Ged_t^{t+1} and GM_t^{t+1}.

Country	*Ged*	*GedTECH*	*GedEFFCH*	GM	*Ged*/GM	Country heterogeneity
Austria	1.001	0.998	1.003	0.989	1.013	Green Group
Belgium	1.001	0.999	1.002	0.987	1.014	Green Group
Bulgaria	1.001	1.000	1.000	1.035	0.967	Yellow Group
Croatia	1.001	0.999	1.002	1.017	0.985	Yellow Group
Cyprus	0.992	1.003	1.019	1.003	0.989	Yellow Group
Czech Republic	1.000	1.000	1.001	0.997	1.003	Green Group
Denmark	1.003	0.999	1.004	0.995	1.008	Green Group
Estonia	1.005	1.003	1.003	1.026	0.980	Yellow Group
Finland	1.002	0.998	1.003	0.992	1.010	Green Group
France	1.000	1.000	1.000	0.989	1.012	Green Group
Germany	1.000	1.000	1.000	0.991	1.009	Green Group
Greece	1.000	0.999	1.001	1.052	0.951	Yellow Group
Hungary	1.001	1.000	1.001	0.996	1.005	Green Group
Ireland	1.003	0.999	1.004	1.017	0.986	Yellow Group
Italy	1.000	1.000	1.000	1.004	0.996	Yellow Group
Latvia	1.004	1.000	1.004	1.042	0.963	Yellow Group
Lithuania	1.003	1.001	1.002	1.026	0.977	Yellow Group
Luxembourg	0.997	1.000	0.997	0.991	1.006	Green Group
Malta	1.009	1.000	1.009	1.001	1.008	Green Group
Netherlands	1.000	0.999	1.001	0.994	1.007	Green Group
Poland	1.000	1.000	1.000	1.004	0.996	Yellow Group
Portugal	1.001	0.999	1.001	1.020	0.981	Yellow Group
Romania	1.000	1.000	1.000	1.019	0.982	Yellow Group
Slovak Republic	1.001	1.000	1.002	1.016	0.985	Yellow Group
Slovenia	1.003	0.997	1.005	1.017	0.986	Yellow Group
Spain	1.000	1.000	1.000	1.014	0.986	Yellow Group
Sweden	1.002	0.998	1.004	0.984	1.018	Green Group

Note: Country heterogeneity: Green group ≥ 1, Yellow group ≤ 0.99; Ged: green economic development; GedEFFCH, GedTECH: the green technical and efficiency change; GM: economic development, Ged/GM: ratio between Ged_t^{t+1} and GM_t^{t+1}.

rate of *Ged* coincides with the fluctuation in the trend of technical changes. It confirms that productivity growth is caused by technical changes, particularly in the period analysed. The empirical results show that the macroeconomic stability of EU countries from 2006 to 2019 years (considering the structure impact of internal (MSP_1) and external (MSP_2) factors) demonstrates the chaotic process of countries' economic stabilisation and different orientation of the macroeconomic proportion of the countries (Figure 4).

The pic value of *MSP* and MSP_1 curves are significantly higher and shifted to the right (Figure 3(a) and (b)) for the 'Green group'. It confirms that the 'Green group' is less vulnerable to negative external shocks, which is conducive to economic growth, sustainable development goals and green economic growth. 'Yellow group' has the pic value of MSP_2 higher than the 'Green group'. However, the 'Green Group' curve trend is more shifted to the right. It should be noted that the average value of macroeconomic stability for all countries is more than 0.5 for the analysed period. In addition, the internal dimensions (MSP_1) have a large share in the MSP structure – from 0.132 to 0.503, and the value of MSP_2 is in the interval from 0.05 to 0.34. The findings show

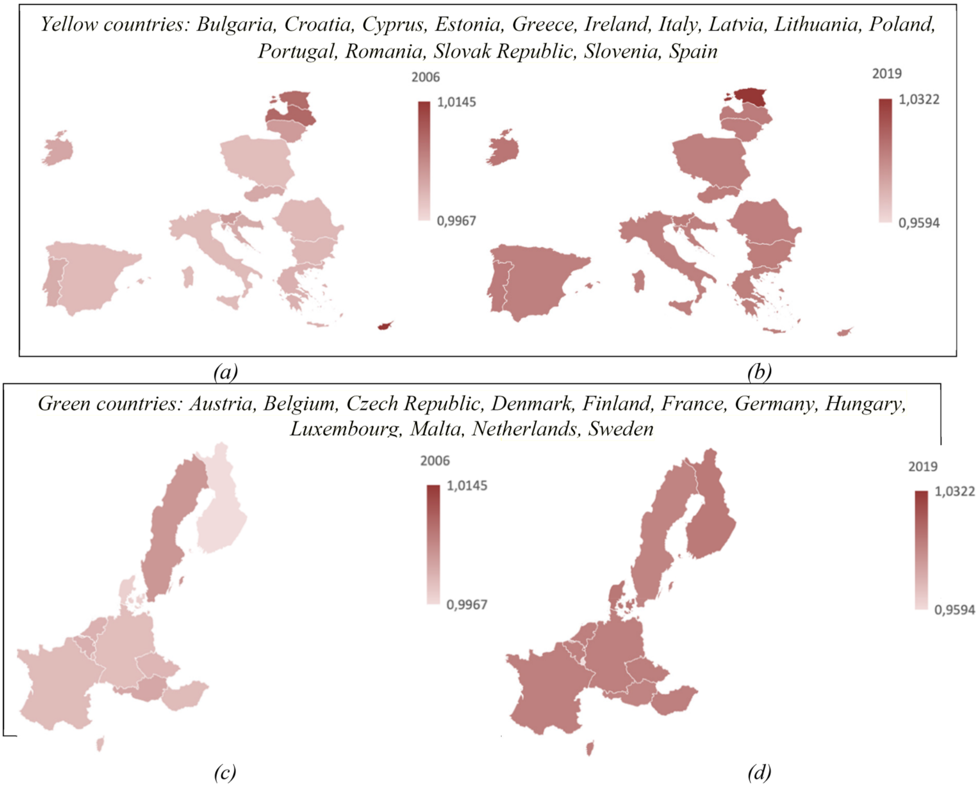

Figure 3. The visualisation map of Ged for the yellow (a, b) and green (c, d) countries in 2006 (a, c) and 2019 (b, d).
Note: the dark colour means the highest value of Ged; light colour means the lowest level of Ged.

that among the 'Yellow group', Greece has the highest value in the analysed period in 2018–0.793. At the same time, in the 'Green Group', Sweden is the leader in MSP (MSP = 0.817 in 2007). The external factors (for Greece, $MSP_1 = 0.4786$, for Sweden, $MSP_1 = 0.4684$) significantly impact the achievement values of MSP. In addition, the findings showed that external factors play a core role in macroeconomic stability (Figure 5). Besides, after the financial recession of 2007–2010, the growth trends of MSP_1 and MSP_2 have similar trends for most EU countries. Furthermore, the values of external dimensions are higher in Estonia (0.503) in the 'Yellow group' and Denmark (0.4907) in the 'Green group'. Thus, in this case, it is logical to analyse macroeconomic stability's impact on Ged.

The results of Tobit estimation (Table 5) show that among the 'Green group', only MSP_1 has a statistically significant impact on the green development of the country. The study provides normalisation of the data within each group ('Green group' and 'Yellow group') depending on green development of the country. Growth of external factors (MSP_1) by 1 point led to the growth of green development of the country by 0.087. It should be noted that among the 'Yellow group' MSP and MSP_1 have a statistically significant impact on the green development of the country. The findings conclude that among the 'Yellow group', the increase of MSP and MSP_1 by 1 point provoke the growth of green development of the country by 0.142 and 0.195, respectively.

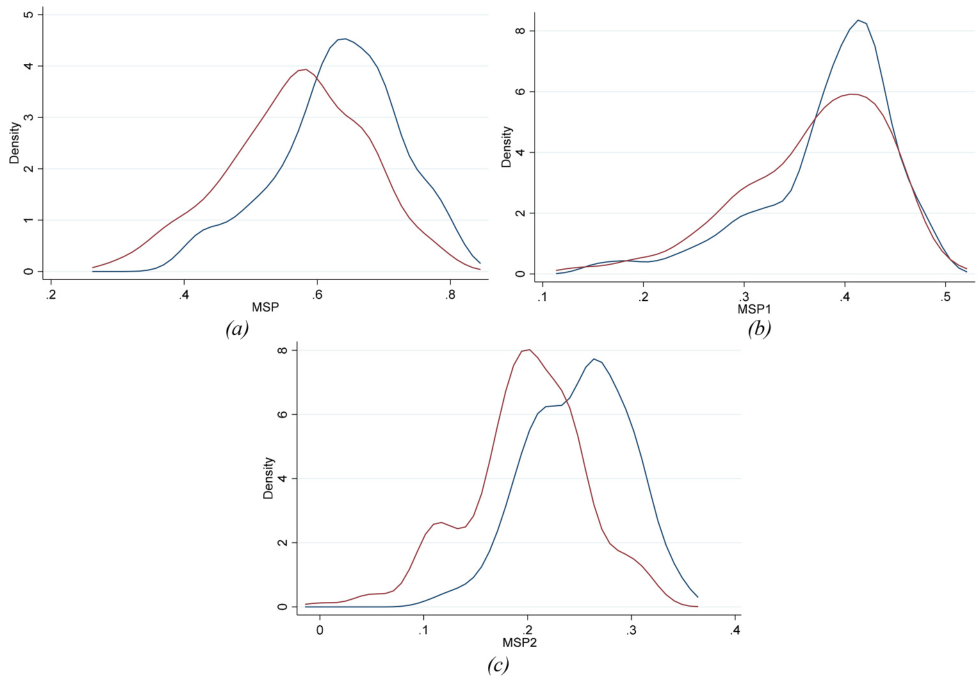

Figure 4. Kernel density plots of macroeconomic stability for countries from the 'Green Group' (blue line) and 'Yellow group' (yellow line): *(a) – MSP; (b) – MSP_1; (c) – MSP_2*.

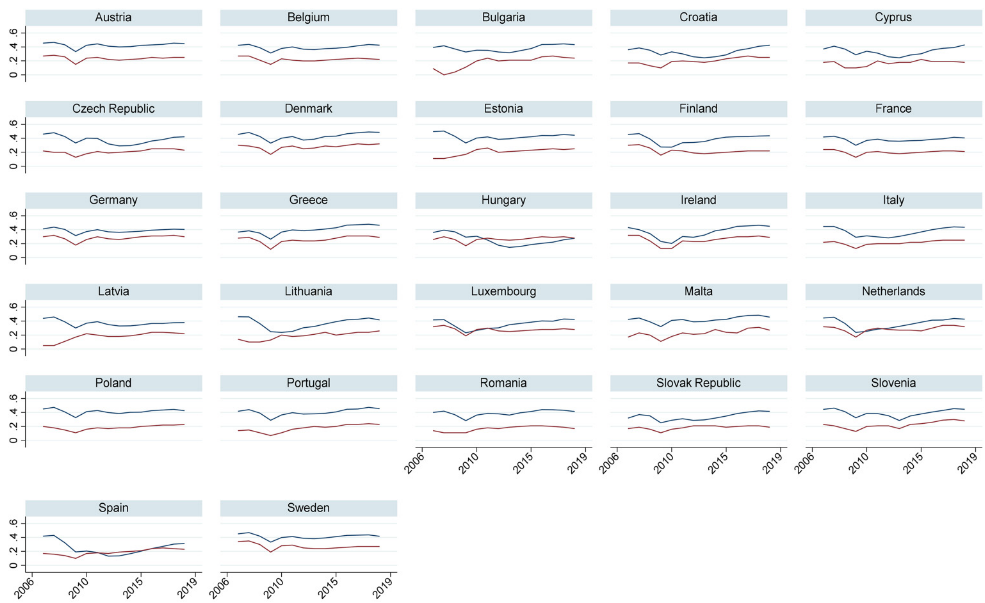

Figure 5. The dynamic of MSP_1 (blue line) and MSP_2 (red line) for the 2006–2019 years.

Table 5. The empirical results of the impact of macroeconomic stability on green development of the country using Tobit estimation.

Variables	Model which includes MSP		Model which includes MSP_1		Model which includes MSP_2	
	Coef.	*p-value*	*Coef.*	*p-value*	*Coef.*	*p-value*
Green Group						
MSP	0.078	0.119	–	–	–	–
MSP_1	–	–	0.085***	0.087	–	–
MSP_2	–	–	–	–	0.028	0.588
const	−0.084***	0.094	−0.084***	0.091	−0.084	0.107
Wald chi2	2.43		2.93***		0.29	
Prob>chi2	0.118		0.087		0.5885	
Log-likelihood	−165.991		−165.750		−167.050	
Yellow Group						
MSP	0.142**	0.032	–	–	–	–
MSP_1	–	–	0.195*	0.004	–	–
MSP_2	–	–	–	–	0.028	0.679
const	−0.029	0.745	−0.029	0.752	−0.030	0.755
Wald chi2	4.59**		8.37*		0.17	
Prob>chi2	0.032		0.004		0.679	
Log-likelihood	−275.707		−273.853		−277.879	

Note: MSP_1: external factors of macroeconomic stability; MSP_2: internal factors of macroeconomic stability; MSP: macroeconomic stability; const: constant of the model; Wald chi2: test Walda; Prob: probability.
*, ** and ***: significance at 1, 5 and 10% levels.

It should be noted that the adding of control variables to the model (12) does not change the impact's power and direction of macroeconomic stability on the green development of the country from the 'Green Group' (Table 6). However, it provokes changes in the absolute value of MSP and MSP_1. It confirms the validity of obtained results in Table 5. Thus, for the 'Green group', the increase of MSP_1 by 1 point led to the growth of green development of the country by 0.085. For countries from the 'Yellow group', the growth of MSP by 1 point provokes increasing the country's green development by 0.157 and MSP_1 by 0.212.

The findings confirm that economic openness (TO) has a statistically significant impact on increasing of green development of the country. It proves that increasing foreign capital to the country could be positively conducive to extending green innovations and technologies. On the other side, the lack of statistically significant influence of FDI on the green development of a country shows that countries need to significantly improve the implementation of innovative green technologies to achieve environmental goals. At the same time, the findings show the positive, statistically significant impact of WGI on the green development of the country. It confirms the efficiency of implemented policies and normative legislation, which aim to optimise the environment for spreading green innovations and boosting the green development of the countries. Thus, for the 'Green group', the increase of WGI by 1 point led to the growth of green development of the country by 0.038 to 0.065, depending on the selected model (Table 6). For countries from the 'Yellow group', the growth of WGI by 1 point provokes increasing in green development of the country by 0.104 for model which include MSP, by 0.132 for model which includes MSP_1, and by 0.043 for model which includes MSP_2.

Table 6. The empirical results of the impact of macroeconomic stability on green development of the country using Tobit estimation with control variables.

	Model which includes MSP		Model which includes MSP_1		Model which includes MSP_2	
Variables	*Coef.*	*p-value*	*Coef.*	*p-value*	*Coef.*	*p-value*
Green group						
MSP	0.078	0.137	–	–	–	–
MSP_1	–	–	0.082	0.113	–	–
MSP_2	–	–	–	–	0.026	0.622
KOF	0.103	0.18	0.117	0.122	0.111	0.159
TO	0.225*	0.003	0.229*	0.002	0.230*	0.003
FDI	0.014	0.778	−0.008	0.866	−0.017	0.738
WGI	0.061***	0.084	0.065***	0.055	0.038***	0.084
const	−0.086	0.074	−0.085	0.074	−0.086	0.075
Wald chi2	13.45**		13.76**		11.34**	
Prob>chi2	0.0195		0.0172		0.0451	
Log-likelihood	−160.815		−160.665		−161.791	
Yellow group						
MSP	0.157**	0.027	–	–	–	–
MSP_1	–	–	0.212*	0.003	–	–
MSP_2	–	–	–	–	0.023	0.742
KOF	−0.133	0.387	−0.163	0.299	−0.044	0.773
TO	0.096**	0.036	0.115***	0.068	0.098**	0.044
FDI	−0.110	0.134	−0.104	0.153	−0.104	0.162
WGI	0.104***	0.093	0.132***	0.093	0.043***	0.076
const	−0.029	0.732	−0.029	0.747	−0.029	0.742
Wald chi2	8.01***		11.75**		7.04***	
Prob>chi2	0.056		0.038		0.094	
Log-likelihood	−274.157		−272.167		−276.506	

Note: MSP_1: external factors of macroeconomic stability; MSP_2: internal factors of macroeconomic stability;
MSP: macroeconomic stability; const: constant of the model; Wald chi2: test Walda; Prob: probability; KOF: economic globalisation; TO: economic openness; FDI: foreign direct investment; WGI: the quality of institutions.
*, ** and ***: significance at 1, 5 and 10% levels.

It also confirms that mechanisms and instruments for nature protection are still in development. In this case, the government investment and support of green technological innovation require an effective convergent strategy of green growth among EU countries. Furthermore, some countries have not had a clear strategy and plans for transition from traditional to green development. Consequently, the countries could not effectively allocate and use the available resources in the country.

Conclusion & discussion

The results of the analysis of the theoretical framework on checking the relation between them showed that the scientists analyse the impact of green growth on macroeconomic stability.[39,41,44,47] However, the analysis results show that green growth could not be achieved without sufficient financial resources, which depends on the country's macroeconomic stability. Thus, under this investigation, the impact of macroeconomic stability on Ged is determined. Thus, the findings allow allocating of two groups of

EU countries, the 'Yellow group' and 'Green group', depending on the value of the Ged index. The highest values of Ged are in Malta among the 'Green Group' and Estonia among the 'Yellow group'. At the same time, the following countries have the highest values of macroeconomic stability: Sweden ('Green group') and Greece ('Yellow group'). The results show that EU countries provide the convergent.

It should be noted that empirical results allow concluding the hypothesis on the statistically significant impact of macroeconomic stability on Ged. The studies confirm similar conclusions.[39,44,47] At the same time, the studies confirm the opposite conclusions (no statistically significant impact of macroeconomic stability on Ged).[18–20] The empirical findings show that the growth of macroeconomic stability by 1 point led to the growth of Ged by 0.085 (MSP_1 among 'Green group'), 0.142 (MSP among 'Yellow group') and 0.195 (MSP_1 among 'Yellow group').

Considering it, the government of EU countries should provide the instruments to improve the macroeconomic stability of the countries by the balancing between external and internal dimensions of it. It allows developing the appropriate environment and conditions for attracting foreign direct investment for providing ecological initiatives and highly qualified labour resources. As the consequence it could boost the sharing of green innovation, best practices and knowledge in green technologies. The scholars[4,6,7,13] proved that harmonising macroeconomic stability among all EU members is the core dimensions for obtaining the synergy effect in achieving goal on green development. In this case, the potential members of EU should implement the coherent policies on providing macroeconomic stability.

Furthermore, the EU government should enlarge the best local practices and initiatives on declining negative impact on nature among all members. It should be noted that one of the effective ways is developing the common platforms for sharing green knowledge and education such as Eco-school.[81] Eco-school aims to increase the green awareness among young generation. The policy of Eco-school is based on the seven bullet points: developed green community; providing the sustainable audit; local Action plan for green development; monitoring and control; curriculum development considering the green values; transparency and involvement; developed the eco policy.[81]

The priory studies[50,51,55,56,65] and the obtained findings confirmed that renewable energies are conducive to Ged. In this case, the EU should develop the incentives for spreading them. Considering the past studies,[51,55,56] the feed in tariff was the most effective instruments at the first stage of renewable energy development. At the next stage the feed in tariff could be replaced by bonuses and premiums. Moreover, the green credit and other fiscal green incentives should quickly be adopted to the market changes.

EU countries should also try to use the capability of renewable energies from the neighbour countries through the cooperation mechanisms. Considering the report of EU commission, the implementing of tender procedure enhances the spreading of green energy. Such practices should be also spreading among potential candidate to EU countries such as Ukraine.

Despite the actual findings on assessing macroeconomic stability and green development and checking the relation between them, this investigation has a few limitations. In further investigation, it would be necessary to consider green investment under the estimation of Ged. The green investment could boost the R&D in green technologies, which is the basis of Ged. Besides, the convergence between green and economic development policies should be analysed. It will be allowed to highlight the gaps and relevant instruments for overcoming them and synchronise both policies.

Author contributions

Conceptualisation: Yang Chen, Oleksii Lyulyov, Tetyana Pimonenko, Aleksy Kwilinski; methodology: Yang Chen, Oleksii Lyulyov, Tetyana Pimonenko, Aleksy Kwilinski; formal analysis: Yang Chen, Oleksii Lyulyov,

Tetyana Pimonenko, Aleksy Kwilinski; investigation: Yang Chen, Oleksii Lyulyov, Tetyana Pimonenko, Aleksy Kwilinski; writing—original draft preparation: Yang Chen, Oleksii Lyulyov, Tetyana Pimonenko, Aleksy Kwilinski; writing—review and editing: Yang Chen, Oleksii Lyulyov, Tetyana Pimonenko, Aleksy Kwilinski; visualisation: Yang Chen, Oleksii Lyulyov, Tetyana Pimonenko, Aleksy Kwilinski. All authors have read and agreed to the published version of the manuscript.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Ministry of Education and Science of Ukraine (grant number 0121U100468).

ORCID iDs

Yang Chen https://orcid.org/0000-0002-4801-4036
Tetyana Pimonenko https://orcid.org/0000-0001-6442-3684

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Yang Chen, born in January 1995, received a bachelor's degree in Economics in 2018 and a master's degree in Economics in 2020. He is currently a PhD student in economics from Fujian Normal University in theoretical economy. He published his researches in 2 SSCI and 1 Scopus. His research interests include green economics & sustainability development, farmer income distribution and so on.

Oleksii Lyulyov is professor of Department of Management, WSB University, Dabrowa Gornicza, Poland, Head of Marketing Department at Sumy State University, Ukraine. He got a scientific degree of DSc in Economics in 2019. The main sphere of his scientific interests includes country marketing policy, country image, macroeconomic stability, innovative development, sustainable economic development, tourism, strategy development, modelling and forecasting development trends.

Tetyana Pimonenko is Fulbright Alumna (2019-2020, MA), DSc in Economics, professor of Department of Management, WSB University, Dabrowa Gornicza, Poland; associate professor at Department of Marketing at Sumy State University, Ukraine. The core scientific interests: green economy; green marketing, green brand, green investment, sustainable economic development, tourism, renewable energy.

Aleksy Kwilinski is professor of Department of Management, WSB University, Dabrowa Gornicza, Poland, Professor of Marketing Department at Sumy State University, Ukraine, The London Academy of Science and Business, London, UK. The main sphere of his scientific interests includes sustainable development, artificial intelligence, Industry 4.0.