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Are OECD Countries Converging in Export Diversification? Evidence from PANIC-Fourier Panel Unit Root Test

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Abstract: This study examines whether OECD countries have converged over time in terms of export diversification. Focusing on the period 1995–2023, the study employs a new Fourier function-enhanced panel unit root test that takes into account gradual changes instead of sudden breaks. The findings show that more than half of OECD countries have not converged in terms of export diversification. Export diversification plays an important role in achieving economic growth and development as well as long-term sustainability goals. In this context, the study provides critical data for policymakers in support of sustainable development goals. The results point to the need to reassess the economic and environmental impacts of export diversification policies in OECD countries.

Keywords: export diversification; convergence; PANIC unit root test; PANIC-Fourier unit root test; OECD; sustainable development; trade policy

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1. Introduction

Export is stated as one of the most important sources of economic growth, as it provides foreign currency inflow to the country by marketing the products. The development level of the countries affects the quality of the exported goods, while the quality of the exported goods plays a decisive role in the economic development of the country. Whereas developed countries export manufactured goods, i.e., secondary and tertiary products (capital-intensive, high-tech and high value-added products), underdeveloped and developing countries export primary products (traditional products with low technology and value added such as raw materials, labor-intensive and agricultural products) [1–3]. The classical trade theory has supported the increase in export intensity of developing countries due to specialization in primary products in which they have comparative advantage and the realization of international division of labor under the name of free foreign trade policy until the 1950s. After the Second World War, the Singer–Prebich (1950) hypothesis [4,5] revealed that the specialization suggested by the classical trade theory would lead to instability in the incomes of developing countries, worsen their terms of trade, and adversely affect their growth. As a result, the development strategy shifted in favor of import substitution, and restrictive trade policies started to be implemented in order to direct development. Most of the developing countries tried to strengthen and protect their own industries by following protectionist foreign trade policies until the 1970s. With the 1980s,

the widespread expression by economists that liberal economic policies would bring faster growth led to a change in the trade policies implemented in developing countries. Starting from this period, developing countries abandoned import substitution policies and started to pursue export-oriented policies [6,7].

Recent policies in foreign trade consist of policies that emphasize export diversification and trade openness, as opposed to the specialization and division of labor favored by the classical trade theory and the concentration of exports in certain products. These policies are also supported by organizations such as the World Bank (2019) and the International Monetary Fund (2020) as they provide significant advantages to developing countries [8,9].

Export diversification, resulting in a paradigm shift in foreign trade, refers to the addition of new products to the existing export basket of a country or increasing exports or products without adding a new product to the existing basket, as well as the expansion of a country's exports to a wide range of export partners. Export diversification provides significant advantages for developing countries by enabling them to increase productivity and employment, improve income distribution, minimize risks in international trade, and contribute to macroeconomic stability and economic growth [10–12]. Successful industrialization experiences of the newly industrialized countries (NICs) in Asia provide the most tangible evidence of these advantages of export diversification. Since the late 1970s, in a global environment of trade liberalization, these countries have achieved significant success through the transformation of their economies by making export diversification the focus of their foreign trade policies [9]. Among the newly industrialized countries in Asia, China has made the most progress in terms of export diversification. With China's accession to the World Trade Organization (WTO) in 2001, export diversification increased impressively in the early 2000s, and China became one of the most diversified exporters. India and Turkey also experienced a rapid increase in export diversification in the same period. The increase in export diversification of these countries continued until the 2008 Global Financial Crisis, and although it paused in 2009, it continued to increase in the following period [13,14]. China, India, and Turkey have achieved significant economic success thanks to their export diversification after 2000. Thanks to their economic successes, China, India, and Turkey achieved average growth rates of 8.3%, 6.2%, and 5.1%, respectively, in the 2000–2023 period [15].

In addition to the success of the newly industrialized countries in Asia, numerous studies show that export diversification positively affects economic growth, macroeconomic stability, employment, labor productivity and income distribution. For example, Agosin (2009) [16] finds that export diversification increased economic growth in the Republic of Korea, Taiwan Province of China, Mauritius, Finland, China, and Chile in the period 1980–2003. Hesse (2008) [14] finds that export diversification positively affected per capita income growth in 99 countries in the period 1961–2000. Mudenda et al. (2014) [17] find evidence that export diversification positively affected economic growth in South Africa during the period 1980–2010. Forgha et al. (2014) [18] found that export diversification had a significant positive impact on economic growth in Cameroon in the period 1980–2012. Matezo et al. (2021) [19] conclude that export diversification positively affected economic growth in 15 countries of the Southern African Development Community in the period 1998–2018. Zhou and Nyandoro (2023) [20] conclude that export diversification increased economic growth in Zimbabwe during the period 1995–2020. Güneri (2019) [21] finds that export diversification reduced the volatility of growth and increased macroeconomic stability in 94 countries in the 1980–2014 period. Kartalcıklar (2016) [22] finds that a 10% increase in export diversification in the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia over the period 1995–2012 lead to a 4.6% decrease in GDP per capita volatility and a 1.12% decrease in sectoral output volatility. McIntrye et al. (2018) [23] find

that export diversification lead to lower output volatility and higher average growth rates in 34 countries over the period 1990–2015. UNCTAD (2018) [11] finds that export diversification expanded employment and reduced vulnerable employment over the period 1991–2010 for a large number of different country groups. Songwe and Winkler (2011) [24] find that product and market diversification in exports increased value added and labor productivity in 30 selected sub-Saharan African countries during the period 1995–2008. Zare and Talayeminaei (2023) [25] find that export diversification reduced income inequality in selected developing countries over the period 2013–2017.

In order to benefit more from these advantages of export diversification, countries have been trying to increase the number of goods in their export baskets as well as the number of markets where they can sell their products. Export diversification is considered to be an important strategy that increases the economic growth potential of countries, as well as their resilience to fluctuations in foreign trade. In this context, export diversification is closely related to the concept of economic convergence. Convergence theory predicts that less developed countries will converge to more developed countries in terms of economic performance over time. Export diversification plays a key role in this process and contributes to countries gaining an advantage in global competition by increasing their productivity levels through diversification of the economic structure. In particular, advances in export diversification promote economic alignment with leading countries and have the potential to reduce income inequalities.

In this endeavor, some countries gain more share and catch up with countries with high export diversification, while others move away from them. This study tries to reveal which countries in 37 OECD countries over the period 1995–2023 converged towards leading countries by increasing export diversification, and which countries diverged away from leading countries by increasing diversification. The study is expected to contribute to the existing literature in several ways. The first of these is the treatment of export diversification from a convergence perspective. Although the existing literature on convergence is quite extensive, there are very few studies that analyze the convergence of export diversification. In this context, this study makes an important contribution to a missing point in the literature by demonstrating the applicability of convergence theory in the context of export diversification.

In addition, the theoretical underpinnings of the relationship between export diversification and economic convergence are also discussed. In particular, the motivation for this study is shaped by the arguments in the literature that export diversification promotes economic growth, increases resilience to economic shocks, and has the potential to reduce income inequalities in the long run. In this context, it is emphasized that the convergence of export diversification is critical not only for economic performance but also for achieving competitive advantage in the global economy. OECD countries are considered in this framework and the potential of export diversification strategies to strengthen their role in the global economy and support sustainable growth is discussed.

Another important contribution of the study is the econometric methodology used. A review of similar studies in the literature reveals that panel data analysis, time series analysis, or traditional unit root tests are generally used. The test used in this study is the next generation Panel Unit Root test developed by Nazlioglu et al. (2023) [26], which allows for multiple structural breaks and cross-correlations in the panel, smooth or gradual changes instead of sudden breaks, and is augmented with a Fourier function. This method provides a more comprehensive and flexible tool to analyze the dynamics of export diversification.

Some limitations of this study should be recognized. First, the focus of the study is limited to OECD countries and generalizability to other country groups is limited. Moreover, it should be noted that the methods used include some assumptions when assessing the effects on export diversification, and these assumptions may not reflect all

real-world conditions. Nevertheless, the findings contribute to the literature and provide valuable insights for policymakers.

The rest of the paper is structured as follows. Section 2 contains the literature review on convergence. Section 3 presents the data and methodology. Section 4 presents the main empirical results and discusses the conclusions. Finally, Section 5 summarizes the paper and concludes with conclusions and policy implications.

2. Literature Review

The issue of whether income differences between countries will be eliminated over time was firstly defined as the convergence hypothesis by Abromovitz (1986) [27]. After the hypothesis was introduced, Abramovitz (1986) [27] and Baumol (1986) [28] conducted the first empirical analyses of the convergence hypothesis using Maddison's (1982) [29] data set, and both studies revealed the existence of convergence. The convergence hypothesis, both theoretically and empirically investigated in the mid-1980s, has continued to be intensively examined with different dimensions until today [30,31].

Since the convergence hypothesis has been proposed on the issue of whether income differences between countries will diminish over time, the first studies conducted to test the convergence hypothesis focused on whether countries converge in terms of income. Therefore, the majority of the studies in belong to income convergence. However, since then, the convergence hypothesis has been extended to finance, employment and unemployment, environment (CO_2 and ecological footprint), energy, tourism, inflation, productivity, income distribution, investment, savings, and foreign trade.

Studies on the convergence hypothesis related to foreign trade are limited compared to other fields. Convergence hypothesis studies on foreign trade have focused on the convergence of exports or imports. Studies on the convergence of export diversification are limited in the literature. For this reason, in the literature review of this study, firstly, convergence studies on foreign trade, exports and imports, and then the limited number of convergence studies on export diversification will be presented.

Hallak and Schott (2011) [32], analyzing whether the quality of exported goods converged in the world's 43 largest exporting countries in the period 1989–2003, found that there is rapid and widespread unconditional convergence in the quality of exported goods across countries. Similarly, Tian (2017) [33] tried to estimate the quality of exported goods at sectoral level by using the data of twelve manufacturing sectors in 19 OECD countries for the period 1995–2006. In their analysis, it was concluded that beta and sigma convergence exist in the quality of exported goods. Henn et al. (2020) [34] investigated the convergence characteristics of export product quality in their study covering 166 countries and more than 800 products in the period 1962–2014, and determined that the export quality in any product group converges rapidly across countries on average, and thus convergence is valid. Pirimova (2021) [35] tested whether Bulgaria's exports to the Eurozone converged structurally for the period of 2002–2018. In his study, Bulgarian exports had tended to increase their structural convergence to Eurozone exports in recent years, and while there are greater similarities in some groups of commodities, higher levels of convergence were found in these groups. Trenczek and Wacker (2021) [36] investigated the convergence in export quality and world income distribution with bilateral export quality estimates for 122 countries and 2700 manufacturing products. In their research, they found that the distribution of total export quality across countries is stable. Moreover, despite the strong link between export quality and income levels, they also demonstrated how previous findings link quality convergence in export commodities to a stable global income distribution. Analyzing the convergence of export and import flows in eight Central and Southeastern European Union countries over the period 2011–2022, Duguleana and Deszke (2023) [37]

revealed that the convergence of export and import flows with economic development is sustainable in the long run for the Central and Southeastern region of the European Union. Gençosmanoğlu and Yamanoğlu (2023) [38] investigated the growth rate and convergence trend of real exports per capita among 81 provinces of Turkey for the period 2004–2021 and revealed that real exports per capita converge across provinces both in absolute and conditional terms.

One of the few studies on the convergence of export diversification is by Akram (2018) [39]. Akram (2018) investigated whether 127 non-OECD countries converged to 34 OECD countries in terms of export diversification in the period 1995–2016 using techniques including panel unit root tests, panel data models, and panel club convergence techniques. In his research, he has stated that countries with low export diversification (non-OECD countries) converge to countries with high export diversification (OECD countries). He also revealed that, in order to achieve high and stable economic growth, non-OECD countries need to diversify their exports at a rate of more than 3% to capture OECD countries. Akram and Rath (2020) [40] analyzed the role of export diversification in the convergence of per capita income (output) in 95 countries (69 developed and 26 developing countries) using the Generalized Method of Moments (GMM) estimator. In their analysis, both absolute and conditional divergence evidence were detected for the aggregate sample and for sub-samples based on income and regions, and they concluded that although high export diversification increases per capita income (output), the gap in per capita income (output) between rich and poor countries is not significantly diminished. Karanfil and Omgba (2023) [41] examined whether countries converge towards the identical level of export diversification and whether structural and institutional factors are effective in export diversification convergence in 31 net oil exporters for the period 1981–2014. In their study, they concluded that structural and institutional factors play a central role in the export diversification process and, in particular, countries with higher quality infrastructure, human capital, and research and development efforts are more likely to converge towards higher export diversification.

Although Hallak and Schott (2011) [32], Tian (2017) [33], Henn et al. (2020) [34], Pirimova (2021) [35], Trenczek and Wacker, (2021) [36], Duguleana and Deszke (2023) [37], and Gençosmanoğlu and Yamanoğlu (2023) [38] conducted studies with country groups, including some of the OECD countries in the field of exports, there is no study analyzing the export diversification of all OECD countries like ours. Our study contributes to the literature in terms of both methodology and timeliness. Among similar studies, Akram (2018) [39] used data up to 2016. Akram and Rath (2020) [40] used data up to 2010. Karanfil and Ombga (2023) [41] used data up to 2014. In our study, we used data up to 2023. Therefore, our study uses the most recent data set in the literature. The method we used also differs from the ones in other studies. Akram (2018) [39] used the IPS panel unit root test developed in 2003, and the CIPS unit root test developed in 2007. Akram and Rath (2020) [40] used a method developed in 1991. Karanfil and Ombga (2023) [41] used the method introduced in the literature in 2007 and 2009. In our study, we used the method developed in 2023. Therefore, it will contribute to the field of export diversification by analyzing the most recent data in the literature with the most up-to-date methods.

Moreover, existing theories and empirical findings on export diversification form the basis of this study. In the literature, many positive effects of export diversification, such as economic growth, reducing income inequality, and increasing economic resilience, have been emphasized [14,42]. In particular, increasing product diversification has been shown to contribute to economic stability and make export revenues more sustainable [43]. In addition, the determinants of export diversification include the transformation of economic structure, access to technology, infrastructure investments, institutional factors,

trade policies, and natural resource wealth [44–46]. Furthermore, regional and global economic integration processes are also considered to have a determinant impact on export diversification [47,48].

In this study, both the positive effects of export diversification on economic growth and its determinants are analyzed in detail. With the methodology and up-to-date data set used, the study aims to provide a deeper understanding of the dynamics of export diversification and provide findings to guide policymakers. At the same time, the critical role of export diversification in the process of convergence with leading countries is emphasized, filling this gap in the literature.

3. Data and Methodology

3.1. Data Sources

This study analyzes the period 1995–2023 for OECD member countries. The export diversification index was used within the scope of the study. Index data are taken from the "UNCTAD statistical port" website [49]. Descriptive statistics of the export diversification index are presented in Table 1.

Table 1. Descriptive Statistics.

Country	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque–Bera	Probability	Sum	Sum Sq. Dev.
Australia	4.140	4.142	4.328	4.012	0.107	0.166	1.610	2.469	0.291	120.069	0.319
Austria	3.520	3.514	3.631	3.444	0.048	0.232	2.482	0.584	0.747	102.082	0.064
Belgium	3.616	3.614	3.766	3.486	0.080	0.265	1.966	1.633	0.442	104.858	0.179
Canada	3.613	3.629	3.704	3.499	0.056	−0.477	2.494	1.410	0.494	104.781	0.086
Chile	4.323	4.324	4.386	4.257	0.033	0.184	2.694	0.276	0.871	125.362	0.031
Colombia	4.146	4.162	4.207	4.022	0.054	−0.980	2.743	4.718 ***	0.095	120.225	0.082
Czechia	3.705	3.709	3.774	3.603	0.050	−0.407	2.156	1.660	0.436	107.436	0.071
Denmark	3.727	3.755	3.813	3.409	0.079	−2.276	9.810	81.075 *	0.000	108.086	0.176
Estonia	3.851	3.822	4.060	3.700	0.098	0.503	2.324	1.773	0.412	111.685	0.268
Finland	3.935	3.943	4.027	3.812	0.053	−0.667	3.241	2.219	0.330	114.107	0.079
France	3.410	3.457	3.560	3.171	0.116	−0.561	1.848	3.126	0.210	98.901	0.377
Germany	3.397	3.412	3.552	3.265	0.079	0.196	2.260	0.846	0.655	98.521	0.173
Greece	3.983	3.995	4.081	3.845	0.066	−0.421	2.103	1.831	0.400	115.502	0.121
Hungary	3.685	3.695	3.769	3.338	0.078	−3.069	14.474	204.608 *	0.000	106.860	0.172
Iceland	4.382	4.382	4.432	4.330	0.026	0.020	2.012	1.181	0.554	127.068	0.019
Ireland	4.156	4.171	4.248	4.003	0.080	−0.692	2.155	3.177	0.204	120.523	0.177
Israel	4.028	4.048	4.151	3.818	0.082	−1.298	4.039	9.451 *	0.009	116.810	0.190
Italy	3.599	3.603	3.650	3.543	0.032	−0.289	1.799	2.147	0.342	104.376	0.028
Japan	3.700	3.693	3.818	3.610	0.054	0.162	2.091	1.126	0.570	107.311	0.082
Latvia	3.921	3.833	4.211	3.757	0.153	0.559	1.633	3.767	0.152	113.709	0.654
Lithuania	3.885	3.877	4.017	3.745	0.088	0.079	1.743	1.941	0.379	112.655	0.217
Luxembourg	3.989	3.990	4.049	3.918	0.028	−0.095	3.270	0.132	0.936	115.682	0.022
Mexico	3.698	3.688	3.819	3.609	0.051	0.479	2.679	1.235	0.539	107.254	0.073
Netherlands	3.514	3.515	3.605	3.440	0.048	0.063	2.307	0.600	0.741	101.915	0.065
New Zealand	4.199	4.180	4.295	4.114	0.052	0.449	1.998	2.186	0.335	121.762	0.076
Norway	4.166	4.166	4.299	4.111	0.041	1.314	5.223	14.318 *	0.001	120.816	0.048
Poland	3.744	3.737	3.891	3.617	0.071	0.017	2.229	0.719	0.698	108.566	0.142
Portugal	3.748	3.722	3.929	3.610	0.084	0.495	2.320	1.744	0.418	108.690	0.197
Slovakia	3.825	3.824	3.903	3.682	0.056	−1.149	4.131	7.922	0.019	110.913	0.088
Slovenia	3.813	3.822	3.874	3.727	0.038	−0.259	2.155	1.186 **	0.553	110.584	0.040

Table 1. *Cont.*

Country	Mean	Median	Max.	Min.	Std. Dev.	Skewness	Kurtosis	Jarque–Bera	Probability	Sum	Sum Sq. Dev.
South Korea	3.757	3.762	3.837	3.639	0.054	−0.441	2.274	1.575	0.455	108.960	0.083
Spain	3.542	3.548	3.587	3.447	0.031	−1.107	4.171	7.577 **	0.023	102.706	0.027
Sweden	3.617	3.604	3.766	3.535	0.069	1.067	2.974	5.502 ***	0.064	104.886	0.134
Switzerland	4.071	4.069	4.210	3.923	0.099	−0.012	1.431	2.977	0.226	118.058	0.277
Türkiye	3.880	3.840	4.148	3.621	0.154	0.312	1.859	2.045	0.360	112.525	0.666
United Kingdom	3.357	3.395	3.605	3.128	0.170	−0.097	1.484	2.822	0.244	97.363	0.812
United States	3.227	3.244	3.319	3.069	0.064	−0.768	2.888	2.865	0.239	93.589	0.114

"*, **, and ***" indicate statistical significance at the "1%, 5%, and 10%" levels, respectively.

Table 1 shows that among 37 OECD countries, the top three countries with the highest average are Iceland (4.382), Chile (4.323), and New Zealand (4.199), while the top three countries with the lowest average are the United States (3.227), the United Kingdom (3.357), and Germany (3.397). The ranking of countries by median is the same as for the average, with Iceland (4.382), Chile (4.324), and New Zealand (4.199) having the highest median and the United States (3.244), United Kingdom (3.395), and Germany (3.412) having the lowest median. The United Kingdom (0.170), Turkey (0.154), and Latvia (0.153) have the highest standard deviation indicating the highest variability, while Iceland (0.026), Luxembourg (0.031), and Spain (0.032) have the lowest standard deviation indicating the least variability. Norway (1.314), Sweden (1.067), and Latvia (0.559) have the highest skewness, while Hungary (−3.069), Denmark (−2.276), and Israel (−1.298) have the lowest skewness. Hungary (14.474), Denmark (9.810), and Norway (5.223) have the highest kurtosis, while Switzerland (1.431), England (1.484), and Australia (1.610) have the lowest. Jarque–Bera test statistics show that the series of all countries, except Colombia, Denmark, Hungary, Israel, Norway, Slovenia, Slovenia, Spain, and Sweden, are normally distributed. Iceland (127.068), Chile (125.362), and New Zealand (121.762) have the highest sum, while the United States (93.589), United Kingdom (97.363), and Germany (98.521) have the lowest sum. The countries with the highest Sum of Squares Deviations (Sum Sq. Dev.) are the UK (0.812), Turkey (0.666) and Latvia (0.654), while the highest Sum Sq. Dev. are Iceland (0.019), Luxembourg (0.022), and Spain (0.27).

In the analysis methods to be used in the study, methods enriched with Fourier expansion were preferred in order to better detect structural breaks and dynamic patterns of variables over time. The Fourier expansion is frequently used in the literature as a powerful method to detect structural breaks and gradual changes in time series. While traditional unit root tests and panel data analysis methods often fail to adequately capture abrupt breaks or nonlinear movements, the Fourier expansion offered the ability to model complex fluctuations and periodic patterns in the data. The main rationale for using the Fourier expansion in this study was the assumption that changes in the export diversification processes of OECD countries may have been shaped not only by abrupt transformations but also by gradual transitions over time. The results obtained with the Fourier expansion provided a more flexible and realistic analysis compared to traditional methods, allowing for a more precise analysis of the dynamics of convergence and divergence in export diversification. Figure 1 presents the graphical representation of the variables together with the Fourier expansion to visually support why this method is preferred.

Figure 1. *Cont.*

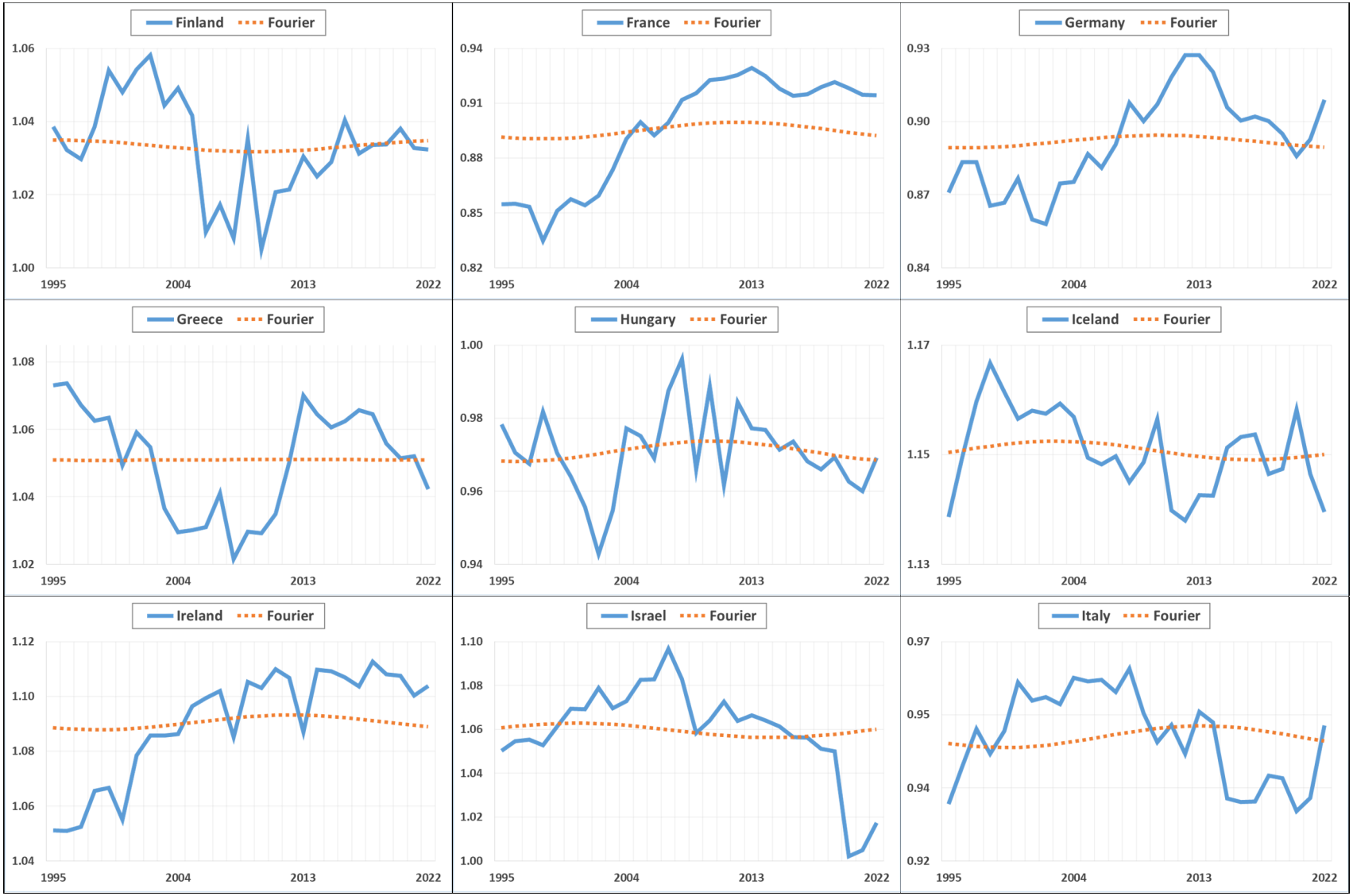

Figure 1. *Cont.*

Figure 1. *Cont.*

Figure 1. Country Series with Fourier approximation.

3.2. Methodology

This study was based on the statistical tests developed by Breusch and Pagan (1980) [50], Pesaran (2004) [51], and Pesaran et al. (2008) [52]. These tests are widely accepted in the economics and finance literature and their detailed formulation is not necessary.

In the next stage of the study, the stochastic convergence of the Export Diversification Index for OECD member countries was calculated. In this process, the relevant data were analyzed using Equation (1) presented below.

$$C_{it} = \ln(E_{it})/\ln(E_t), \;\; E = EDI \text{ (Export Diversification Index)}. \tag{1}$$

In this study, we first applied the PANIC (Panel Analysis of Nonstationarity in Idiosyncratic and Common Components) procedure developed by Bai and Ng (2014) [53]. This method provided a framework that allowed for structural breaks using LM unit root tests and could also account for cross-correlations in the panel data set. Bai and Ng's (2014) [53] PANIC procedure has been introduced in the literature as an important method for panel data analysis. The analytical framework of the paper was built on the following data generation process (DGP) based on the unobservable component representation. This process provided the basic framework for the application of LM tests with structural breaks (Equation (2)).

$$y_{i,t} = d_{i,t} + \pi_i' F_t + e_{i,t} \;\; (i = 1, \ldots, N; t = 1, \ldots, T), \tag{2}$$

where "$d_{i,t}$" is a polynomial trend function and "F_t" is a vector of common factors of size "r × 1". "π_i'" is a vector representing factor loadings. The series "$y_{i,t}$" is the sum of a deterministic component "$d_{i,t}$", a common component "$\pi_i' F_t$" and a largely idiosyncratic (individual) error term "$e_{i,t}$". A factor model with "N" variables contains unique components for each variable, but only a limited number of common factors. This structure allows the model to analyze both common and idiosyncratic sources of variance.

$$(I - L)F_t = C(L)u_t, \tag{3}$$

$$(1 - p_i L)e_{i,t} = H_i(L)e_{i,t}. \tag{4}$$

Here, "$C(L) = \sum_{j=0}^{\infty} C_J l^j$", "$H_i(L) = \sum_{j=0}^{\infty} H_{i,J} L^j$", and "L" is the delay operator. Moreover, the factor "F_t" used here can be defined as a first-order integrated [I(1)] or stationary [I(0)] process, depending on the degree of the "C(1)" matrix. This plays an important role in determining the dynamic properties of the factor model and shapes the basic assumptions of the analysis.

$$\Delta y_{i,t} = \acute{\mu} \Delta d_{i,t} + \pi_i' \Delta F_t + u_{i,t} \; (u_{i,t} = \Delta e_{i,t}). \tag{5}$$

The unit root test statistics are then obtained from the following regression:

$$\Delta y_{i,t} = \acute{\mu} \Delta d_{i,t} + \pi_i' \Delta F_t + \psi \widetilde{S}_{t-1} + e_{i,t}, \tag{6}$$

where "$\widetilde{S}_{t-1}$" denotes the detrended series with

$$\widetilde{S}_t = y_{i,t} - \widetilde{\varphi} - d_{i,t} \acute{\mu}. \tag{7}$$

Here, "$\acute{\mu}$" is the coefficient in the regression of "$\Delta y_{i,t}$" on "$d_{i,t}$" in Equation (5) and "$\widetilde{\varphi}$" is the restricted MLE of "φ", i.e., "$\widetilde{\varphi} = y_1 - d_1 \acute{\mu}$". It is important to emphasize that in the detrending procedure (Equation (7)), the coefficients are obtained using the first differenced

data from the regression analysis in Equation (5). This procedure plays a critical role in minimizing trend effects and making the analysis more accurate.

For the stochastic convergence analysis, the Panel Unit Root Test developed by Nazlioglu et al. (2023) was used [26]. This test allows for multiple structural breaks in the panel data set, controls for cross-correlations, and allows for smooth or gradual changes instead of abrupt breaks. Moreover, the test is augmented with a Fourier function. This method, which is also used by Husein and Kara (2023) [54], is called PANIC-Fourier Unit Root Test. The same nomenclature was preferred in this study. Nazlioglu et al. (2023) [26] first estimated the parameters in the Fourier function separately for each i-th cross-section unit (Equation (8)):

$$\Delta y_{i,t} = y_i + \sum_{k=1}^{m_i} a_{ik}\Delta\cos\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{m_i} b_{ik}\Delta\sin\left(\frac{2\pi kt}{T}\right) + q_{i,t}. \quad (8)$$

In order to calculate residual values, the "Z_{it}" equation was developed using the estimated parameters and factor terms. This equation combines the deterministic terms and factors to obtain more accurate residual values (Equation (9)).

$$Z_{it} = \Delta y_{i,t} - y_i - \sum_{k=1}^{\hat{m}_i} \hat{a}_{ik}\Delta\cos\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{\hat{m}_i} \hat{b}_{ik}\Delta\sin\left(\frac{2\pi kt}{T}\right) - \hat{\pi}_i'\hat{f}_t. \quad (9)$$

When the change in the sum of squared residuals in Equation (3), "$SSR = \sum_{i=1}^{N}\sum_{t=2}^{T}\hat{z}_{i,t}^2$", is less than the desired tolerance level, for example "10^{-7}", the iteration is stopped.

Developed by Nazlioglu et al. (2023) [26], this LM version of the PANIC tests integrates a Fourier function to account for smooth or gradual structural breaks. In this framework, the specified Fourier function is applied, and the test statistic for each cross-sectional unit is derived from the corresponding regression equation (Equation (10)):

$$\Delta y_{i,t} = \varphi_i + \beta_i\widetilde{S}_{i,t-1} + \sum_{k=1}^{m_i} a_{ik}\Delta\cos\left(\frac{2\pi kt}{T}\right) + \sum_{k=1}^{m_i} b_{ik}\Delta\sin\left(\frac{2\pi kt}{T}\right) + \pi_i'\hat{f}_t + \sum_{s=1}^{p_t} c_{is}\Delta\widetilde{S}_{i,t-s} + v_{i,t}. \quad (10)$$

In this context, the lagged value of "$\widetilde{S}_{i,t}$", the estimated frequencies, the factors "$\hat{f}_t$", and the expanded terms of "$\Delta\widetilde{S}_{i,t}$" are included in the model to correct for autocorrelations. Then, using Equation (10), the null hypothesis of a unit root for the i-th horizontal cross-section unit is rejected as "$H_0 : \beta_i = 0$". The t-statistic corresponding to the null hypothesis "$\beta_i = 0$" is denoted as "$\hat{\tau}_i$".

$$\hat{\tau}_i = t - statistic\ for\ \beta_i = 0\ in\ (4) \quad (11)$$

In the study, for the PANIC Unit Root Test and PANIC-Fourier Unit Root Test, "t-statistical significance" was preferred as the information criterion by calculating the lags as 1 and 2 separately according to the maximum cumulative frequency number (m).

Our study used current data. In the methodology part, we determined different methods compared to other studies and used two different econometric analysis methods. The first one is the cross-section dependence test and the other one is the unit root test. The first cross-section dependence test is based on Breusch and Pagan (1980) [50]. We used this method, along with the ones by Pesaran (2004) [51] and Pesaran et al. (2008) [52], which are advanced versions of the Breusch and Pagan (1980) [50] method, and we made sure that these tests would give similar results. The other test we used is the unit root test. We also used the first version of the PANIC unit root test developed by Bai and NG (2004) [53], as well as the PANIC-Fourier Unit Root Test developed in Nazlioglu et al. (2023) [26], which

is the most recent version of the PANIC test. By using the initial and final versions of the tests, we aimed to better compare them with the results of past studies.

4. Empirical Results

At this stage, the horizontal cross-section dependence was analyzed. Horizontal cross-section dependence was detected using the tests proposed by Breusch and Pagan (1980) [50] (LM Test (1)), Pesaran (2004) [51] (CDLM Test (2)), and Pesaran et al. (2008) [52] (CDL Madjective Test (3)).

The results of the horizontal cross-section dependence test for the 37 countries used in the panel data analysis are presented in Table 2.

Table 2. Result of the Cross-Section Dependence Tests.

CD Tests	Statistics	Probability Value
(1)	2771.060 ***	0.000
(2)	57.678 ***	0.000
(3)	33.934 ***	0.000

*** indicate significance at the 1% level.

In all tests applied for the analysis of horizontal cross-section dependence, the probability value is less than 0.05. Therefore, it is concluded that the data used in the panel data analysis have a horizontal cross-sectional dependence.

Convergence analysis for series with horizontal cross-section dependence is performed using the PANIC Unit Root Test. The results of the related tests are given in Table 3.

Table 3. PANIC Unit Root Test.

Country	Constant			Trend		
	Wald Stat.	*p* Value	Lag	Wald Stat.	*p* Value	Lag
Australia	−1.853 *	0.065	0	1.833	0.980	0
Austria	−1.381	0.155	0	−0.394	0.510	0
Belgium	−0.898	0.312	0	−0.344	0.527	0
Canada	−1.239	0.193	0	−0.815	0.345	0
Chile	−1.506	0.125	0	−1.793 *	0.072	0
Colombia	−1.345	0.163	2	−1.711	0.085	0
Czechia	−1.355	0.160	0	−0.029	0.640	0
Denmark	−1.345	0.163	0	−0.552	0.448	0
Estonia	−1.490	0.128	0	0.316	0.750	2
Finland	−2.945 ***	0.005	0	−2.265 **	0.028	0
France	−1.104	0.237	0	0.637	0.833	0
Germany	−2.642 **	0.013	3	−0.030	0.640	0
Greece	−1.224	0.198	0	−0.453	0.487	0
Hungary	−2.598 **	0.013	0	−0.003	0.650	2
Iceland	−2.086 **	0.040	2	−1.637 *	0.098	2
Ireland	−0.979	0.280	1	0.467	0.792	1
Israel	−1.076	0.247	0	−1.117	0.233	0
Italy	−1.251	0.190	0	−0.771	0.360	0

Table 3. *Cont.*

Country	Constant			Trend		
	Wald Stat.	***p* Value**	**Lag**	**Wald Stat.**	***p* Value**	**Lag**
Japan	−2.593 **	0.013	0	0.012	0.655	1
Latvia	−1.728 *	0.083	2	−0.440	0.492	2
Lithuania	−1.603	0.105	0	0.316	0.750	0
Luxembourg	−2.373 **	0.022	0	−2.922 ***	0.005	0
Mexico	−2.129 **	0.037	0	−0.054	0.632	0
Netherlands	−2.217 **	0.030	0	−1.953 *	0.052	0
New Zealand	−1.412	0.147	3	0.027	0.660	3
Norway	−1.209	0.203	1	−1.289	0.180	1
Poland	−1.351	0.163	0	0.079	0.677	0
Portugal	−3.475 ***	0.000	0	−0.057	0.632	1
Slovakia	−3.927 ***	0.000	0	−3.731 ***	0.000	0
Slovenia	−0.791	0.352	3	−0.789	0.355	3
South Korea	−2.621 **	0.013	0	−0.341	0.527	1
Spain	−2.246 **	0.028	0	−1.621 *	0.100	0
Sweden	−0.999	0.273	0	0.203	0.718	0
Switzerland	−2.470 **	0.018	0	1.429	0.953	0
Türkiye	−2.760 ***	0.007	0	2.157	0.990	1
United Kingdom	−1.820 *	0.070	0	0.337	0.757	0
United States	−1.153	0.220	0	0.888	0.885	0

In the table, *** represents (1%), ** (5%), and * (10%).

According to the results of the PANIC Panel Unit Root Test used in this study, 17 countries converged for constant: Australia, Finland, Germany, Hungary, Iceland, Japan, Latvia, Luxembourg, Mexico, Netherlands, Portugal, Slovakia, South Korea, Spain, Switzerland, Turkey, and the United Kingdom. For the trend, 7 countries converged, which are Chile, Finland, Iceland, Luxembourg, Netherlands, Slovakia, and Spain.

Convergence analysis for series with horizontal cross-section dependence is performed using the test developed by Nazlioglu et al. (2023) [26]. The results of the related tests are given in Table 4.

Table 4. PANIC-Fourier Panel Unit Root Test Results.

Country	M = 1						M = 2					
	Stat.	**Pval.**	**Lag**	**Critical Value**			**Stat.**	**Pval.**	**Lag**	**Critical Value**		
				%10	**%5**	**%1**				**%10**	**%5**	**%1**
Australia	−4.351 **	0.037	3	−3.784	−4.176	−5.036	−3.746	0.420	0	−4.875	−5.343	−6.404
Austria	−3.825	0.116	0	−3.909	−4.326	−5.166	−5.476 **	0.042	0	−4.875	−5.343	−6.404
Belgium	−2.277	0.795	0	−3.909	−4.326	−5.166	−3.206	0.675	0	−4.875	−5.343	−6.404
Canada	−3.467	0.210	0	−3.909	−4.326	−5.166	−4.749	0.117	1	−4.859	−5.318	−6.363
Chile	−2.687	0.573	0	−3.909	−4.326	−5.166	−3.694	0.444	0	−4.875	−5.343	−6.404
Colombia	−4.025 *	0.078	1	−3.877	−4.277	−5.121	−4.820 *	0.093	3	−4.768	−5.225	−6.286
Czechia	−4.255 **	0.048	2	−3.836	−4.227	−5.077	−4.730	0.106	3	−4.768	−5.225	−6.286
Denmark	−3.369	0.243	0	−3.909	−4.326	−5.166	−3.603	0.487	0	−4.875	−5.343	−6.404

Table 4. *Cont.*

Country	M = 1						M = 2					
	Stat.	Pval.	Lag	Critical Value			Stat.	Pval.	Lag	Critical Value		
				%10	%5	%1				%10	%5	%1
Estonia	−3.195	0.271	3	−3.784	−4.176	−5.036	−4.490	0.169	1	−4.859	−5.318	−6.363
Finland	−3.225	0.300	0	−3.909	−4.326	−5.166	−4.970 *	0.087	0	−4.875	−5.343	−6.404
France	−3.828	0.109	1	−3.877	−4.277	−5.121	−4.790	0.111	1	−4.859	−5.318	−6.363
Germany	−2.097	0.874	0	−3.909	−4.326	−5.166	−4.678	0.130	1	−4.859	−5.318	−6.363
Greece	−2.999	0.403	0	−3.909	−4.326	−5.166	−4.310	0.192	3	−4.768	−5.225	−6.286
Hungary	−3.522	0.159	3	−3.784	−4.176	−5.036	−3.813	0.357	3	−4.768	−5.225	−6.286
Iceland	−3.125	0.343	0	−3.909	−4.326	−5.166	−3.701	0.449	1	−4.859	−5.318	−6.363
Ireland	−5.515 ***	0.005	0	−3.909	−4.326	−5.166	−5.351 **	0.045	2	−4.824	−5.278	−6.324
Israel	−3.081	0.363	0	−3.909	−4.326	−5.166	−4.224	0.242	1	−4.859	−5.318	−6.363
Italy	−4.152 *	0.067	0	−3.909	−4.326	−5.166	−5.113 *	0.060	3	−4.768	−5.225	−6.286
Japan	−3.807	0.120	0	−3.909	−4.326	−5.166	−4.135	0.261	2	−4.824	−5.278	−6.324
Latvia	−2.365	0.753	0	−3.909	−4.326	−5.166	−3.746	0.421	0	−4.875	−5.343	−6.404
Lithuania	−3.102	0.354	0	−3.909	−4.326	−5.166	−4.855 *	0.096	2	−4.824	−5.278	−6.324
Luxembourg	−3.631	0.131	3	−3.784	−4.176	−5.036	−3.729	0.393	3	−4.768	−5.225	−6.286
Mexico	−3.039	0.364	2	−3.836	−4.227	−5.077	−4.975 *	0.074	3	−4.768	−5.225	−6.286
Netherlands	−4.133 *	0.059	2	−3.836	−4.227	−5.077	−4.201	0.240	2	−4.824	−5.278	−6.324
New Zealand	−2.752	0.487	3	−3.784	−4.176	−5.036	−5.095 *	0.061	3	−4.768	−5.225	−6.286
Norway	−5.089 **	0.011	1	−3.877	−4.277	−5.121	−5.023 *	0.079	1	−4.859	−5.318	−6.363
Poland	−1.870	0.946	0	−3.909	−4.326	−5.166	−3.202	0.646	3	−4.768	−5.225	−6.286
Portugal	−5.357 ***	0.007	0	−3.909	−4.326	−5.166	−4.190	0.243	2	−4.824	−5.278	−6.324
Slovakia	−4.843 **	0.019	0	−3.909	−4.326	−5.166	−4.808	0.110	0	−4.875	−5.343	−6.404
Slovenia	−7.011 ***	0.000	2	−3.836	−4.227	−5.077	−6.749 ***	0.005	2	−4.824	−5.278	−6.324
South Korea	−5.442 ***	0.005	3	−3.784	−4.176	−5.036	−7.020 ***	0.003	3	−4.768	−5.225	−6.286
Spain	−2.314	0.738	3	−3.784	−4.176	−5.036	−4.958 *	0.087	1	−4.859	−5.318	−6.363
Sweden	−3.033	0.386	0	−3.909	−4.326	−5.166	−4.112	0.279	1	−4.859	−5.318	−6.363
Switzerland	−3.041	0.382	0	−3.909	−4.326	−5.166	−4.048	0.302	1	−4.859	−5.318	−6.363
Türkiye	−3.815	0.118	0	−3.909	−4.326	−5.166	−4.115	0.268	2	−4.824	−5.278	−6.324
United Kingdom	−3.144	0.335	0	−3.909	−4.326	−5.166	−4.787	0.113	0	−4.875	−5.343	−6.404
United States	−3.612	0.148	2	−3.836	−4.227	−5.077	−3.129	0.711	0	−4.875	−5.343	−6.404

In the table, *** represents (1%), ** (5%), and * (10%).

According to the results of the PANIC-Fourier Panel Unit Root Test used in this study, 11 countries converged within one category (m = 1 or 2). These countries are Australia, Austria, Czechia, Finland, Lithuania, Mexico, Netherlands, New Zealand, Portugal, Slovakia, and Spain. Six countries (Colombia, Ireland, Italy, Norway, Slovenia, and South Korea) have convergence in all categories (m = 1 and 2). The results of the study reveal that approximately 46% of OECD countries have converged under the Export Diversification index, while the rest have not. These results indicate that most OECD countries do not have uniform policies regarding export diversification decisions.

Table 5 summarizes the country-specific results from the PANIC Unit Root Test and PANIC-Fourier Panel Unit Root Test.

The PANIC unit root test (sum of constant and trend) developed by Bai and Ng (2004) [53] results in a higher rejection of the null hypothesis of stationarity in the export diversification series of OECD countries compared to the PANIC-Fourier Unit Root test (sum of M = 1 and M = 2) developed by Nazlioglu et al. (2023) [26]. For scholastic convergence, the PANIC-Fourier Unit Root test developed by Nazlioglu et al. (2023) [26], which allows multiple structural breaks and control of cross-correlations in the panel and allows smooth or gradual change instead of sudden breaks, makes the results closer to reality than the PANIC unit

root test. When this method, which has these important advantages, is used, the null hypothesis of stationarity is rejected less frequently as in our study.

Table 5. Summary of the country-specific results.

Country	PANIC Unit Root Test Results		PANIC-Fourier Panel Unit Root Test Results	
	Constant	Trend	M = 1	M = 2
Australia	✓		✓	
Austria				✓
Belgium				
Canada				
Chile		✓		
Colombia			✓	✓
Czechia			✓	
Denmark				
Estonia				
Finland	✓	✓		✓
France				
Germany	✓			
Greece				
Hungary	✓			
Iceland	✓	✓		
Ireland			✓	✓
Israel				
Italy			✓	✓
Japan	✓			
Latvia	✓			
Lithuania				✓
Luxembourg	✓	✓		
Mexico	✓			✓
Netherlands	✓	✓	✓	
New Zealand				✓
Norway			✓	✓
Poland				
Portugal	✓		✓	
Slovakia	✓	✓	✓	
Slovenia			✓	✓
South Korea	✓		✓	✓
Spain	✓	✓		✓
Sweden				
Switzerland	✓			
Türkiye	✓			
United Kingdom	✓			
United States				

✓ indicates that the null hypothesis of "there is a unit root" is rejected at a significance level of at least 10 percent, implying convergence in export diversification for the given country.

5. Conclusions

One of the most important economic indicators among the economic relations that have developed with the impact of globalization is foreign trade indicators [55]. Among foreign trade indicators, the most important one for countries is export indicators. Export diversification has an important place in countries' foreign trade and international trade competition. Export diversification convergence of 37 OECD countries is analyzed in this study. It is seen that the use of different econometric methods in convergence analyses in the literature leads to different results. In our study, in order to compare such a situation, the first version of the PANIC test and the most up-to-date version of the PANIC unit root test in the literature, the Fourier PANIC unit root test, were used.

If the results of both tests used in the study are evaluated, while convergence was detected in 17 countries according to the Constant model of the PANIC unit root test, convergence was detected in 7 countries according to the results of the PANIC test trend model. Finland, Iceland, Luxembourg, Netherlands, Slovakia, and Spain were the countries where convergence was detected in both models. According to the results of the PANIC-Fourier Unit Root Test, convergence was detected in 11 countries for m = 1 and in 12 countries for m = 2. Convergence was detected in Colombia, Ireland, Italy, Norway, Slovenia, and South Korea at both values of m. The results of both tests were found to be different from each other. This shows that different results can be obtained according to the methods used in econometric analysis. However, when the results of the PANIC-Fourier-Unit-Root

Test, which is the most recent PANIC test, are taken into account, it is understood that convergence is found in only 6 of the OECD countries. According to the results of both unit root tests used in the study, it is found that there is no widespread export diversification convergence among OECD countries. These results differ from those by Akram (2018) [39]. However, the results obtained by Akram and Rath (2020) [40] were similar. Karanfil and Ombga (2023) [41] found partial convergence in export diversification. Their result is similar to ours.

The low number of convergent countries can be interpreted as the fact that countries have not yet been sufficiently influenced by each other in terms of exports. One of the most important outcomes of the study is that OECD member countries, which are an economic union, do not yet have sufficient interaction in their foreign trade. The economic relations of OECD countries should be further developed, especially in the field of foreign trade, and their interaction should be increased. Considering that the main purpose of OECD countries is economic cooperation and development, the importance of increasing foreign trade interaction between them becomes more important.

An important point here is that export diversification policies should serve not only economic growth objectives but also sustainable development goals. Today, the promotion of environmentally friendly production and green innovation offers significant opportunities to both broaden the composition of exports and achieve long-term sustainability goals. The growing demand for environmentally friendly and sustainable products in international markets further increases the strategic importance of investments in this area. Aligning export diversification policies of OECD countries with sustainability principles will contribute to economic development as well as global sustainability goals.

However, the development of more effective export diversification strategies by OECD countries depends on strengthening regional and global cooperation mechanisms. For example, trade and investment agreements can be used to deepen economic ties, expand export markets, and promote sustainable innovation projects. Moreover, such cooperation should not be limited to OECD countries, but should also build stronger ties with emerging economies, creating new market opportunities that support sustainable development. Emerging markets, particularly in Asia and Africa, are critical regions to consider in OECD countries' sustainable export diversification strategies.

For non-OECD countries, promoting convergence in export diversification strategies is critical to reducing inequalities in global trade, enhancing economic resilience and supporting sustainable development. In this context, especially for developing countries, implementing policies such as technology transfer, infrastructure investments, and reducing trade barriers can enhance export diversification performance and sustainable growth capacity. OECD countries taking a leading role in this process, developing joint projects with developing countries and providing technical assistance to these countries will contribute not only to global economic development but also to achieving long-term sustainability goals.

In conclusion, our study provides a strategic guide for policymakers by presenting the current state of export diversification and convergence dynamics in OECD countries. The findings of our study are important not only for evaluating the export policies of OECD countries, but also for providing lessons that can be applied to other economies. Especially when considering the impact of export diversification strategies on the global trading system and sustainable development, the need to develop more inclusive and sustainable policies in this area should be emphasized.

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