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Research article

Revisiting the export-led growth hypothesis for OECD countries. A fractionally integrated heterogeneous panel data framework

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Abstract: The export-led growth hypothesis (ELGH) has been extensively explored; however, previous studies have predominantly relied on standard integration and cointegration techniques, and empirical evidence supporting the ELGH remains inconclusive. This research re-examined the ELGH for developed economies using advanced fractional methods. By analyzing quarterly data on GDP, real effective exchange rates, and goods exports for 27 OECD countries from 1995 to 2021, our study showed that conventional cointegration methods may overlook significant long-run relationships. In contrast, the fractional approach offers a more flexible and accurate estimation of the trade-growth nexus. These findings underscore the importance of refined econometric methods in international trade research, particularly for evaluating the long-term effects of exports on economic performance.

Keywords: export-led growth hypothesis; panel data; fractional integration and cointegration

JEL Codes: F14, F4, C12

1. Introduction

From a theoretical point of view, export orientation is widely recognized as a key strategy for promoting economic growth (Tang et al., 2015). The export-led growth hypothesis (ELGH) asserts that an increase in exports relative to total output directly stimulates economic expansion. Trade openness enhances productivity by facilitating more efficient resource allocation, exploiting economies of scale, and promoting the diffusion of technological knowledge and innovation (Dawson, 2005). Additionally, exports help mitigate the effects of weak domestic demand, reducing vulnerability to economic downturns; generate foreign exchange earnings, easing pressure on the current account; and enable the importation of capital goods and advanced technology, thereby fostering investment. Collectively, these mechanisms create a multiplier effect that further accelerates economic growth. While these factors are particularly vital for fostering economic development in emerging economies, exports also play a significant role in driving growth in advanced economies.

The standard empirical approach to investigate the ELGH is based on classical integration and cointegration methods. This strategy has been employed in studies focusing on both developed (Marin, 1992; Kónya, 2006; Ribeiro et al., 2016; Seok and Moon, 2021; Seok and Kim, 2023) and developing countries (Jin, 1995; Shan and Sun, 1999; Medina-Smith, 2000; Abual-Foul, 2004; Tang et al., 2015; Islam et al., 2022; Islam, 2023), and considering cross-sectional, time-series, and panel data approaches. However, empirical findings on the ELGH remain inconclusive. Literature reviews by Giles and Williams (2000) and Sannassee et al. (2014) synthesized the extensive research on this topic, noting that most studies focus on developing or emerging economies, where identifying the sources of economic growth is particularly critical. Nonetheless, a meta-regression analysis conducted by Sannassee et al. (2014) suggested that lower-income countries benefit less from export growth than higher-income nations. Similarly, Jun (2007) found that exports exert a greater impact on economic growth in high-income countries than in low-income ones. However, research on the ELGH in developed countries remains relatively limited.

Our contribution to the empirical literature on the ELGH is twofold. First, while most empirical studies focus on developing countries, often yielding inconclusive results, this study examines the ELGH in a panel of developed countries, where exports are expected to play a relevant role in driving economic growth. In high-income economies, particularly those in the OECD, exports from high-tech industries stimulate economic growth by facilitating knowledge spillovers across sectors, enhancing the productivity of production factors, and strengthening firms' competitiveness in global markets (Marin, 1992; Sojoodi and Baghbanpour, 2023). In contrast, most developing countries primarily export natural resources and commodities, which are less conducive to long-term economic growth due to their relatively inelastic supply and susceptibility to significant price fluctuations. As a result, these exports tend to be less competitive than manufactured goods. Indeed, previous research has shown that countries that export high-tech and high-value-added products experience higher growth rates than those reliant on low-tech and primary commodities (Lall, 2020; Hausman et al, 2007). Furthermore, endogenous growth models (Romer, 1990; Grossman and Helpman, 1991) suggest that export-led growth is more viable in high-income countries, which primarily export industrial and high-tech products. Consequently, the impact of exports on economic growth is expected to be more pronounced in developed economies.

Second, we depart from the standard empirical strategy and employ fractional cointegration techniques to analyze the ELGH. Traditional time series and panel data methods have been widely used to examine short-run causality and the long-run relationship between exports and economic activity. However, these methods impose overly restrictive assumptions by requiring memory parameters to be fixed at 0, 1, or 2. In contrast, fractional cointegration techniques allow these parameters to remain unknown and estimate them, providing greater flexibility and reducing the risk of model misspecification (Hualde and Nielsen, 2023). Fractional methods account for fractional integration, meaning that shocks to economic variables may exhibit long-term persistence, and any return to equilibrium, if it exists, can occur more gradually. Notably, unit root tests and conventional cointegration analyses often perform poorly when data series are fractionally integrated (Dittman, 2000; Gil-Alana et al., 2014). Indeed, fractional methods are particularly well-suited for capturing persistence, a key characteristic of time series data used to study the ELGH. Traditional methods, which assume a rapid return to equilibrium, may lead to misleading conclusions and cause policymakers to underestimate the efforts required to mitigate the adverse effects of economic shocks. By contrast, fractional methods offer a more precise estimation of the speed of adjustment to equilibrium, providing valuable insights for policy formulation.

To the best of our knowledge, fractional methods have not yet been applied to investigate the ELGH. Most previous applications of fractional cointegration have focused on financial or price data (Gil-Alana and Hualde, 2009), whereas applications in international trade remain limited, primarily related to tourism, a specific subset of trade in services. For example, in a time series context, Fischer and Gil-Alana (2009) examined fractional cointegration between the number of German tourists visiting Spain and German imports of Spanish wine. Similarly, Pérez-Rodríguez et al. (2021) applied fractional cointegration techniques to test the tourism-led growth hypothesis (TLGH) for seven European countries. In a panel data framework, Pérez-Rodríguez et al. (2022) employed panel fractional cointegration methods to analyze the TLGH across 14 European countries.

In summary, while previous research has extensively examined the ELGH, it has primarily focused on developing countries and relied on standard integration and cointegration methods, often yielding inconclusive results. The present research re-evaluates the ELGH by applying the fractional integrated heterogeneous panel data approach developed by Ergemen and Velasco (2017). This methodology allows for more flexible persistence and cointegration relationships, offering a more comprehensive understanding of the relationship between exports and economic growth. Furthermore, this study focuses on developed countries, where empirical research remains limited despite the availability of more and better data. Specifically, the analysis considers homogeneous quarterly data on trade, GDP, and exchange rates for 27 OECD countries over the period 1995–2021.

The paper is organized as follows: Section 2 provides a brief literature review of the theory and empirical evidence of the export-led growth hypothesis. Section 3 discusses the methods used in this study, namely the cross-sectional error correction model (CS-ECM) and the fractional integrated panel data estimator. Section 4 describes the data and presents the results. Finally, Section 5 discusses the empirical findings, while Section 6 presents the main conclusions, limitations, and further research.

2. Literature review

2.1. Theoretical support of the ELGH

The ELGH is supported by several theoretical arguments. First, export expansion directly contributes to economic growth, as exports constitute a component of aggregate output and stimulate job creation. This, in turn, enhances consumer spending and promotes overall economic activity. Additionally, exports generate foreign exchange earnings, thereby helping to reduce current account imbalances. This latter idea aligns closely with Thirlwall's law (Thirlwall, 1979), which states that a country's long-term growth rate is constrained by its ability to maintain equilibrium in the balance of payments. Specifically, if a country persistently runs a current account deficit, it cannot sustain high growth without resorting to borrowing or depleting foreign reserves, leading to a decline in investment and a slowdown in technological progress.[1] In this regard, economies experiencing sustained rapid growth typically undergo significant changes in their export composition, shifting toward more complex and higher value-added products. Indeed, Romero and McCombie (2016) show that moving exports from low-tech to high-tech sectors is necessary, although not sufficient, to foster long-term growth. However, many emerging and developing economies remain specialized in low-technology, low-value-added goods, which limits their ability to achieve sustained long-term growth (Hausmann, 2024).

Additionally, export expansion generates specialization, particularly in the production of tradable goods, allowing the reallocation of resources from relatively inefficient non-tradable sectors to more productive export-oriented sectors (Ribeiro et al., 2016). This is the development strategy followed by some emerging economies, such as the East Asian Tiger economies. However, other developing regions, such as Latin American countries, have been less successful in following this strategy because their concentration on commodities as their main export goods makes their insertion in global markets sensitive to price and exchange rate volatility (Palley, 2012). As a consequence, the ELGH is not always empirically supported for developing countries. Precisely, since export-expansion strategies may impede the development of domestic markets, developing countries face the direct competition of developed economies, and being dependent on foreign demand turns them more vulnerable to financial uncertainty and political instability.

Export-oriented strategies are also relevant for developed countries to promote economic growth. Exports are a source of foreign exchange that reduces current account deficits and enables the import of intermediate and capital goods that increase capital formation, stimulating long-run growth (Balassa, 1978; Buffie, 1992). Furthermore, exports to foreign markets help to compensate for the weakness of domestic growth factors in developed countries. For instance, exports help offset the chronic shortage of domestic growth in the Eurozone (Torres, 2019). At the microeconomic level, trade openness induces a self-selection of firms, where the most productive firms become exporters and the least productive ones exit, which in turn improves the economy's aggregate productivity (Melitz, 2003). Finally, endogenous growth theories hold that knowledge accumulation increases productivity, thereby improving economic growth. Therefore, competition in international markets drives companies to become more productive and innovative, which not only benefits exporters but also spills over to the broader economy, fostering technological advancement and productivity gains. The experiences of industrialized high-income countries show that their development path passes through the development of high-tech sectors, and engaging in high-tech trade is expected to positively affect a country's level of competitiveness and innovation (Sojoodi and Baghbanpour, 2023).

2.2. Empirical evidence of the ELGH

Previous empirical studies have investigated the validity of the ELGH in both developing and high-income countries. However, research focusing on developing countries remains inconclusive, often yielding contradictory findings. Sannasse et al.'s (2014) review shows that the ELGH has been

[1] McCombie and Roberts (2002) and McCombie and Thirlwall (2004) offer reviews of tests and extensions of the model.

extensively examined in low- and middle-income countries, but their meta-regression results suggest that the impact of exports on economic growth becomes more pronounced as income levels rise. Similarly, Medina-Smith (2001) found evidence supporting the ELGH in Costa Rica but argued that the effect of exports on economic growth in developing countries is relatively modest and constrained. In a broader study of numerous developing countries, Bahmani-Oskooee and Economidou (2009) reported mixed results depending on the specific country context. More recently, Odhiambo (2022) provided evidence of the ELGH for high-income nations in Sub-Saharan Africa but not for low- and middle-income economies, highlighting the importance of robust institutional, infrastructural, industrial, and financial conditions in successfully implementing an export expansion strategy. Meanwhile, Islam (2022) validated the positive impact of trade on economic growth in South Asian countries but noted that they mostly export low-technology products, suggesting the need to diversify toward high-technology exports to foster growth and reduce vulnerability to trade shocks. Similarly, Parteka (2020) showed that technological convergence in low-income economies is necessary to reduce their exposure to export risk.

While investigating ELGH in developed economies is of interest, the empirical literature on this topic remains limited. Marin (1992) confirmed the validity of ELGH for four OECD countries—Germany, the United Kingdom, Japan, and the United States—using monthly data from 1960 to 1987. Kónya (2006) examined Granger causality between exports and real GDP in 24 OECD countries from 1960 to 1997, finding one-way causality from exports to GDP in eight countries and two-way causality in three. Similarly, Emirmahmutoglu and Kose (2011) analyzed Granger causality within heterogeneous mixed panels using quarterly data for 20 OECD countries between 1987 and 2006, identifying a one-way causal relationship from exports to economic growth across all 20 countries. Further evidence comes from Ribeiro et al. (2016), who used annual data for 26 European Union countries from 1995 to 2014 and established a strong link between real exports and real output growth. Their findings suggest that developed countries should prioritize the export of high-technology products and diversify their exports across trading partners with higher growth potential rather than simply increasing the number of trade partners. Additionally, empirical research highlights the significant role of high-technology exports in driving economic growth in high-income countries (Falk, 2009; Demir, 2018; Buchinskaya and Dyatel, 2019). These studies primarily use annual data on the share of high-technology exports relative to total exports.

Regarding econometric techniques, fractional methods have not yet been applied to test the validity of the ELGH. Previous research has employed both standard time series and panel data frameworks to investigate the causality and long-run relationship between exports and economic activity. In terms of time series methods, previous studies have applied the Engle and Granger (1987) causality method (Jin, 1995; Xu, 1996; Dutt and Ghosh, 1996; Shan and Sun, 1999; Kónya, 2008; Herzer et al., 2006; Shafiullah et al., 2017), the vector error correction model (VECM) (Abual-Foul, 2004; Mishra, 2011; Sahoo et al., 2014), or Johansen's cointegration method (Bodman, 1996; Ribeiro Ramos, 2001; Jun, 2007; Tang et al., 2015). As for panel data methods, the ELGH has been tested for panel cointegration using Pedroni's method (Bahmani-Oskooee et al., 2005; Parida and Sahoo, 2007; and Aslan and Topcu, 2018), the common correlated effect (CCE) estimator (Pesaran, 2006), and the dynamic CCE (DCCE) (Chudik and Pesaran, 2015) with heterogeneous panel data (Dreger and Herzer, 2013; Hagemejer and Mućk, 2019; Nguyen and Örsal, 2020). Granger causality in heterogeneous panel data models has been studied using Dumitrescu and Hurlin's (2012) simple non-causality test (Aslan and Topcu, 2018) or nonlinear causality analysis using a non-parametric approach (Lim and Ho, 2013). Generally, results regarding the effect of exports on economic growth are mixed and depend on the specification and methodology used (Giles and Williams, 2000).

In summary, previous empirical research has predominantly employed standard integration and cointegration methods to examine the role of exports in economic growth. Moreover, in line with theoretical arguments, empirical findings supporting the ELGH appear more robust for high-income countries than for developing nations. Consequently, this paper contributes to the existing literature by assessing the ELGH for OECD countries using fractional methods and comparing the results with those derived from standard approaches. By relaxing the restrictive assumptions of conventional techniques, this methodology offers a more comprehensive understanding of the relationship between exports and economic growth, thereby enhancing both analytical rigor and policy relevance.

3. Methodology

In the empirical analysis, we apply both standard and fractional methods. We analyze the time series properties of the different series using panel unit root tests and individual estimates of the memory. Then, we estimate a standard and fractional panel model. Finally, we test for standard and fractional cointegration and perform two robustness checks.

3.1. Panel unit root and panel cointegration tests

We start with Pesaran's (2015) CD test for cross-sectional dependence of errors. The null is (at most) weak cross-sectional dependence, and the alternative is strong cross-sectional dependence. While first-generation unit root tests assume cross-sectional independence, second-generation unit root tests allow for cross-sectional dependence. We employ two second-generation tests: the cross-sectional augmented Dickey-Fuller (CADF) test (Pesaran, 2006), which extends the Dickey-Fuller test to account for cross-sectional dependence, and the CIPS test (Pesaran, 2007), which incorporates a single unobserved common factor and enables cross-section dependence (see references for further details).

We also analyze standard panel cointegration using the methods of Pedroni (1999, 2004) and Westerlund (2005). Both test the null hypothesis of no cointegration against a homogeneous alternative, i.e., all series being stationary with the same persistence, and a heterogeneous alternative. We deal in an ad hoc fashion with cross-sectional dependence by approximating such dependence by averages of common time effects and subtracting cross-sectional means (see Westerlund, 2005).

3.2. Cross-sectional error correction model (CS-ECM)

The dynamic common correlated effect (DCCE) estimator by Chudik and Pesaran (2015) explicitly allows for unobserved dependence between cross-sectional units in a dynamic context:

$$\begin{gathered} y_{\mathrm{it}}=\alpha_i + \lambda_i y_{\mathrm{it\text{-}1}}+\beta_i^{'} x_{\mathrm{it}}+\mathrm{u}_{\mathrm{it}}, \\ u_{\mathrm{it}} = \gamma_i^{'} f_t + e_{it} \end{gathered} \tag{1}$$

where $y_{it}$is the endogenous variable; $x_{it} = \left(x_{1i,t}, \ldots, x_{ki,t}\right)'$ are the covariates; α_i is a unit-specific fixed-effect; f_t is an unobserved common factor with heterogeneous factor loading γ_i; and e_{it} is a cross-section unit-specific independent and identically distributed error term. $\beta_i = (\beta_{1i}, \ldots, \beta_{ki})'$ collects the k unknown heterogeneous coefficients. Equation (1) can then be expressed as autoregressive distributed lag model (ARDL) of order p and q (ARDL(p,q)):

$$y_{it} = \sum_{j=1}^{p} \lambda_{ij} y_{it-j} + \sum_{j=0}^{q} \delta_{ij} x_{it-j} + v_{ij}, \tag{2}$$

where p and q are the lag length of the autoregressive distributed lag model in period t, and v_{it} is an innovation. The long-run coefficients and the dynamic common correlated effect mean-group (or DCCEMG, hereafter) coefficient can be estimated in three ways: the cross-sectionally augmented ARDL (CS-ARDL), the cross-sectionally augmented distributed lag (CS-DL) (Chudik et al., 2016), and the cross-sectional error correction model (CS-ECM) (Ditzen, 2019, 2021).

In this paper, we use the CS-ECM approach for two reasons. It allows us first to jointly estimate both the short- and long-run dynamics, and second to assess the long-run relationship using an error-correction test. Equation (2) can be rewritten as a CS-ECM-ARDL(p,q):

$$\Delta y_{it} = \varphi_i (y_{it-1} - \beta_i x_{it}) - \sum_{j=1}^{p-1} \lambda_{ij} \Delta y_{it-j} - \sum_{j=0}^{q} \delta_{ij} \Delta x_{it-j} + \sum_{l=0}^{p_T} \gamma_{il} \, \bar{z}_{t-l} + u_{it,} \tag{3}$$

where $\varphi_i$is the error-correction speed of adjustment coefficient for country i (estimated as $\hat{\varphi}_i = -\left(1 - \sum_{j=1}^{p} \hat{\lambda}_{ij}\right)$), and $(y_{it-1} - \beta_i x_{it})$ is the error correction term; β_i is country i's long-run coefficient (estimated as $\frac{\hat{\beta}_i = \sum_{j=0}^{q} \hat{\delta}_{ij}}{\hat{\varphi}_i}$), and λ_{ij} and δ_{ij} represent the country-specific coefficients of the short-term dynamics. Chudik and Pesaran (2015) recommend including $p_T = \sqrt[3]{T}$ lags of the cross-sectional averages, $\bar{z}_t = (\bar{y}_t, \bar{x}_t)$. These averages approximate the unobserved common factors. Finally, u_{it} is an i.i.d. innovation. Rewriting the Equation (3) in a linear form, the parameters can be estimated by OLS. The DCCEMG estimate of Equation (3) is $\tilde{\beta}_{DCCEMG} = \sum_{i=1}^{N} \hat{\beta}_i$ (Ditzen, 2019). The long-run coefficients' variance and covariance matrix is calculated using the delta method (see Ditzen (2019) for an overview).

We further perform two specification tests: first, a Hausman test of the null hypothesis that parameters in the standard CS-ECM model are homogeneous, i.e., pooled estimates are adequate, against the alternative that they are heterogeneous and, consequently, mean group (MG) estimator should be used; second, Blomquist and Westerlund's (2013) test for homogeneous slope coefficients. The DCCEMG deals with both heterogeneous slopes and cross-section dependence.

3.3. Fractionally integrated heterogeneous panel data model

The fractionally integrated heterogeneous panel data model proposed by Ergemen and Velasco (2017) extends Pesaran's (2006) static factor structure (i.e., Equation (1) without the lagged dependent variable) into a fractional framework, where both data and innovations are fractionally integrated. It also enables cross-sectional dependence through common factors and accounts for fixed effects.

Specifically, the model reads as:

$$y_{it} = \alpha_i + \beta_{i0}' x_i + \gamma_i' f_t + \Delta_t^{d_{i0}} e_{1it},\ i = 1, \dots, N, t = 1, \dots, T x_{it} = \mu_i + \Upsilon_i' f_t + \Delta_t^{\vartheta_{i0}} e_{2it}, \tag{4}$$

where $\beta_{i0} = (\beta_{1i0}, \dots, \beta_{ki0})'$ collects the unknown heterogeneous coefficients, and f_t is an *mx1* unobserved common factor that is fractionally integrated to the order ω ($f_t \sim I(\omega)$) and determines the cross-sectional dependence. λ_i, Υ_i are the corresponding factor loadings; e_{1it} and e_{2it} are covariance stationary idiosyncratic shocks; the memory parameters of interest are the residual integration order d_{i0} and the memory of the defactored (unobserved) explanatory variable ϑ_{i0}. x_{it}'s memory is then $max\{\vartheta_{i0}, max_i\, \omega_i\}$ and the one of y_{it} is $max\{\vartheta_{i0}, d_{i0}, max_i\, \omega_i\}$. α_i and μ_i are covariate-specific fixed effects, and Δ_t^{δ} denotes the truncated fractional filter ${\Delta_t}^{\delta} = \sum_{j=0}^{t-1} \pi_j(\delta) L^j$, with L denoting the lag operator, $\Delta = 1 - L$, $\pi_j(\delta) = \frac{\Gamma(j-\delta)}{[\Gamma(j+1)\Gamma(-\delta)]}$ and the scalar δ representing the memory. The values of d_{i0} that determine the asymptotic stationarity or nonstationarity of $y_{it} - \alpha_i - \beta_{i0}' x_{it} - \gamma_i' f_t$ are $d_{i0} < 0.5$ and $d_{i0} \geq 0.5$, respectively. If $d_{i0} < \vartheta_{i0}$, the idiosyncratic components of the observed variables are cointegrated, which can be tested via the t-test $t = (\hat{\vartheta}_{i0} - \hat{d}_{i0})/s.e.(\hat{\vartheta}_{i0} - \hat{d}_{i0})$. Note that it is possible for some countries to be fractionally cointegrated, while others may not be. This generalizes the restriction of either all countries or no country being cointegrated in standard panel cointegration methods.

Averaging the individual slope coefficients obtains the common-correlation mean-group (CCMG) estimate:

$$\hat{\beta}_{CCMG}(\hat{d}, \hat{\vartheta}) = \left[\frac{1}{N} \sum_{i=1}^{N} \hat{\beta}_{i0}(\hat{d}_i, \hat{\vartheta}_i) \right], \tag{5}$$

The corresponding t-test is:

$$t_{CCMG} = \sqrt{N} \frac{(\hat{\beta}_{CCMG} - \beta_0)}{\hat{\Omega}_w(\hat{d}, \hat{\vartheta})^{1/2}}, \tag{6}$$

where the asymptotic variance-covariance matrix estimate is obtained as:

$$\hat{\Omega}_w(\hat{d}, \hat{\vartheta}) = \frac{1}{N-1} \sum_{i=1} \left(\hat{\beta}_{i0}(\hat{d}_i, \hat{\vartheta}_i) - \hat{\beta}_{CCMG}(\hat{d}, \hat{\vartheta}) \right) \times \left(\hat{\beta}_{i0}(\hat{d}, \hat{\vartheta}_i) - \hat{\beta}_{CCMG}(\hat{d}, \hat{\vartheta}) \right)', \tag{7}$$

4. Empirical analysis

4.1. Model, data, and their time series properties

Applying panel data techniques requires homogeneous data for the relevant variables for a group of countries. In that respect, more data are available for developed countries than for developing ones.

The ELGH states that exports explain GDP. While several other variables, such as labor and capital, also explain GDP, our model specification is based on Tang et al. (2015), which considers the following trivariate model of real GDP, real export, and real exchange rate variables:

$$\log \mathrm{GDP}_{\mathrm{it}} = \alpha_i + \beta_1 \log\mathrm{Exports}_{\mathrm{it}} + \beta_2 \log REER_{\mathrm{it}} + \mathrm{u}_{\mathrm{it}}, \quad (8)$$

where the dependent variable is the natural logarithm of real GDP, and the explanatory variables are the natural logarithm of the real exports and the natural logarithm of the real exchange rate (log REER). α_i are country fixed effects and u_{it} is an i.i.d. innovation.

Specifically, we use quarterly data for Q1 of 1995 to Q1 of 2021 for 27 OECD countries for the following variables:

1. Gross domestic product (GDP), seasonally adjusted and in US$ by converting from domestic currencies to US$ through nominal exchange rates, i.e. national currency per US$ at constant 2010 prices (nominal series adjusted by the seasonally adjusted US GDP deflator);
2. Free on board exports of goods in US$ at constant 2010 prices (nominal series adjusted by the seasonally adjusted US GDP deflator);[2]
3. Real effective exchange rates (REER) based on the Consumer Price Index. The three series are collected from OECD Quarterly National Accounts (OECD, 2022).

For the empirical analysis, we focus on the countries that joined the OECD up to 2000, although, due to data availability, we exclude Hungary, Korea, and Turkey. Therefore, the data set contains the following 27 countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovak Republic, Spain, Sweden, Switzerland, UK, and US. We restrict the analysis to the 1995–2021 period since homogeneous exports and GDP data are missing for several countries prior to 1995. Consequently, there is a trade-off between a longer time series and a larger number of countries. Since our focus is on OECD countries—rather than, say, on a few major European countries—we opt for the latter. Moreover, we use a more recent sample period than previous research for developed economies, as we aim to focus on the recent effect of exports on economic growth during the EU integration process and the 3.0 globalization period.

Figures A1–A3 show the series of log GDP, log REER, and log exports, respectively, for the countries included in the analysis (see Appendix). Most series are upward trending and appear to be persistent. Next, we examine their time series characteristics using cross-sectional dependence tests.

First, we analyze whether the individual series are nonstationary. We test the weak cross-dependence of errors using the CD statistic. The null hypothesis of (at most) weak cross-sectional dependence is rejected (CD test = 2.85, p-value = 0.00), and the series are strongly cross-sectionally dependent. For this reason, we employ second-generation unit-root tests. Table 1 summarizes the results of the CADF (Pesaran, 2006) and the CIPS (Pesaran, 2007) unit-root tests allowing for cross-sectional dependence. For most but not all cases, we reject the null hypothesis of all panels containing unit roots at the 10% significance level. Therefore, some panels are stationary. The rejection of the panel unit root hypothesis can be taken as evidence that a statistically significant proportion of the units are stationary (see Pesaran, 2012). However, as mentioned earlier, standard unit root tests are known to

[2] It is worth noting that a standardized quarterly dataset on high-technology exports for OECD countries is not available.

perform poorly if series are fractionally integrated. Consequently, we take these results as evidence for the need for the consequent fractional analysis.

Table 1. Panel unit root tests.

		Log GDP		Log Exports		Log REER	
Test	Deterministic part	Statistic	p-value	Statistic	p-value	Statistic	p-value
CADF	Constant	−2.26	0.00	−2.18	0.01	−2.64	0.00
	Trend	−3.15	0.00	−2.60	0.07	−3.13	0.00
CIPS	Constant	−2.67	0.00	−2.22	0.01	−4.87	0.00
	Trend	−4.97	0.00	−1.48	0.07	−4.82	0.00

Note: CADF: cross-sectional augmented Dickey–Fuller test (Pesaran, 2006); CIPS: cross-sectional IPS test (Pesaran, 2007).

Therefore, before applying the fractional cointegration method in Section 4.2, we estimate the memory parameters of the three series for each country. Table 2 presents the local Whittle memory estimates (Robinson, 1995) using bandwidths 0.6 and 0.7, together with the 5% confidence intervals for the 27 countries and the three series. As can be observed, all series are highly persistent with memory parameters above 0.5. However, most memory point estimates in the series differ from 1, and several confidence intervals do not contain 1, thus motivating the following fractional analysis.

Table 2. Local Whittle memory estimates.

Country	Log GDP		Log exports		Log REER	
	b = 0.6	b = 0.7	b = 0.6	b = 0.7	b = 0.6	b = 0.7
Australia	1.07 [0.82;1.31]	1.1 [0.91;1.29]	1 [0.75;1.24]	1.2 [1;1.39]	0.96 [0.71;1.2]	0.96 [0.76;1.15]
Austria	0.87 [0.63;1.12]	1 [0.8;1.19]	0.91 [0.67;1.16]	1 [0.81;1.19]	0.83 [0.58;1.07]	1.13 [0.94;1.33]
Belgium	0.88 [0.64;1.13]	0.99 [0.79;1.18]	0.88 [0.64;1.13]	0.94 [0.75;1.13]	0.91 [0.67;1.16]	1.18 [0.99;1.37]
Canada	0.89 [0.64;1.13]	0.95 [0.76;1.15]	0.74 [0.5;0.99]	0.89 [0.69;1.08]	0.97 [0.72;1.21]	1.05 [0.85;1.24]
Czech Republic	0.85 [0.6;1.09]	0.97 [0.78;1.17]	0.9 [0.65;1.14]	1.01 [0.82;1.21]	0.87 [0.62;1.11]	0.98 [0.78;1.17]
Denmark	0.93 [0.68;1.17]	1.11 [0.91;1.3]	0.86 [0.61;1.1]	0.94 [0.75;1.14]	0.79 [0.54;1.03]	1.15 [0.96;1.34]
Finland	0.93 [0.68;1.17]	0.77 [0.58;0.96]	0.8 [0.56;1.05]	0.95 [0.76;1.14]	0.66 [0.41;0.9]	0.91 [0.72;1.1]
France	0.72 [0.47;0.96]	0.77 [0.57;0.96]	0.75 [0.51;1]	0.84 [0.65;1.03]	0.91 [0.66;1.15]	1.18 [0.98;1.37]
Germany	0.82 [0.58;1.07]	0.92 [0.73;1.11]	0.88 [0.64;1.13]	0.98 [0.79;1.18]	0.89 [0.65;1.14]	1.18 [0.99;1.37]
Greece	0.67 [0.43;0.92]	0.85 [0.65;1.04]	0.7 [0.45;0.94]	1.06 [0.87;1.25]	1.12 [0.88;1.37]	1.13 [0.94;1.33]
Iceland	0.85 [0.61;1.1]	0.81 [0.62;1.01]	0.71 [0.46;0.95]	0.89 [0.69;1.08]	1.18 [0.93;1.42]	1.43 [1.23;1.62]
Ireland	1.18 [0.93;1.42]	0.9 [0.7;1.09]	1.14 [0.89;1.38]	0.99 [0.8;1.19]	1.06 [0.82;1.31]	1.24 [1.05;1.43]
Italy	0.86 [0.61;1.1]	0.72 [0.53;0.91]	0.79 [0.55;1.04]	0.96 [0.77;1.15]	0.94 [0.69;1.18]	1.15 [0.96;1.34]
Japan	0.83 [0.58;1.07]	0.53 [0.33;0.72]	0.69 [0.44;0.93]	0.91 [0.71;1.1]	1.06 [0.81;1.3]	1.06 [0.87;1.25]
Luxembourg	0.84 [0.6;1.09]	0.87 [0.68;1.06]	1.13 [0.89;1.38]	1.13 [0.94;1.33]	0.94 [0.7;1.19]	1.18 [0.99;1.37]
Mexico	0.85 [0.6;1.09]	0.82 [0.62;1.01]	0.76 [0.52;1.01]	0.85 [0.66;1.05]	1.07 [0.83;1.32]	1 [0.8;1.19]
Netherlands	0.87 [0.63;1.12]	0.94 [0.74;1.13]	0.84 [0.59;1.08]	0.98 [0.78;1.17]	0.9 [0.66;1.15]	1.22 [1.03;1.41]
New Zealand	0.93 [0.68;1.17]	0.79 [0.59;0.98]	0.91 [0.66;1.15]	1.11 [0.92;1.3]	1 [0.76;1.25]	1.1 [0.91;1.3]
Norway	0.95 [0.71;1.2]	0.91 [0.71;1.1]	1 [0.75;1.24]	1.11 [0.92;1.3]	0.77 [0.53;1.02]	0.94 [0.75;1.13]
Poland	0.77 [0.52;1.01]	0.59 [0.39;0.78]	0.92 [0.67;1.16]	1.05 [0.85;1.24]	0.84 [0.6;1.09]	0.95 [0.76;1.14]
Portugal	0.85 [0.61;1.1]	0.81 [0.61;1]	0.67 [0.42;0.91]	0.8 [0.61;0.99]	0.93 [0.69;1.18]	1.12 [0.93;1.31]
Slovak Republic	1.07 [0.82;1.31]	0.83 [0.63;1.02]	1 [0.75;1.24]	1.1 [0.91;1.29]	1.08 [0.83;1.32]	1.19 [1;1.39]
Spain	0.94 [0.69;1.18]	0.96 [0.77;1.15]	0.74 [0.5;0.99]	0.85 [0.65;1.04]	0.99 [0.75;1.24]	1.25 [1.06;1.44]
Sweden	0.83 [0.59;1.08]	0.92 [0.73;1.12]	0.84 [0.59;1.08]	1.09 [0.9;1.28]	0.87 [0.62;1.11]	1.04 [0.85;1.23]
Switzerland	0.96 [0.71;1.2]	0.87 [0.68;1.06]	1.01 [0.77;1.26]	0.97 [0.77;1.16]	1 [0.76;1.25]	1.05 [0.85;1.24]
UK	0.91 [0.66;1.15]	0.93 [0.74;1.13]	0.68 [0.43;0.92]	0.78 [0.59;0.97]	1.19 [0.95;1.44]	1.23 [1.04;1.43]
US	1.06 [0.82;1.31]	0.96 [0.77;1.15]	0.87 [0.62;1.11]	1.04 [0.85;1.23]	0.94 [0.69;1.18]	1.05 [0.85;1.24]

Notes: Whittle estimator (Robinson, 1995) and confidence interval in brackets were implemented in MATLAB using codes by Katsumi Shimotsu.

4.2. Estimation results

Before the cointegration analysis, we check three econometric aspects of the regression model of log GDP on log exports and log REER estimated by OLS: the functional form error test (RESET test), the residual autocorrelation (Ljung-Box or LBQ-statistic), and Granger causality between log GDP and log exports using Dumitrescu and Hurlin (2012)'s non-causality test in heterogeneous panels. Table A1 in the appendix shows these model diagnostics for both models. In particular, from the RESET test in Panel A, the relationship between log GDP, log REER, and log exports might be nonlinear. Panel A also shows the Ljung–Box statistics for ten lags for both models for the 27 countries. In the standard model, all residuals appear to be autocorrelated, providing additional evidence for the fractional model. The fractional model's residuals are more often uncorrelated, yet still in several instances autocorrelated. Finally, Panel B shows the panel data Granger causality test between the GDP and exports and finds that exports Granger causes GDP, but GDP does not Granger cause exports. This provides additional support for the used ELGH specification with log GDP depending on log exports.

Next, we provide the estimation results of both the CS-ECM and the fractionally integrated heterogeneous panel data model (Ergemen and Velasco, 2017) defined by Equations (3) and (4), respectively. First, the results of the (standard) panel cointegration tests considering cross-sectional dependence; second, for each country, the individual estimates and the standard and fractional cointegration results at country level with both methods; and, finally, the mean group estimates. We use the DCCEMG estimates to make these estimates comparable to the CCMG estimates of the fractional integrated heterogeneous panel data method. For the CS-ECM model, we further perform two specification tests. First, we test in the standard CS-ECM model for DCCEMG and pooled estimates (parameters are homogeneous between panels), considering cross-sectional dependence in both cases. Specifically, the Hausman test indicates that the MG model is preferred over the pooled model (Hausman test = 5.21, p-value = 0.35). Second, we evaluate the slope homogeneity using Blomquist and Westerlund (2013)'s test for the null hypothesis of homogeneous slope coefficients. The adjusted Bloomquist and Westerlund's (2013) test of 17.31 (p-value = 0.00) indicates that there is slope heterogeneity in our panel. These results confirm that the DCCEMG estimator is the appropriate choice within the CS-ECM model.

4.2.1. Standard panel cointegration

We report the standard panel cointegration results in Table 3, specifically the test statistics and corresponding p-values of the Pedroni and Westerlund panel cointegration tests. Recall that both tests subtract cross-sectional means to deal with cross-sectional dependence in an ad hoc fashion. All tests allow for time trends, and, as previously mentioned, subtracting cross-sectional means deals with cross-sectional dependence in an ad hoc fashion.

Table 3. Standard panel cointegration tests.

	Statistic	p-value
Panel A. Allowing cross-sectional dependence in an ad-hoc manner		
A.1) Pedroni cointegration test		
Modified Phillips–Perron *t*	−31.30	0.00
Phillips–Perron *t*	−25.39	0.00
Augmented Dickey–Fuller *t*	−27.27	0.00
A.2) Westerlund cointegration test		
Variance ratio: all panels	−3.93	0.00
Variance ratio: some panels	−2.30	0.01
Panel B. Explicitly allowing cross-sectional dependence		
B.1) CS-ECM		
Mean group estimate for the EC speed of adjustment: t-test	−8.99	0.00

Notes: In the Pedroni panel cointegration test, the order is chosen by AIC, and the series can have a time trend and are time demeaned. In the Westerlund cointegration test, the series can have a time trend, are time-demeaned, and the alternative is cointegration in at least some panels. Both tests allow for heterogeneous intercepts and trend coefficients across cross-sections and were performed in Stata using *xtcointtest*. The CS-ECM shows the t-test for the estimated mean group coefficient of the error correction (EC) speed of adjustment in a CS-ECM-ARDL (1,1) model.

Results for all three Pedroni tests—modified Phillips–Perron *t*, Phillips–Perron *t*, and augmented Dickey–Fuller *t*—clearly reject the null hypothesis of no cointegration. Similarly, both versions of the Westerlund test—with homogeneous and heterogeneous alternative hypotheses—find cointegration too. Finally, the t-test of the error correction adjustment speed coefficient (p-value = 0.00) within the CS-ECM framework also indicates that there is a long-run relationship.

4.2.2. Individual estimates and cointegration analyses at the country level

Table 4 presents the estimation results of the CS-ECM and the fractionally integrated heterogeneous panel data model for each country, with $\hat{\beta}_{1i}$ and $\hat{\beta}_{2i}$ being the CS-ECM slope estimates of log exports and log REER, respectively, and $s.e.\left(\hat{\beta}_{1i}\right)$ and $s.e.\left(\hat{\beta}_{2i}\right)$ the corresponding standard errors. For the fractionally integrated heterogeneous panel data model, the slope estimates are $\hat{\beta}_{1i,0}$ and $\hat{\beta}_{2i,0}$, and the standard errors are $s.e.\left(\hat{\beta}_{1i,0}\right)$ and $s.e.\left(\hat{\beta}_{2i,0}\right)$; $\hat{\vartheta}_{i0}$ is the memory estimate of the defactored explanatory variable, and $\hat{d}_{i0}$is the estimated residual integration order. $CI^{90\%}_{\vartheta_{i0}}$ and $CI^{90\%}_{d_{i0}}$ show the respective confidence intervals at the 90% level. Non-trivial cointegration requires that $\hat{d}_{i0} < \hat{\vartheta}_{i0}$, which we test via the t-test $t = (\hat{\vartheta}_{i0} - \hat{d}_{i0})/s.e.(\hat{\vartheta}_{i0} - \hat{d}_{i0})$; these results appear in the last column of Table 4, where bold numbers indicate that the null of no cointegration is rejected.

As mentioned earlier, the fractional model is more general in that it allows for memory parameters different from 1 and for the memory of the cointegration error to be different from 0.

Table 4 indicates in bold the cases where the confidence intervals of the memory estimates do not contain 1 and those of the memory of the cointegration error do not contain 0.

Regarding the individual estimates of the CS-ECM and the fractionally integrated heterogeneous panel model, the following results stand out: for the CS-ECM analysis, there is high variability in terms of both magnitude and significance of the parameters. The coefficients for the log exports are statistically significant at the conventional 5% level for 9 out of 27 countries, varying from 0.47 for Mexico to 10.61 for Germany. Particularly, exports matter for economic growth for the Czech Republic, Denmark, Finland, Germany, Greece, Iceland, Ireland, Japan, and Mexico. The coefficients of the real exchange rate are statistically significant for 6 out of 27 countries, and they are mostly positive, except for Germany.

Table 4. Estimation of the CS-ECM and fractionally integrated heterogeneous panel data model.

Country	CS-ECM					Fractionally integrated heterogeneous panel data model								
	Log exports		Log REER		Error correction speed of adjustment test	Log exports		Log REER		Memory estimates and their confidence intervals				Cointegrat ion test
	$\hat{\beta}_{1i}$	$s.e.(\hat{\beta}_{1i})$	$\hat{\beta}_{2i}$	$s.e.(\hat{\beta}_{2i}$	t-test	$\hat{\beta}_{1i,0}$	$s.e.(\hat{\beta}_{1i,0}$	$\hat{\beta}_{2i,0}$	$s.e.(\hat{\beta}_{2i}$	$\hat{\vartheta}_{i0}$	$CI^{90\%}_{\vartheta_{i0}}$	$\hat{d}_{i0}$	$CI^{90\%}_{d_{i0}}$	t-test
Australia	0.3510	0.7815	0.7830	3.0853	−0.06	0.1301***	0.0361	0.3071***	0.0151	0.9923	[0.598;1.387]	0.146	[0.091;0.201]	3.49
Austria	0.0449	1.7116	0.9571	4.4047	−0.03	0.5123**	0.1993	0.1554***	0.0580	1.1325	[0.882;1.383]	0.03	[−0.138;0.198]	6.18
Belgium	0.7137	1.5400	1.2715	2.1482	−0.08	0.4234***	0.1394	0.2310***	0.0468	1.1824	[0.932;1.433]	0.001	[−0.14;0.142]	6.61
Canada	0.1000	0.5951	0.6005	0.5222	−1.56	0.2902***	0.0395	0.3705***	0.0364	0.9166	[0.558;1.275]	0.622	[0.474;0.77]	1.26
Czech Rep.	1.3098***	0.4533	0.0702	0.3187	−1.00	0.9509***	0.1465	−0.0316	0.0497	1.1663	[0.998;1.335]	0.789	[0.683;0.895]	3.20
Denmark	3.1305**	1.7498	10.364***	3.5424	−0.01	0.9539***	0.1585	0.0759	0.0754	0.8526	[0.541;1.164]	0.021	[−0.277;0.319]	3.21
Finland	0.7514*	0.2761	0.0949	0.7900	−4.36	1.0048***	0.1358	−0.3739	0.1045	0.8233	[0.495;1.152]	0.568	[0.157;0.979]	0.80
France	0.6554	1.1710	2.1598	2.2452	−0.05	1.0177***	0.0821	0.5659***	0.1074	0.7877	[0.527;1.049]	0.75	[0.505;0.995]	0.17
Germany	10.614***	0.9572	−5.464***	1.0402	−0.03	3.508**	1.5224	−0.3791	0.3831	1.1333	[0.975;1.292]	0.001	[−0.777;0.779]	2.35
Greece	1.1900***	0.1586	2.1363*	1.2282	−0.13	0.9380***	0.0520	−0.1169	0.0578	0.9681	[0.137;1.799]	0.617	[0.302;0.933]	0.66
Iceland	1.4454**	0.6681	−0.1395	0.2646	−0.25	0.5841***	0.0462	−0.0836***	0.0246	0.8541	[0.338;1.37]	0.001	[−0.186;0.188]	2.57
Ireland	2.3427**	0.9949	2.7891	2.2295	−0.02	0.7106***	0.1156	−0.0264	0.0855	1.1006	[0.838;1.364]	0.844	[0.549;1.139]	1.08
Italy	−0.4091	0.8514	−0.4661	2.9237	−0.14	0.0159	0.1537	0.3122***	0.0281	1.0136	[0.577;1.45]	0.705	[0.517;0.893]	1.07
Japan	0.5997*	0.3588	0.9200***	0.2939	−2.41	0.3839***	0.1341	1.0885***	0.1494	0.9454	[0.533;1.358]	0.72	[0.262;1.178]	0.60
Luxembourg	−0.0378	0.2859	0.9618	3.1867	−0.07	0.0465*	0.0273	0.0763*	0.0433	1.0724	[0.762;1.383]	0.588	[0.459;0.718]	2.30
Mexico	0.4742*	0.2521	0.8487**	0.3599	−5.14	0.4939***	0.0913	0.5319***	0.0461	1.0574	[0.603;1.511]	0.001	[−0.198;0.2]	3.50
Netherlands	0.0207	0.8532	0.5709	1.4001	−0.52	0.4125***	0.1476	0.1867***	0.0484	1.1032	[0.835;1.371]	0.612	[0.459;0.765]	2.68
New Zealand	0.2498	0.4236	1.0986	0.9532	−0.39	0.0997	0.0848	0.3236***	0.0350	1.0746	[0.619;1.531]	0.637	[0.478;0.796]	1.49
Norway	0.2705	0.2809	1.0600	0.9153	−0.51	0.3037***	0.0500	0.1047***	0.0367	0.9734	[0.5;1.446]	0.717	[0.567;0.867]	0.84

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Country	CS-ECM					Fractionally integrated heterogeneous panel data model								
	Log exports		Log REER		Error correction speed of adjustment test	Log exports		Log REER		Memory estimates and their confidence intervals				Cointegration test
	$\hat{\beta}_{1i}$	$s.e.(\hat{\beta}_{1i})$	$\hat{\beta}_{2i}$	$s.e.(\hat{\beta}_{2i}$	t-test	$\hat{\beta}_{1i,0}$	$s.e.(\hat{\beta}_{1i,0}$	$\hat{\beta}_{2i,0}$	$s.e.(\hat{\beta}_{2i}$	$\hat{\vartheta}_{i0}$	$CI^{90\%}_{\vartheta_{i0}}$	$\hat{d}_{i0}$	$CI^{90\%}_{d_{i0}}$	t-test
Poland	0.0256	0.1178	0.7252**	0.3655	−3.13	0.3472*	0.2094	0.2041***	0.0233	1.0454	[0.519;1.572]	0.515	[0.355;0.675]	1.62
Portugal	0.0583	1.1459	3.0385	4.7706	−0.01	0.3008***	0.0828	0.0417	0.1057	0.9055	[0.691;1.12]	0.866	[0.662;1.07]	0.22
Slovak Rep.	0.2497	0.1721	0.4462	0.3826	−4.79	0.4244***	0.1074	0.2619**	0.1218	1.1497	[1.044;1.256]	0.682	[0.525;0.839]	3.89
Spain	0.0527	1.2960	2.9122	6.4507	−0.01	0.2096**	0.0854	0.2714***	0.0519	1.0607	[0.892;1.229]	0.962	[0.841;1.083]	0.77
Sweden	−0.1129	0.2674	0.9817**	0.3953	−2.81	0.2396	0.1547	0.4264***	0.0666	1.0168	[0.699;1.335]	0.371	[0.103;0.64]	2.50
Switzerland	0.1449	0.6271	0.8537	2.8343	−0.06	0.0719**	0.0324	0.2271***	0.0245	1.0327	[0.491;1.574]	0.003	[−0.091;0.097]	3.07
UK	0.0493	0.3637	1.0140	1.1586	−0.43	−0.0196	0.0467	0.6023***	0.0481	1.0717	[0.66;1.483]	0.001	[−0.206;0.208]	3.82
USA	0.6084	3.7787	1.4148	7.1905	−0.01	0.6086***	0.0791	0.3853***	0.0341	1.1244	[0.66;1.589]	0.001	[−0.142;0.144]	3.69

Notes: Table presents estimates of the slope coefficients of the DCCE in the CS-ECM form and their standard errors. Estimates of the slope coefficients of the memory of the defactored series. Residual integration order (all with standard errors) with the panel fractional cointegration approach. *, **, and *** denote significance at the 10%, 5%, and 1% level, respectively. Bold numbers indicate cases in which the null of no cointegration is rejected. The estimation was performed in STATA using *xtdcce2* for the DCCE and in MATLAB using a modified version (allowing for two regressors) of the original codes provided by E. Ergemen for the panel fractional cointegration.

When comparing the estimates obtained from the two models, we observe that the estimates from the fractionally integrated heterogeneous panel data model are smaller in magnitude but are more often statistically significant. In contrast, estimates from the CS-ECM model often find log exports to be insignificant, and some estimates, such as the 10.61 estimate parameter for German exports, are unreasonably large. The fractional analysis shows that the effect of exports on economic growth is significantly positive in 23 out of 27 cases, with only Italy, New Zealand, Sweden, and the United Kingdom not being statistically significant. Additionally, the real exchange rate is significant in 22 out of 27 cases and mostly positive, except for Finland, Greece, and Iceland. This is expected, as an increase in REER raises export competitiveness, subsequently boosting export volume and generating economic growth.

At the country level, the fractional approach provides slightly stronger evidence for cointegration than standard methods. Using the CS-ECM model, cointegration is only found for 6 out of the 27 countries (Finland, Japan, Mexico, Poland, Slovak Republic, and Sweden), while the fractionally integrated heterogeneous panel data model finds evidence of (fractional) cointegration for 15 out of the 27 countries (Australia, Austria, Belgium, Czech Republic, Denmark, Germany, Iceland, Luxembourg, Mexico, Netherlands, Slovak Republic, Sweden, Switzerland, the United Kingdom and the United States). Interestingly, evidence of cointegration is found only for Mexico, the Slovak Republic, and Sweden after applying both standard and fractional cointegration analysis. As predicted by the endogenous growth models, these countries present a large share of high- and medium-technology exports (exceeding 60% of total manufactured exports). Indeed, 12 out of the 15 countries for which evidence of fractional cointegration is found present a share of high- and medium-technology exports larger than 50%.[3]

Recall that while the standard panel cointegration analysis (in Table 3) either finds cointegration for all or none, the cointegration analysis at the country level (in Table 4) is more informative since it allows for cointegration for a subset of countries. However, as mentioned before, results from standard methods might not be that reliable when dealing with fractionally integrated data, and therefore, the findings of the standard methods may be misleading. Fractional analysis provides empirical support for ELGH, although the magnitude of the effect is more conservative than previous findings.

4.2.3. Mean group (MG) estimates

Table 5 presents the mean group estimates obtained as averages of the individual estimates using both the CS-ECM and the fractionally integrated heterogeneous panel data model. For the CS-ECM, the DCCEMG estimates are significantly positive at a 1% significance level, specifically 0.92 for log exports and 1.18 for log REER. In contrast, for the fractionally integrated heterogeneous panel data model, the CCMG estimate for log exports is 0.55, and for log REER it is 0.21, both positive and statistically significant at the 1% significance level. Once again, the DCCEMG estimates of the CS-ECM are considerably larger than those from the fractional model. This result is driven by some large individual estimates obtained using the standard method. Therefore, it is possible that the CS-ECM results overestimate the effect of REER and exports on GDP since they do not allow for more general persistence.

[3] According to data from the World Development Indicators (WDI, 2023) for the average period 2015–2021.

Table 5. MG estimation results.

	CS-ECM		Fractionally integrated heterogeneous panel data model	
	Coefficient	p-value	Coefficient	p-value
Log exports	0.92	0.02	0.55	0.00
Log REER	1.19	0.01	0.21	0.00
R-squared (MG)	0.78			
CD statistic	2.91	0.00		

Notes: R-squared (MG) is the mean group R^2. CD statistic is the Pesaran (2015) test for weak cross-sectional dependence. A heterogeneous constant is partialled out.

In any case, we obtain evidence in favor of the ELGH with the export elasticity being smaller than unity, indicating that an increase in exports leads to a less than proportional increase in GDP. However, considering that developed economies grow at a lower rate than developing ones, a real GDP increase of 0.55% (due to a 1% increase in exports) is noteworthy.

A general conclusion from this section is that the fractionally integrated heterogeneous panel data model provides more conclusive and reasonable results than traditional methods. There is evidence in favor of the ELGH for most OECD countries, particularly for those specializing in exporting high- and medium-technology products. Seok and Moon (2021) pointed out that the ELGH mainly holds for European Union (EU) countries since they have better access to a common market. In our analysis, by applying fractional methods, we did not find a statistically significant relationship between exports and economic growth for non-Euro countries such as New Zealand, the United Kingdom, and Sweden. Italy is the exception, but it is one of the Eurozone countries that exports less to the rest of the members of the common market (around 50%).

4.3. Robustness checks

In this section, we perform two robustness checks: first with respect to the time period and second with respect to subgroups of the countries. Table 6, panel A shows results for the sample split into before and after the global financial crisis; Panel B compares results for cointegrated and not-cointegrated countries.

Table 6. MG estimation results: Robustness.

	CS-ECM		Fractionally integrated heterogeneous panel data model	
	Coefficient	p-value	Coefficient	p-value
Panel A: Global financial crisis				
1) Period before crisis: 1995–2007Q3				
Log exports	0.90	0.05	0.45	0.00
Log REER	0.14	0.87	0.27	0.00
R-squared (MG)	0.91			
CD statistic	2.65	0.01		
2) Period after crisis: 2007Q4–2021				

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	CS-ECM		Fractionally integrated heterogeneous panel data model	
	Coefficient	p-value	Coefficient	p-value
Log exports	0.53	0.00	0.52	0.00
Log REER	1.37	0.01	0.35	0.00
R-squared (MG)	0.87			
CD statistic	-0.53	0.60		
Panel B: Cointegrated vs. not-cointegrated countries				
1) Cointegrated countries				
Log exports	0.44	0.02	0.44	0.00
Log REER	0.70	0.00	0.23	0.00
R-squared (MG)	0.91			
CD statistic	-6.45	0.00		
2) Not-cointegrated countries				
Log exports	0.84	0.01	0.52	0.00
Log REER	1.26	0.02	0.36	0.00
R-squared (MG)	0.79			
CD statistic	2.68	0.01		

Notes: R-squared (MG) is the mean group R^2. CD statistic is the Pesaran (2015) test for weak cross-sectional dependence. A heterogeneous constant is partialled out.

4.3.1. Global financial crisis

First, as a robustness check and to investigate the results' sensitivity to major shocks, we separate the sample into the sample before and the one after the global financial crisis. In particular, we repeat the standard and fractional analyses for the periods 1995–2007Q3 and 2007Q4–2021, respectively. Table 6 (Panel A) displays the corresponding mean-group estimates. For the standard model, the DCCEMG estimates vary between these two periods; in particular, the DCCEMG estimate of log REER is 0.14 and not significant before the crisis and 1.37 after the crisis. The DCCEMG estimate of the log exports is 0.90 before and 0.52 after the crisis. For the fractional model, on the other hand, the CCMG estimates are rather comparable for the two sub-periods and the whole period. In particular, for the period before the financial crisis, the CCMG estimate for log REER is 0.27, and for log exports it is 0.45. For the period after the financial crisis, the CCMG estimates are 0.35 for log REER and 0.52 for log exports. These findings again illustrate the quite variable estimation with the standard model.

We further perform rolling window estimation for the fractional model with a window length of 50 periods, corresponding to the time series dimension prior to the financial crisis. Figure 1 displays the corresponding CCMG estimates for log exports and log REER, which show a comparable variation as the CCMG estimates in Table 6 (Panel A).

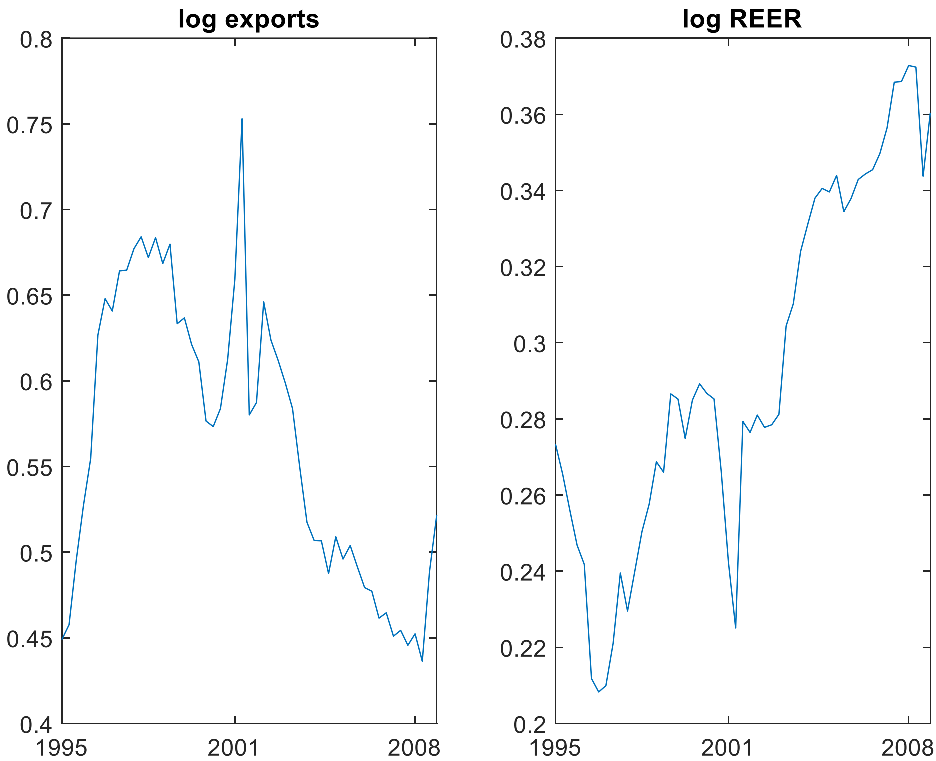

Figure 1. Rolling window CCMG estimates from the fractional model. Notes: Rolling window with window length 50. X-axis denotes the start year of 50 quarter period used.

4.3.2. Subgroup analysis

As mentioned before, with the standard method, we find cointegration for the following countries: Finland, Japan, Mexico, Poland, Slovak Republic, and Sweden. With the fractional method, on the other hand, we find fractional cointegration for the following countries: Australia, Austria, Belgium, Czech Republic, Denmark, Germany, Iceland, Luxembourg, Mexico, Netherlands, Slovak Republic, Sweden, Switzerland, the United Kingdom, and the United States. In this section, we first repeat the analysis for this group of (fractionally) cointegrated countries and second for the remaining countries. Table 6 (Panel B) shows the mean group estimates for the two groups for the standard method on the left and the fractional method on the right. For the former group of cointegrated countries, the DCCEMG estimates from the standard model are considerably smaller than those of the not-cointegrated countries (0.44 vs .0.84 for log exports and 0.70 vs. 1.26 for log REER). For the fractional method, the CCMG estimate of log REER is 0.233, and for log exports, it is 0.442. For the latter group of not cointegrated, it is 0.196 for log REER and 0.622 for log exports. Both exercises hint at more robust estimates from the fractional model, providing additional evidence for this model.

5. Discussion

The literature on the ELGH has produced mixed results depending on the database and methodology used (see the literature review section). Previous research on the ELGH mostly applied standard cointegration techniques to explore its validity for developing countries (e.g., Bahmani-Oskooee et al., 2005; Hagemejer and Mućk, 2019; among others). However, we depart from the standard empirical strategy and employ fractional cointegration techniques to analyze the ELGH. Hence, we do not impose overly restrictive assumptions by requiring memory parameters to be fixed at 0, 1, or 2, providing greater flexibility and reducing the risk of model misspecification (Hualde and Nielsen, 2023).

This paper is the first to apply fractional heterogeneous panel data techniques to investigate whether exports promote economic growth. It does so for a set of 27 OECD countries over the 1995–2021 period. This methodology overcomes certain limitations of standard cointegration methods by allowing for a more general persistence and cointegration relationship, incorporating individual and interactive fixed effects, and allowing for cross-sectional dependence. The study presents estimates derived from both standard and fractional integration and cointegration analyses and subsequently compares the obtained results.

Our empirical analysis is based on different panel cointegration tests used in ELGH literature. Particularly, we have employed standard panel cointegration tests, such as Pedroni's cointegration tests, and tests recently proposed in econometric literature, such as the CS-ECM model (derived from the CS-ARDL) and the fractionally integrated heterogeneous panel data model by Ergemen and Velasco (2017). Although standard panel cointegration methods show evidence of cointegration in our database, they are, however, restrictive insofar as they test for cointegration for all analyzed countries together. On the other hand, estimates based on standard methods considering heterogeneous panel data may also be misleading and should be interpreted with caution because of the existence of fractional integration. Our findings both confirm and extend previous literature that relies on standard cointegration techniques in panel data models. Studies such as Bahmani-Oskooee et al. (2005), Parida and Sahoo (2007), and Aslan and Topcu (2018), which used Pedroni's method, have found a significant long-run relationship between exports and economic growth, thereby supporting the ELGH across various regional contexts. Moreover, research employing a heterogeneous panel data model, such as Pesaran's (2006) CCE estimator (Dreger and Herzer, 2013) and DCCE methods based on Chudik and Pesaran (2015) (Hagemejer and Mućk, 2019; Nguyen and Örsal, 2020), has also found evidence of cointegration between exports and economic growth.

It is important to note, however, that the time series in our analysis are fractionally integrated. Consequently, the fractionally integrated heterogeneous panel data model may provide more reliable results by reducing the risk of misspecification (see Hualde and Nielsen, 2021). Our fractionally integrated model yields three key insights. First, at the individual country level, estimates generally support the ELGH, with coefficients for log exports and log real effective exchange rates (REER) being predominantly positive and statistically significant. In particular, fractional cointegration methods identify cointegration in 15 out of 27 countries, compared to only 6 countries when using standard methods. Second, these fractional techniques yield a more conservative estimate of the impact of trade on economic growth. Third, mean group estimates differ in magnitude between the CS-ECM (DCCEMG) and the fractionally integrated panel model (CCMG), with notably lower effects for exports and REER in the latter.

The policy implications of these results are significant and provide a robust framework for informing export promotion policies in developed economies. Our analysis suggests that conclusions based on standard cointegration techniques may be misleading, as they can overlook important evidence of the ELGH that is detectable with fractional methods. This research confirms that exports stimulate economic growth in high-income countries. Accordingly, policymakers in developed nations should consider implementing measures that promote exports, such as providing incentives, subsidies, and targeted support to export-oriented industries. Given that cointegration is most evident in countries with a high share of high- and medium-technology exports, it is advisable for these nations to focus on increasing exports of value-added products and to facilitate investment in research and development (R&D). Such policies would foster innovation and technological advancements, particularly in high-tech sectors with strong export potential.

6. Conclusions

Our study shows that employing a fractionally integrated panel data model can yield more robust and reliable results compared to conventional methods. If the export-led growth hypothesis is stable, with exports consistently Granger-causing economic growth, policies promoting export expansion will be highly effective in fostering growth. However, if the relationship is unstable, exports may not serve as a reliable driver of long-term economic growth, making the stability of this causal link crucial for assessing the effectiveness of export-driven macroeconomic policies. This has three important policy implications. First, the gradual transmission of shocks to international trade flows suggests that policymakers should adopt long-term strategies rather than expecting immediate economic benefits from trade liberalization or export promotion. Second, given the potential role of high-technology exports in sustaining growth, governments should prioritize policies that enhance technological innovation, support research and development, and facilitate the transition toward higher-value-added industries. Finally, addressing potential structural shifts and nonlinear dynamics in trade-growth relationships requires a more adaptive policy framework, incorporating flexible trade policies that can respond to changing global economic conditions. By improving the methodological approach of the ELGH analysis and highlighting the significance of gradual trade dynamics, our research provides valuable insights for policymakers seeking to enhance the effectiveness of export-oriented growth strategies in developed economies.

Our research encounters several methodological limitations. During the sample period, significant structural shifts may have occurred, potentially leading to parameter instability. However, since no results for structural breaks are available for the used fractional methods, we assume model stability. Nevertheless, our robustness checks partially address this issue. Additionally, while the standard model allows for the inclusion of a lagged dependent variable as a regressor, this feature is not available in the corresponding fractional model. Furthermore, asymmetry may be an important factor, and hidden panel cointegration could potentially capture the resulting nonlinear cointegration relationships. However, theoretical insights on this aspect remain scarce, particularly within the fractional framework. Another key limitation is the reliance on high-technology exports as a critical driver of economic growth in developed countries. Many arguments supporting the ELGH for high-income economies are based on their higher share of technology-intensive exports. However, the lack of a standardized quarterly dataset on high-technology exports for OECD countries prevents us from conducting a more granular analysis of this relationship.

An extension of the current research could investigate the validity of ELGH using fractional methodology for developing nations. Finally, a more comprehensive analysis of different clusters, beyond cointegrated and non-cointegrated countries, could further enhance the justification of our findings.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

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Author Contributions

All three authors contributed equally to writing the research. María Santana-Gallego was responsible for the conceptualization of the study and the compilation of the database. Jorge V. Pérez-Rodríguez and Heiko Rachinger primarily developed and applied the methodology. All authors contributed equally to the original draft preparation, as well as to the validation, review, editing, and supervision of the final version of the manuscript. All authors have read and approved the final version of the manuscript for publication.

Conflict of interest

All authors declare no conflicts of interest in this paper.

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