Exports and Growth: Granger Causality Analysis on OECD Countries With a Panel Data Test and Bootstrap Critical Values[*]

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Abstract

This paper investigates the possibility of Granger causality between the logarithms of real exports and real GDP in twenty-four OECD countries from 1960 through 1997. A new panel-data approach is used which is based on SUR systems and Wald tests with country specific bootstrap critical values. Two different models have been used. A bivariate (*GDP-exports*) model and a trivariate (*GDP-exports-openness*) model, both without and with a linear time trend. In each case the analysis focussed on direct, one-period-ahead causality between exports and GDP. The results indicate one-way causality from exports to GDP in Belgium, Denmark, Iceland, Ireland, Italy, New Zealand, Spain and Sweden, one-way causality from GDP to exports in Austria, France, Greece, Japan, Mexico, Norway and Portugal, two-way causality between exports and growth in Canada, Finland and the Netherlands, while in the case of Australia, Korea, Luxembourg, Switzerland, the UK and the USA there are no evidence of causality in either direction.

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[*] This work was started in the second half of 2000 while the author was visiting the Department of Economics of the Central European University, Budapest. Of course, the usual caveat applies for responsibility. Comments are fully appreciated. Email: *Laszlo.Konya@vu.edu.au*.

I. Introduction

Since the early 1960s policy makers and scholars alike, have shown great interest in the possible relationship between exports and economic growth. The motivation is clear. Should a country promote exports to speed up economic growth or should it primarily focus on economic growth, which in turn will generate exports?

There are basically four propositions. According to the so-called export-led growth (ELG) hypothesis export activity leads economic growth. Trade theory provides several plausible explanations in favour of this idea. For example, export promotion directly encourages the production of goods for exports. This may lead to further specialisation in order to exploit economies of scale and the nation's comparative advantages. Moreover, increased exports may permit the imports of high quality products and technologies, which in turn may have a positive impact on technological change, labour productivity, capital efficiency and, eventually, on the nation's production. The second proposition, the growth-driven exports (GDE) hypothesis, postulates a reverse relationship. It is based on the idea that economic growth itself induces trade flows. It can also create comparative advantages in certain areas leading to further specialisation and facilitating exports. These two approaches certainly do not exclude each other; therefore the third notion is a feedback relationship between exports and economic growth. Finally, it is also possible, though unlikely, that there is no relationship or just a simple contemporaneous, maybe spurious relationship, between these two variables.

There is a vast empirical literature on this issue. The most recent and most comprehensive survey of this literature is due to Giles and Williams (2000a) who review more than one hundred and fifty export-growth applied papers published between 1963 and 1999. These papers fall into three groups. The first group of studies is based on cross-country rank correlation coefficients, the second applies cross-sectional regression analysis, and the third uses time series techniques on a country-by-country basis. Two thirds of the papers belong to this third group, and more than seventy of these are based on the concept of Granger causality and on various tests for it.

There are forty-five studies surveyed by Giles and Williams (2000a), which test for Granger causality between exports and economic growth in one or several OECD countries. Most of them consider only one or two countries, but the most extensive studies, Afxentiou and Serletis (1991), Pomponio (1996) and Riezman, Summers and Whiteman (1996), investigate sixteen, fifteen and twenty-eight countries, respectively. The conclusions are fairly mixed and often contradicting. For example, within a bivariate framework, in the case of the USA Afxentiou and Serletis (1991) find both the ELG and GDE hypotheses reasonable, while Pomponio (1996) finds support only for ELG and Riezman et al. (1996) for none. In the case of Canada, Afxentiou and Serletis (1991) and Pomponio (1996) report GDE, but Riezman et al. (1996) reject both ELG and GDE. For Australia Riezman et al. (1996) reach the conclusion of GDE, but the main outcome of Pomponio (1996) is that neither ELG nor GDE is a justifiable proposition. For the UK Riezman et al. (1996) again conclude GDE, but Afxentiou and Serletis (1991) reject both hypotheses.

Contradictions like these might be explained by several reasons. Firstly, they are partly due to the fact that different studies on a given country hardly ever use the same methods and data. This makes comparisons difficult since it is virtually impossible to tell whether the deviations in the conclusions are mainly accounted for the different methods or for the various variable selections, time frames and frequencies. Secondly, some of the studies surveyed by Giles and Williams (2000a) can also be challenged on the ground that, prior to testing for causality, the data had not been analysed thoroughly.[1] In essence, testing for Granger causality between variables in all possible directions is a relatively simple matter. It is a series of Wald, Lagrange multiplier or likelihood ratio tests for linear restrictions on the parameters of a finite-order vector autoregressive (VAR) model in order to establish whether the lags of a given variable enter into the equation for another variable. However, the proper specification of the model and the sampling distributions of the test statistics depend on the uni- and multivariate properties of the data. This makes data analysis an essential part of causality studies, requiring a sequential pretesting procedure.[2] Thirdly, despite all efforts, the preliminary unit-root and cointegration test results are often ambiguous because these tests in general suffer from low power and are sensitive to the selection of the lag order and to the presence of deterministic components or auxiliary variables in the VAR model. When the unit-root and cointegration test results are uncertain or contradicting, the proper decision is to study causality under all reasonable assumptions and see whether the final conclusion regarding causality is sensitive to these assumptions. If the final conclusion is robust, the researcher can be confident of it, otherwise it is fair to admit that the sample information and/or the methods applied are not sufficient to reach an unambiguous outcome.[3]

This strategy was followed in Kónya (2000), which studied the possibility of Granger causality between the logarithms of real exports and GDP in twenty-five OECD countries from 1960 through 1998. In order to re-enforce the results two complementary strategies were applied. On the one hand, depending on the time series properties of the data, causality was tested with Wald tests within VAR models in levels and/or in first-differences. On the other hand, the modified Wald (MWald) procedure of Toda and Yamamoto (1995), which is valid for integrated and cointegrated processes of an arbitrary order, was also used.[4] All things considered, Kónya (2000) concluded that there is no causality between exports and growth in Hungary, France, Greece, Luxembourg and the Netherlands, exports cause growth in Australia, Austria, Belgium, Denmark, Iceland, Ireland, Spain and Switzerland, growth causes exports in Canada, Finland, Japan and Korea, and there is two-way causality in Sweden and in the UK. However, in the case of Italy, Mexico, New Zealand, Norway, Portugal and the USA the results were too controversial to make a simple choice.

[1] About the most important aspects and problems of the time series causality studies see Giles and Williams (2000a, pp. 267-277) and (2000b).

[2] The Monte Carlo study of Giles and Mirza (1999) demonstrates the pitfalls of pretesting and that how crucial it can be to the Granger causality test results.

[3] Studies that do not experiment with alternative test procedures and model specifications, obviously do not face this problem, they simply ignore it.

[4] Though MWald is very appealing, its potential disadvantage is that it is based on an augmented VAR system in levels, and in relatively small samples the extra, redundant regressors may lead to costly losses in power and efficiency. Moreover, it is not absolutely free of pretesting, the researcher still has to find the maximal order of integration to occur in the system.

The current paper is a further step in this direction. Granger causality between the logarithms of real exports and GDP is tested with Wald tests in seemingly unrelated regressions (SUR), using country specific bootstrap critical values.[5] This approach has two advantages. On the one hand, it does not require joint hypotheses for all panel members, but allows for contemporaneous correlation across them, making possible to exploit the extra information provided by the panel data setting. On the other hand, apart from the lag structure, there is no need for pretesting.

Our focus is on bivariate systems. Yet, we consider a trivariate specification, as well. In this latter model the third economic variable is the logarithm of openness, defined as the proportion of the total real trade flows to GDP. However, this variable is treated as an auxiliary variable, so the analysis can handle only direct, one-period-ahead causality between exports and economic growth, disregarding the possibility of indirect causality at longer time horizons.

Our research suggests one-way causality from exports to GDP in Belgium, Denmark, Iceland, Ireland, Italy, New Zealand, Spain and Sweden, one-way causality from GDP to exports in Austria, France, Greece, Japan, Mexico, Norway and Portugal, two-way causality between exports and growth in Canada, Finland and the Netherlands, while in the case of Australia, Korea, Luxembourg, Switzerland, the UK and the USA there are no evidence of causality between these variables.

The rest of this paper unfolds as follows. The technical issues, including the data, the model, the estimation method and the test procedure, are discussed in Section II. The empirical results relating to model estimation and Granger causality are presented in Section III. The concluding remarks are in Section IV. Finally, the model is detailed in the Appendix.

II. Technical Issues

Data

To make reasonable comparisons possible, apart from some minor changes, the data set used in this study is the same than in Kónya (2000). It is from *EconData, World Bank World Tables*, and comprises annual measures on 24 OECD countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Greece, Iceland, Ireland, Italy, Japan, Korea Rep., Luxembourg, Mexico, Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, UK and USA. The sample period is 1960-1997 for all countries.[6]

The variables are

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[5] Originally Breuer, McNown and Wallace (1999) recommended a similar approach for unit-root testing, and that test was compared to other panel data unit root tests in Kónya (2001).

[6] At the moment the OECD has 29 members. However, only those countries were considered in Kónya (2000) for which in early 2000 the World Bank's *World Tables* published at least twenty observations for each variable. Consequently, four countries, the Czech Republic, Germany, Poland and Turkey were disregarded and the sample period was 1960-1997 for all countries, except Hungary (1970-1998), Korea and Mexico (1960-1998). In the current study, in order to have a balanced data set, we also disregard Hungary, and for the remaining 24 countries we use the common sample period of 1960-1997.

	GDP:	GDP in 1995 $US (million);
	EXP:	Exports of goods and services in 1995 $US (million);
	IMP:	Imports of goods and services in 1995 $US (million)[7];
and	OPEN:	Openness, defined as (Exports+Imports)/GDP.

GDP, EXP and OPEN have been transformed in natural logarithms and the resulting variables are denoted as LNGDP, LNEXP and LNOPEN. Our purpose is to test for Granger causality between LNGDP and LNEXP within a bivariate framework, but later we augment the information set with LNOPEN.

Model

In Kónya (2000) the possibility of Granger causality between LNGDP and LNEXP was studied for each country individually within the following bivariate VAR model:

$$\begin{aligned} y_{i,t} &= \alpha_{1,i} + \sum_{l=1}^{mly_i} \beta_{1,i,l}\, y_{i,t-l} + \sum_{l=1}^{mlx_i} \gamma_{1,i,l}\, x_{i,t-l} + \varepsilon_{1,i,t} \\ x_{i,t} &= \alpha_{2,i} + \sum_{l=1}^{mly_i} \beta_{2,i,l}\, y_{i,t-l} + \sum_{l=1}^{mlx_i} \gamma_{2,i,l}\, x_{i,t-l} + \varepsilon_{2,i,t} \end{aligned} \qquad (1)$$

where index i refers to the country ($i = 1,..., N$), t to the time period ($t = 1,..., T$) and l to the lag. $\epsilon_{1,i,t}$, $\epsilon_{2,i,t}$ are supposed to be white-noise errors (i.e. they have zero means, constant variances and are individually serially uncorrelated) that may be correlated for a given country, but not across countries.[8] Moreover, it is assumed that y_t and x_t are stationary or cointegrated so, depending on the time-series properties of the data, they denote the level or the first difference of LNGDP and LNEXP, respectively.[9]

With respect to this system, in country i there is one-way Granger causality running from X to Y if in the first equation not all γ_{1i}'s are zero but in the second all β_{2i}'s are zero, there is one-way Granger causality from Y to X if in the first equation all γ_{1i}'s are zero but in the second not all β_{2i}'s are zero, there is two-way Granger causality between Y and X if neither all β_{2i}'s nor all γ_{1i}'s are zero, and there is no Granger causality between Y and X if all β_{2i}'s and γ_{1i}'s are zero.[10]

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[7] The original trade figures extracted from the World Bank's *World Tables* are nominal exports and imports given in $US, and index numbers (1995=100) calculated from real exports and imports in 1995 local currencies. In order to obtain real trade data in 1995 $US, the index series have been multiplied by the 1995 trade figures given in 1995 $US (million).

[8] $\varepsilon_{1,i,t}$ and $\varepsilon_{2,i,t}$ are correlated when there is feedback between X and Y, i.e. in the non-reduced form of (1), called structural VAR, y_t depends on x_t and/or x_t depends on y_t. For a proof see Enders (1995, pp. 294-296).

[9] As the analysis of Kónya (2001) showed, for each country LNGDP and LNEXP are either stationary or integrated of order 1.

[10] This definition implies causality for one period ahead. This concept has been generalised by Dufour and Renault (1998) to causality h periods ahead, and to causality up to horizon h, where h is a positive integer.

As regards the estimation of (1), since for a given country both equations contain the same predetermined, i.e. lagged exogenous and endogenous variables, the OLS estimates of the parameters are consistent and asymptotically efficient.[11] This suggests, that the $2N$ equations involved in the analysis can be estimated one-by-one, in any preferred order. For example, we can divide the equations into two groups, the first one consisting of the equations on Y and the second of the equations on X. In other words, instead of the N VAR systems like (1), we can consider the following two sets of equations:

$$\left.\begin{aligned}
y_{1,t} &= \alpha_{1,1} + \sum_{l=1}^{mly_1} \beta_{1,1,l} y_{1,t-l} + \sum_{l=1}^{mlx_1} \gamma_{1,1,l} x_{1,t-l} + \varepsilon_{1,1,t} \\
y_{2,t} &= \alpha_{1,2} + \sum_{l=1}^{mly_1} \beta_{1,2,l} y_{2,t-l} + \sum_{l=1}^{mlx_1} \gamma_{1,2,l} x_{2,t-l} + \varepsilon_{1,2,t} \\
&\vdots \\
y_{N,t} &= \alpha_{1,N} + \sum_{l=1}^{mly_1} \beta_{1,N,l} y_{N,t-l} + \sum_{l=1}^{mlx_1} \gamma_{1,N,l} x_{N,t-l} + \varepsilon_{1,N,t}
\end{aligned}\right\} \qquad (2a)$$

and

$$\left.\begin{aligned}
x_{1,t} &= \alpha_{2,1} + \sum_{l=1}^{mly_2} \beta_{2,1,l} y_{1,t-l} + \sum_{l=1}^{mlx_2} \gamma_{2,1,l} x_{1,t-l} + \varepsilon_{2,1,t} \\
x_{2,t} &= \alpha_{2,2} + \sum_{l=1}^{mly_2} \beta_{2,2,l} y_{2,t-l} + \sum_{l=1}^{mlx_2} \gamma_{2,2,l} x_{2,t-l} + \varepsilon_{2,2,t} \\
&\vdots \\
x_{N,t} &= \alpha_{2,N} + \sum_{l=1}^{mly_2} \beta_{2,N,l} y_{N,t-l} + \sum_{l=1}^{mlx_2} \gamma_{2,N,l} x_{N,t-l} + \varepsilon_{2,N,t}
\end{aligned}\right\} \qquad (2b)$$

Compared to (1), this alternative specification has two distinctive features. Firstly, each equation in (2a), and also in (2b), has different predetermined variables. The only possible link among individual regressions is contemporaneous correlation within the systems.[12] Hence, these sets of equations are not VAR but SUR systems.[13] Secondly, since we shall use country specific bootstrap critical values, y_t and x_t are not supposed to be stationary, they denote the levels of LNGDP and LNEXP, irrespectively of the time-series properties of these variables.

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[11] As Enders (1995, p. 301) points out, in spite of the possible correlation of the error terms across the two equations, each equation can be estimated with OLS. However, if the lag lengths are allowed to be different in the equations, i.e. in the case of a near-VAR, then SUR is more efficient than OLS.

[12] Due to the strong economic ties and interrelationships among the OECD countries, contemporaneous correlation is very likely in these systems. For example, if the GDPs of countries i and j ($i \neq j$) are correlated, then there is correlation between $\varepsilon_{i,t}$ and $\varepsilon_{j,t}$ in (2a). Similarly, if the exports of countries i^* and j^* ($i^* \neq j^*$) are correlated, then there is correlation between $\varepsilon_{i^*,t}$ and $\varepsilon_{j^*,t}$ ($i^* \neq j^*$) in (2b).

[13] About the seemingly unrelated regressions model see, e.g. Greene (1993), Section 17.2.

With respect to these SUR systems, in country i there is one-way Granger causality running from X to Y if in (2a) not all γ_{1i} 's are zero but in (2b) all β_{2i} 's are zero, there is one-way Granger causality from Y to X if in (2a) all γ_{1i} 's are zero but in (2b) not all β_{2i} 's are zero, there is two-way Granger causality between Y and X if neither all β_{2i} 's nor all γ_{1i} 's are zero, and there is no Granger causality between Y and X if all β_{2i} 's and γ_{1i} 's are zero.

In order to include a third variable into our analysis, namely the logarithm of openness, we shall also consider the following augmented variants of (2a) and (2b)

$$\left.\begin{aligned}
y_{1,t} &= \alpha_{1,1} + \sum_{l=1}^{mly_1} \beta_{1,1,l}\, y_{1,t-l} + \sum_{l=1}^{mlx_1} \gamma_{1,1,l}\, x_{1,t-l} + \sum_{l=1}^{mlz_1} \eta_{1,1,l}\, z_{1,t-l} + \varepsilon_{1,1,t} \\
y_{2,t} &= \alpha_{1,2} + \sum_{l=1}^{mly_1} \beta_{1,2,l}\, y_{2,t-l} + \sum_{l=1}^{mlx_1} \gamma_{1,2,l}\, x_{2,t-l} + \sum_{l=1}^{mlz_1} \eta_{1,2,l}\, z_{2,t-l} + \varepsilon_{1,2,t} \\
&\vdots \\
y_{N,t} &= \alpha_{1,N} + \sum_{l=1}^{mly_1} \beta_{1,N,l}\, y_{N,t-l} + \sum_{l=1}^{mlx_1} \gamma_{1,N,l}\, x_{N,t-l} + \sum_{l=1}^{mlz_1} \eta_{1,N,l}\, z_{N,t-l} + \varepsilon_{1,N,t}
\end{aligned}\right\} \qquad (3a)$$

and

$$\left.\begin{aligned}
x_{1,t} &= \alpha_{2,1} + \sum_{l=1}^{mly_2} \beta_{2,1,l}\, y_{1,t-l} + \sum_{l=1}^{mlx_2} \gamma_{2,1,l}\, x_{1,t-l} + \sum_{l=1}^{mlz_2} \eta_{2,1,l}\, z_{1,t-l} + \varepsilon_{2,1,t} \\
x_{2,t} &= \alpha_{2,2} + \sum_{l=1}^{mly_2} \beta_{2,2,l}\, y_{2,t-l} + \sum_{l=1}^{mlx_2} \gamma_{2,2,l}\, x_{2,t-l} + \sum_{l=1}^{mlz_2} \eta_{2,2,l}\, z_{2,t-l} + \varepsilon_{2,2,t} \\
&\vdots \\
x_{N,t} &= \alpha_{2,N} + \sum_{l=1}^{mly_2} \beta_{2,N,l}\, y_{N,t-l} + \sum_{l=1}^{mlx_2} \gamma_{2,N,l}\, x_{N,t-l} + \sum_{l=1}^{mlz_2} \eta_{2,N,l}\, z_{N,t-l} + \varepsilon_{2,N,t}
\end{aligned}\right\} \qquad (3b)$$

where $z_{i,t-l}$ ($l = 1, ..., mlz_i$) denote the lagged values of LNOPEN. However, in these trivariate systems our focus will remain on the bivariate, one-period-ahead relationship between LNGDP and LNEXP, so we shall not study the possibility of causality at longer horizons, nor the possibility of two variables jointly causing the third one. In other words, LNOPEN is treated as an auxiliary variable; it will not be directly involved in the Granger causality analysis.

In the rest of this chapter we discuss how to estimate the bivariate systems, (2a) and (2b), and how to test for Granger causality within these systems. Nevertheless, both procedures apply to the (3a) and (3b) trivariate systems as well.

Estimation Method

The appropriate method to estimate (2a) and (2b) depends on the properties of the error terms. If there is no contemporaneous correlation across countries, then each equation is a classical regression. Consequently, the equations can be estimated one-by-one with OLS and the OLS estimators of the parameters are the best linear unbiased estimators. On the other hand, in the presence of contemporaneous correlation across countries the OLS estimators are not efficient because they fail to utilise this extra information. In order to obtain more efficient estimators, the equations in (2a), and also in (2b), must be stacked[14] and the two stacked equation can be estimated individually with the feasible generalised least squares or maximum likelihood methods. In this study we use the SUR estimator proposed by Zellner (1962).[15]

Prior to estimation, we have to specify the number of lags. This is a crucial step because the causality test results may depend critically on the lag structure. In general, both too few and too many lags may cause problems. Too few lags mean that some important variables are omitted from the model and this specification error will usually cause bias in the retained regression coefficients, leading to incorrect conclusions. On the other hand, too many lags waste observations and this specification error will usually increase the standard errors of the estimated coefficients, making the results less reliable.

Unfortunately, there is no simple rule to decide on the maximal lag, though there are formal model specification criteria to rely on. Ideally, the lag structure is allowed to vary across countries, variables and equation systems. However, for a relatively large panel like ours, this would increase the computational burden substantially. For this reason in each system we allow different maximal lags for *Y* and *X*, but do not allow them to vary across countries. This means that altogether there are four maximal lag parameters. Assuming that their range is 1−4, we estimate (2a) and (2b) for each possible pair of mly_1, mlx_1 and mly_2, mlx_2 respectively, and choose the combinations which minimize the Akaike Information Criterion (AIC) and Schwartz Criterion (SC) defined as:

$$AIC_k = \ln|\mathbf{W}| + \frac{2N^2 q}{T} \tag{4}$$

$$SC_k = \ln|\mathbf{W}| + \frac{N^2 q}{T}\ln(T) \tag{5}$$

where **W** is the estimated residual covariance matrix, *N* is the number of equations, *q* is the number of coefficients per equation and *T* is the sample size, all in system k = 1, 2. Occasionally, these two criteria select different lag lengths.

The SUR estimators are more efficient than the OLS estimators only if there is contemporaneous correlation in the system. Therefore, it is of interest to test whether the variance-covariance matrix of the errors is diagonal. For a given *k*, the null and alternative hypotheses are as follows:

$$H_0: \; Cov(\varepsilon_{k,i,t}, \varepsilon_{k,j,t}) = 0 \quad \text{for} \quad i \neq j$$

$$H_A: \; Cov(\varepsilon_{k,i,t}, \varepsilon_{k,j,t}) \neq 0 \quad \text{for at least one pair of } i \neq j$$

[14] The stacked forms of (2a) and (2b) are shown in the Appendix.

[15] The estimations were performed by the SUR routine of TSP4.5.

If H_0 is true there is no payoff to SUR. Assuming normality, Breusch and Pagan (1980), BP in brief, suggested the following Lagrange multiplier test statistic:

$$\lambda = T\sum_{i=2}^{N}\sum_{j=1}^{i-1} r_{ij}^2 \qquad (6)$$

where r_{ij} is the estimated correlation coefficient between $\varepsilon_{k,i,t}$ and $\varepsilon_{k,j,t}$ (for a given k and $i \neq j$) from individual OLS regressions. Under H_0, this statistic has an asymptotic chi-square distribution with $N(N\text{-}1)/2$ degrees of freedom.[16]

Testing for Granger Causality

In Kónya (2000) for each country we estimated (1) with OLS and performed Wald tests for the parameter restrictions implied by Granger causality.[17] Under H_0 the test statistics had a limiting chi-square distribution with degrees of freedom equal to the number of restrictions in the null hypothesis. This time we consider all countries simultaneously so as to allow for contemporaneous correlation across countries, and test for Granger causality from X to Y in (2a) and from Y to X in (2b). Again we perform Wald tests, however, instead of the usual chi-square critical values, we use country specific bootstrap critical values.

Bootstrapping is basically a re-sampling method.[18] The main issue is how to generate and use the bootstrap samples. For the sake of simplicity, we focus on testing causality from X to Y in (2a), a similar procedure is applied for causality from Y to X in (2b). The procedure is as follows.

Step 1: Estimate (2a) under the null hypothesis that there is no causality from X to Y (i.e. assuming the $\gamma_{1,i,l} = 0$ restriction for all i and l) and obtain the residuals

$$e_{H_0,i,t} = y_{i,t} - \hat{\alpha}_{1,i} - \sum_{l=1}^{mly_1} \hat{\beta}_{1,i,l}\, y_{i,t-l} \quad \text{for } i = 1,\dots, N \text{ and } t = 1,\dots, T.$$

From these residuals develop the $N{\times}T$ $[e_{H_0,i,t}]$ matrix.

Step 2: Re-sample these residuals. In order to preserve the contemporaneous cross-correlation structure of the error terms in (2a), do not the draw the residuals for each country one-by-one, but rather randomly select a full column from the $[e_{H_0,i,t}]$ matrix at a time. Denote the selected bootstrap residuals as $e^*_{H_0,i,t}$, where $t = 1,\dots, T^*$ and T^* can be greater than T.

Step 3: Generate a bootstrap sample of Y assuming again that it is not caused by X, i.e. using the following formula:

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[16] Greene (1993), p. 492.

[17] The only exception was when we used the MWald test of Toda and Yamamoto (1995) with SUR.

[18] About bootstrapping in general see eg. Maddala and Kim (1998, 10.2).

$$y^*_{i,t} = \hat{\alpha}_{1,i} + \sum_{l=1}^{mly_1} \hat{\beta}_{1,i,l} y^*_{i,t-l} + e^*_{H_0,i,t} \quad , \quad t = 1, \ldots, T^* \tag{7}$$

Step 4: Substitute $y^*_{i,t}$ for $y_{i,t}$, estimate (2a) without imposing any parameter restriction on it, and for each country perform a Wald test implied by the no-causality null hypothesis.

Step 5: Develop the empirical distributions of the Wald test statistics repeating steps 2-4 many times, and specify the bootstrap critical values by selecting the appropriate percentiles of these sampling distributions.

There are a few remarks to be made. In this study the common sample size for all countries is $T = 38$ and the maximal lags are allowed to vary between 1−4, inclusively. In *Steps 2* and *3*, depending on the lag structure, we draw at least $T^* = 68$ bootstrap residuals and generate the same number of bootstrap $y^*_{i,t}$ values for each country. To kick off the recursive algorithm defined by (7) the first 2-5 $y^*_{i,t}$ values are set equal to zero and, in order to minimize the effect of this initialisation onto the results, in *Step 4* the Wald tests are performed over only the last 34−37 values. In *Step 5*, the bootstrap distribution of each test statistic is derived from 10,000 replications.

III. Empirical Results

Apart from the lag structure, we have used eight different specifications: the (2a), (2b) bivariate and the (3a), (3b) trivariate systems, both without and with a linear time trend. The time trend is a proxy variable that might substitute for some variables that are missing from the original specifications. In the trivariate models, for the sake of simplicity, we assumed that $mlz_1 = mlx_1$ in (3a) and that $mlz_2 = mly_2$ in (3b).

In each case the analysis consisted of three stages. We started with the estimation of each system with SUR for all possible pairs of maximal lags, and selected mly_1, mly_2, mlx_1 and mlx_2 by minimizing the (4) and (5) model selection criteria. Interestingly, AIC and SC always took their smallest values at a single lag for each variable. Overall, the bivariate systems without time trend generated the lowest, and the trivariate systems with time trend generated the highest AIC and SC. Yet, since the correct specification might change from country to country, we kept all eight options alive. Then, we performed the BP test. In all eight cases we could reject the null hypothesis of no contemporaneous correlation within the system even at the half percent significance level, justifying the application of SUR. Finally, we tested for Granger causality with Wald tests and country specific bootstrap critical values from LNEXP to LNGDP in (2a) and (3a), and from LNGDP to LNEXP in (2b) and (3b). Since our main interest is in testing for causality, only these latter results are reported in this paper.[19]

[19] On request, all the details are available to the interested readers.

Causality from LNEXP to LNGDP

The Granger causality test results for the null hypothesis *LNEXP does not cause LNGDP* are shown in *Tables 1-4*. Notice, that the bootstrap critical values are substantially higher than the chi-square critical values usually applied with the Wald test,[20] and that they vary considerably from country to country and from table to table. Yet, for 16 out of the 24 countries the tests are robust in the sense that they lead to the same conclusion regardless of the specification. Namely, at the 10 percent significance level there is not sufficient evidence against the null hypothesis in the case of Austria, France, Greece, Japan, Korea, Luxembourg, Mexico, Norway, Portugal, Switzerland, the UK and the USA, while it can be rejected in the case of Finland, Iceland, Italy and Sweden.

As for the remaining 8 countries (Australia, Belgium, Canada, Denmark, Ireland, the Netherlands, New Zealand and Spain), the test results are contradictory and without further analysis it is not possible to decide which specification to prefer. Although the overall AIC, SC measures supported the bivariate systems without the time trend, this specification is not necessarily best for every country. For this reason, we have also calculated the following single-equation versions of (4) and (5):

$$AIC_i = \ln\left(\hat{\sigma}_{i,i}^2\right) + \frac{2q}{T} \tag{4*}$$

and

$$SC_i = \ln\left(\hat{\sigma}_{i,i}^2\right) + q\frac{\ln T}{T} \tag{5*}$$

where i refers to the country (i =1,2, ..., N) and $\hat{\sigma}_{i,i}^2$ is the variance of the residuals from the i^{th} equation, i.e. the $(i,i)^{th}$ element of the estimated residual covariance matrix, **W**. These criteria select the bivariate model without time trend for Australia, Belgium, Denmark, New Zealand and Spain, the bivariate model with time trend for Ireland, the trivariate model without time trend for Australia and Canada, and the trivariate model with time trend for the Netherlands. Consequently, we reject the null hypothesis in the case of Belgium, Canada, Denmark, Ireland, the Netherlands, New Zealand and Spain, but maintain it for Australia.

In summary, there is evidence of exports Granger-causing growth at the 5 percent or lower significance level in Belgium, Canada, Denmark, Finland, Iceland, Ireland, Italy, the Netherlands, Spain and Sweden, and at the 10 percent level in New Zealand.

[20] The chi-square critical values for one degree of freedom, i.e. for Wald tests with a single restriction, are 6.6349 (1%), 3.8415 (5%) and 2.7055 (10%).

Table 1: Granger causality tests
H_0 : LNEXP does not cause LNGDP,
Bivariate models without trend

Country	*Test. Stat.*	*Bootstrap Critical Values*			*p-value, decision*
		1%	*5%*	*10%*	
Australia	14.0354	46.3559	23.9342	16.5506	0.14 → H_0
Austria	2.2599	62.8019	33.1471	22.4611	0.58 → H_0
Belgium	49.9296	84.3959	44.9849	31.5651	0.04 → H_A **
Canada	8.7767	56.7728	31.1144	21.2145	0.28 → H_0
Denmark	47.5470	46.7049	25.5098	17.5914	0.01 → H_A ***
Finland	117.0711	81.7748	46.7888	32.6505	0.01 → H_A ***
France	1.1604	81.3904	47.5087	33.3071	0.76 → H_0
Greece	1.6566	70.3146	36.0907	25.5742	0.67 → H_0
Iceland	59.3819	70.8289	36.5695	25.4032	0.02 → H_A **
Ireland	4.6040	59.3401	31.0093	20.6354	0.42 → H_0
Italy	41.6957	66.9769	36.2394	25.3153	0.04 → H_A **
Japan	0.5740	101.7512	57.9946	41.2662	0.87 → H_0
Korea Rep.	14.7746	45.0959	26.4705	18.4592	0.14 → H_0
Luxembourg	0.5566	83.2505	46.4273	32.5585	0.83 → H_0
Mexico	0.0003	45.3087	22.5652	15.2157	0.99 → H_0
Netherlands	1.5367	65.0687	35.2122	24.1087	0.68 → H_0
New Zealand	18.2058	47.7755	26.3025	17.9973	0.10 → H_A *
Norway	15.2294	77.0165	39.3330	27.1631	0.21 → H_0
Portugal	12.9984	68.1022	38.3697	26.5469	0.25 → H_0
Spain	34.1144	39.5807	21.8654	14.7806	0.02 → H_A **
Sweden	52.4326	57.3112	29.8017	20.2532	0.02 → H_A **
Switzerland	22.8821	65.4215	33.9300	23.4155	0.11 → H_0
UK	1.6239	66.4740	38.2939	26.3185	0.69 → H_0
USA	2.1799	68.6377	36.8282	25.5935	0.63 → H_0

Note: ***, ** and * indicate significance at the 1, 5 and 10 percent levels, respectively.

Table 2: Granger causality tests
H_0 : LNEXP does not cause LNGDP,
Bivariate models with trend

Country	*Test. Stat.*	*Bootstrap Critical Values*			*p-value, decision*
		1%	*5%*	*10%*	
Australia	4.9274	44.9502	23.7773	15.8615	0.34 → H_0
Austria	2.0903	46.0760	25.5603	17.7136	0.55 → H_0
Belgium	40.7549	67.2100	36.0454	25.9321	0.04 → H_A **
Canada	1.9880	50.4355	28.1825	19.0841	0.59 → H_0
Denmark	1.9171	47.9771	25.7858	17.7085	0.58 → H_0
Finland	95.9589	67.3755	39.5021	28.0329	0.01 → H_A ***
France	2.5671	58.9602	32.9669	23.3843	0.59 → H_0
Greece	5.6056	55.7208	29.3109	19.5535	0.36 → H_0
Iceland	48.1102	52.1462	28.5711	19.6107	0.02 → H_A **
Ireland	24.0476	38.9385	18.9367	12.6405	0.04 → H_A **
Italy	26.7408	61.0029	32.8487	23.0069	0.08 → H_A *
Japan	0.5573	63.7872	34.6542	23.3168	0.80 → H_0
Korea Rep.	11.2901	48.9211	26.4227	18.0600	0.19 → H_0
Luxembourg	2.5827	45.5638	23.2729	15.7491	0.49 → H_0
Mexico	3.9819	57.4964	30.9360	20.8873	0.47 → H_0
Netherlands	0.9676	46.8398	25.2731	17.5979	0.70 → H_0
New Zealand	1.0328	61.6849	31.9327	21.6903	0.71 → H_0
Norway	1.2722	66.2453	33.2371	22.9609	0.69 → H_0
Portugal	6.2695	59.1283	31.7518	21.7676	0.37 → H_0
Spain	19.2891	58.0146	29.9086	20.4672	0.11 → H_0
Sweden	54.5221	75.0285	41.9063	28.8297	0.03 → H_A **
Switzerland	5.5612	52.6466	27.0917	18.5265	0.36 → H_0
UK	1.0506	61.3449	33.3542	23.0641	0.73 → H_0
USA	8.8579	83.5405	45.1425	30.6277	0.38 → H_0

Note: ***, ** and * indicate significance at the 1, 5 and 10 percent levels, respectively.

Table 3: Granger causality tests
H_0 : LNEXP does not cause LNGDP,
Trivariate models without trend

Country	*Test. Stat.*	*Bootstrap Critical Values*			*p-value, decision*
		1%	*5%*	*10%*	
Australia	20.1310	70.8388	38.9654	27.1498	0.16 $\rightarrow H_0$
Austria	4.4312	56.8711	29.3511	19.7442	0.42 $\rightarrow H_0$
Belgium	8.3532	44.4521	25.0899	17.5941	0.25 $\rightarrow H_0$
Canada	50.3255	77.6141	44.1090	31.5578	0.04 $\rightarrow H_A^{**}$
Denmark	24.8830	40.3318	21.3206	14.9248	0.04 $\rightarrow H_A^{**}$
Finland	64.4543	38.9966	20.4078	14.0350	0.01 $\rightarrow H_A^{***}$
France	0.3142	61.1686	32.1122	21.7349	0.84 $\rightarrow H_0$
Greece	4.0504	50.2856	26.4782	17.4576	0.42 $\rightarrow H_0$
Iceland	56.2137	65.4543	34.9303	24.3757	0.02 $\rightarrow H_A^{**}$
Ireland	2.4428	31.6640	16.1893	11.0039	0.43 $\rightarrow H_0$
Italy	176.5551	65.5361	35.4477	23.2992	0.01 $\rightarrow H_A^{***}$
Japan	7.7595	36.6456	19.4813	13.2128	0.20 $\rightarrow H_0$
Korea Rep.	15.4466	77.4050	40.9225	28.6700	0.23 $\rightarrow H_0$
Luxembourg	0.0460	61.6956	34.1923	23.6342	0.95 $\rightarrow H_0$
Mexico	0.2332	36.3429	19.5024	13.1556	0.83 $\rightarrow H_0$
Netherlands	2.9943	49.4201	29.0913	19.5493	0.52 $\rightarrow H_0$
New Zealand	0.1760	44.9626	23.6473	16.4965	0.86 $\rightarrow H_0$
Norway	2.8951	32.9314	17.2651	11.9219	0.41 $\rightarrow H_0$
Portugal	22.2611	75.1086	41.2025	28.3773	0.15 $\rightarrow H_0$
Spain	15.0647	33.3295	18.3991	12.7532	0.08 $\rightarrow H_A^{*}$
Sweden	55.2470	39.4812	20.9282	14.6339	0.01 $\rightarrow H_A^{***}$
Switzerland	4.0053	47.6054	25.8869	17.4781	0.42 $\rightarrow H_0$
UK	0.9630	54.2225	31.5985	22.4790	0.74 $\rightarrow H_0$
USA	1.0979	68.9215	36.3892	24.2719	0.74 $\rightarrow H_0$

Note: ***, ** and * indicate significance at the 1, 5 and 10 percent levels, respectively.

Table 4: Granger causality tests
H_0 : LNEXP does not cause LNGDP,
Trivariate models with trend

Country	*Test. Stat.*	*Bootstrap Critical Values*			*p-value, decision*
		1%	*5%*	*10%*	
Australia	20.6420	47.9166	24.5841	17.1082	0.08 → H_A^{*}
Austria	2.0723	52.7526	26.6879	18.3595	0.57 → H_0
Belgium	8.3174	42.8557	23.3806	16.1799	0.24 → H_0
Canada	46.5293	59.1462	33.8297	23.8910	0.03 → H_A^{**}
Denmark	2.9905	42.6331	23.5976	16.2990	0.48 → H_0
Finland	81.9133	38.1726	21.2960	15.2674	0.01 → H_A^{***}
France	1.6366	51.4130	28.7956	19.5556	0.63 → H_0
Greece	5.7806	37.3312	19.1748	13.2258	0.27 → H_0
Iceland	35.2216	33.8635	17.9201	12.3765	0.01 → H_A^{***}
Ireland	10.8147	38.4173	20.1125	13.5368	0.15 → H_0
Italy	138.2330	51.1509	27.7067	18.2875	0.01 → H_A^{***}
Japan	4.7571	51.1845	26.0837	17.9016	0.39 → H_0
Korea Rep.	8.2592	52.6153	28.5190	19.2131	0.28 → H_0
Luxembourg	0.0360	27.1431	15.3509	10.3613	0.93 → H_0
Mexico	2.3028	31.4106	16.7033	11.3480	0.46 → H_0
Netherlands	28.3924	50.5739	26.9187	18.5134	0.05 → H_A^{**}
New Zealand	0.0653	53.1587	26.6861	17.8886	0.93 → H_0
Norway	0.9634	52.0038	27.9259	18.8886	0.71 → H_0
Portugal	12.6993	60.8617	31.6792	21.3500	0.20 → H_0
Spain	8.1976	42.3827	23.1044	15.4865	0.23 → H_0
Sweden	77.7667	47.0224	25.3123	16.8852	0.01 → H_A^{***}
Switzerland	3.9464	44.6977	23.5394	16.0739	0.40 → H_0
UK	0.6244	57.7400	30.4047	20.7797	0.78 → H_0
USA	5.1053	56.3187	30.7782	21.4997	0.43 → H_0

Note: ***, ** and * indicate significance at the 1, 5 and 10 percent levels, respectively.

Causality from LNGDP to LNEXP

The Granger causality test results for the null hypothesis LNGDP does *not cause LNEXP* are shown in *Tables 5-8*. This time, the test results are unambiguous for 13 out of the 24 countries. There is not sufficient evidence against the null hypotheses, not even at the 10 percent significance level, in the case of Australia, Belgium, Iceland, Ireland, Italy, Korea, Luxembourg, New Zealand, Spain, Switzerland, the UK and the USA, but it can be rejected for Japan.

In the other 11 cases the (4*) and (5*) statistics pick the bivariate model without time trend for Sweden, the bivariate model with time trend for Austria, Denmark, Finland, Portugal and Sweden, the trivariate model without time trend for France, Greece and Mexico, and the trivariate model with time trend for Canada, France, the Netherlands and Norway. Therefore, we reject the null hypothesis in the case of Austria, Canada, Finland, France, Greece, Mexico, the Netherlands, Norway and Portugal, but maintain it for Denmark. As for Sweden, the two models selected by AIC and SC lead to contradicting outcomes.

In summary, there is evidence of growth Granger-causing exports at the 5 percent or lower significance level in Canada, Finland, France, Greece, the Netherlands, Norway, and at the 6-10 percent level in Austria, Japan, Mexico and Portugal.

IV. Concluding Remarks

This paper has studied the possibility of Granger causality between the logarithms of real exports and real GDP in 24 OECD countries from 1960 through 1997. A new panel-data approach has been applied which is based on SUR systems and Wald tests with country specific bootstrap critical values. This approach has two advantages. On the one hand, it does not assume that the panel is homogeneous, so it makes possible to perform Granger-causality tests on each individual panel member separately. However, since contemporaneous correlation is allowed across countries, it makes possible to exploit the extra information provided by the panel data setting. On the other hand, this approach does not require pretesting for unit roots and cointegration, though it still requires the specification of the lag structure. This is an important feature since the unit-root and cointegration tests in general suffer from low power, different tests often lead to contradicting outcomes, so the conclusions drawn from them are usually conditional on the more or less arbitrary decisions made by the researcher.

Two different models have been used. A bivariate (*GDP-exports*) model and a trivariate (*GDP-exports-openness*) model, both without and with a linear time trend. In each case the analysis focussed on direct, one-period-ahead causality between exports and GDP. All things considered, our results indicate one-way causality from exports to GDP in Belgium, Denmark, Iceland, Ireland, Italy, New Zealand, Spain and Sweden, one-way causality from GDP to exports in Austria, France, Greece, Japan, Mexico, Norway and Portugal, two-way causality between exports and growth in Canada, Finland and the Netherlands, while in the case of Australia, Korea, Luxembourg, Switzerland, the UK and the USA there are no evidence of causality between these variables.

Table 5: Granger causality tests
H_0 : LNGDP does not cause LNEXP,
Bivariate models without trend

Country	*Test. Stat.*	*Bootstrap Critical Values*			*p-value, decision*
		1%	*5%*	*10%*	
Australia	0.8819	98.3000	57.7863	42.1248	0.90 → H_0
Austria	15.9799	115.7287	70.3122	52.0452	0.40 → H_0
Belgium	0.4013	111.7765	67.3121	49.5530	0.92 → H_0
Canada	0.6753	113.3162	72.0254	53.1896	0.92 → H_0
Denmark	1.4953	62.6198	33.6888	22.5928	0.67 → H_0
Finland	6.3672	128.6086	76.5622	55.1843	0.67 → H_0
France	37.4613	96.8379	57.5567	41.7498	0.13 → H_0
Greece	27.7548	96.8532	54.7762	40.4995	0.20 → H_0
Iceland	4.6933	93.1382	54.0679	39.2226	0.62 → H_0
Ireland	2.1777	109.7144	66.1653	48.9091	0.90 → H_0
Italy	0.1459	93.6821	54.3334	39.3522	0.96 → H_0
Japan	45.8411	106.3809	59.6395	44.2198	0.10 → H_A^*
Korea Rep.	0.0682	91.3334	49.9548	35.9302	0.95 → H_0
Luxembourg	0.1002	67.3298	39.6455	26.9615	0.93 → H_0
Mexico	14.7100	75.7252	44.7650	32.7233	0.32 → H_0
Netherlands	17.6714	123.3528	74.2962	53.8880	0.38 → H_0
New Zealand	2.3334	92.6045	51.6368	36.1042	0.68 → H_0
Norway	0.2159	75.7752	41.5942	28.4166	0.91 → H_0
Portugal	0.7087	89.8361	54.3521	39.6245	0.89 → H_0
Spain	0.2952	85.9868	46.3169	32.1964	0.89 → H_0
Sweden	27.3850	100.7840	58.3013	42.1561	0.19 → H_0
Switzerland	12.9077	94.1938	53.3470	37.3508	0.35 → H_0
UK	4.1126	74.4471	39.4244	27.9551	0.54 → H_0
USA	2.7763	53.6381	29.1731	20.4057	0.56 → H_0

Note: ***, ** and * indicate significance at the 1, 5 and 10 percent levels, respectively.

Table 6: Granger causality tests
H_0 : LNGDP does not cause LNEXP,
Bivariate models with trend

Country	*Test. Stat.*	*Bootstrap Critical Values*			*p-value, decision*
		1%	*5%*	*10%*	
Australia	0.3307	43.3755	23.0001	15.5643	0.81 → H_0
Austria	35.4676	86.4247	47.1006	33.8906	0.09 → H_A *
Belgium	0.0002	57.5291	30.8494	21.3749	0.99 → H_0
Canada	4.3071	46.3592	26.4467	18.8979	0.43 → H_0
Denmark	13.9720	43.4269	23.0596	15.9555	0.13 → H_0
Finland	46.3945	67.3102	35.7893	24.8318	0.04 → H_A **
France	56.6527	81.3019	47.7234	33.8019	0.04 → H_A **
Greece	61.6615	63.3730	34.3919	23.9783	0.02 → H_A **
Iceland	0.1003	48.8035	26.7032	18.1656	0.90 → H_0
Ireland	0.9425	54.0794	28.3393	18.8245	0.71 → H_0
Italy	0.6928	51.0959	26.7375	18.1925	0.74 → H_0
Japan	33.6077	79.7445	43.8029	30.9001	0.09 → H_A *
Korea Rep.	9.5427	51.9153	28.0543	19.0599	0.24 → H_0
Luxembourg	0.4512	68.6783	39.2664	27.0169	0.84 → H_0
Mexico	0.4909	68.3765	34.8457	24.0258	0.81 → H_0
Netherlands	14.5229	90.0013	52.2619	37.5673	0.34 → H_0
New Zealand	0.0131	53.3064	28.2870	19.8061	0.97 → H_0
Norway	10.6962	38.4943	20.3301	13.4083	0.14 → H_0
Portugal	16.0039	37.8578	19.6813	13.5150	0.08 → H_A *
Spain	1.2708	68.2161	37.3349	26.1451	0.72 → H_0
Sweden	40.7920	86.3040	48.1827	33.1017	0.07 → H_A *
Switzerland	2.9082	61.6371	34.8936	24.4103	0.58 → H_0
UK	2.4230	52.3366	28.7249	19.8541	0.57 → H_0
USA	4.6243	34.1554	23.3234	16.0332	0.37 → H_0

Note: ***, ** and * indicate significance at the 1, 5 and 10 percent levels, respectively.

Table 7: Granger causality tests
H_0 : LNGDP does not cause LNEXP,
Trivariate models without trend

Country	*Test. Stat.*	*Bootstrap Critical Values*			*p-value, decision*
		1%	*5%*	*10%*	
Australia	18.4669	92.9481	55.4531	40.2989	0.32 $\rightarrow H_0$
Austria	18.4063	81.9743	46.7939	33.3903	0.24 $\rightarrow H_0$
Belgium	11.3644	37.5814	20.6099	14.2706	0.14 $\rightarrow H_0$
Canada	0.5803	94.1784	55.9398	41.5133	0.91 $\rightarrow H_0$
Denmark	3.0132	39.2341	20.2542	13.9073	0.44 $\rightarrow H_0$
Finland	1.5883	33.6595	18.2407	12.6130	0.55 $\rightarrow H_0$
France	57.9532	50.5674	29.0961	20.8293	0.01 $\rightarrow H_A^{***}$
Greece	50.1496	60.4609	31.6846	22.1718	0.02 $\rightarrow H_A^{**}$
Iceland	5.3795	57.0858	30.6256	21.3012	0.43 $\rightarrow H_0$
Ireland	0.1711	34.5615	18.3770	12.3687	0.85 $\rightarrow H_0$
Italy	0.3993	30.4559	16.0901	10.8139	0.75 $\rightarrow H_0$
Japan	37.3399	37.1087	21.5716	14.7479	0.01 $\rightarrow H_A^{***}$
Korea Rep.	1.9969	48.2031	27.0832	18.9960	0.62 $\rightarrow H_0$
Luxembourg	1.7402	42.1811	22.9960	15.4688	0.59 $\rightarrow H_0$
Mexico	16.5632	35.0900	20.0979	13.7748	0.08 $\rightarrow H_A^{*}$
Netherlands	19.5892	69.9783	39.3454	27.5250	0.18 $\rightarrow H_0$
New Zealand	1.6898	69.4404	39.0297	27.5560	0.71 $\rightarrow H_0$
Norway	0.3292	62.0416	36.5409	25.9934	0.88 $\rightarrow H_0$
Portugal	0.4846	41.9566	21.8595	14.9851	0.78 $\rightarrow H_0$
Spain	0.2214	40.4031	20.9357	14.2798	0.83 $\rightarrow H_0$
Sweden	20.8996	37.4208	21.1919	14.4703	0.06 $\rightarrow H_A^{*}$
Switzerland	0.1063	61.4697	34.6876	24.7604	0.92 $\rightarrow H_0$
UK	4.7013	47.1445	25.9812	17.8356	0.40 $\rightarrow H_0$
USA	0.8040	27.6822	15.2195	10.2969	0.64 $\rightarrow H_0$

Note: ***, ** and * indicate significance at the 1, 5 and 10 percent levels, respectively.

Table 8: Granger causality tests
H_0 : LNGDP does not cause LNEXP,
Trivariate models with trend

Country	*Test. Stat.*	*Bootstrap Critical Values*			*p-value, decision*
		1%	*5%*	*10%*	
Australia	1.1421	35.3809	18.3251	12.6579	0.60 → H_0
Austria	27.9341	53.6904	29.9627	20.6628	0.06 → $H_A{}^{*}$
Belgium	14.5016	52.6378	26.8427	18.0250	0.14 → H_0
Canada	24.3781	42.5754	23.1491	15.8331	0.05 → $H_A{}^{**}$
Denmark	18.3794	48.6563	24.9390	17.3463	0.10 → $H_A{}^{*}$
Finland	9.3529	29.5567	17.0451	11.4237	0.14 → H_0
France	57.4876	40.5761	22.8344	16.1348	0.01 → $H_A{}^{***}$
Greece	54.7808	42.7186	23.6121	15.9743	0.01 → $H_A{}^{***}$
Iceland	0.0426	33.3752	17.6697	11.9799	0.92 → H_0
Ireland	0.0810	37.3879	19.0692	13.0853	0.90 → H_0
Italy	0.9626	45.7625	23.6018	16.2401	0.69 → H_0
Japan	17.3196	43.4852	22.9667	15.4694	0.09 → $H_A{}^{*}$
Korea Rep.	6.8006	45.4066	23.5793	15.9233	0.27 → H_0
Luxembourg	4.5059	54.1428	28.4616	19.7105	0.43 → H_0
Mexico	4.3484	38.2491	19.5170	13.3698	0.34 → H_0
Netherlands	52.8830	58.8734	34.0082	23.5373	0.02 → $H_A{}^{**}$
New Zealand	3.8092	51.4202	26.0709	18.0444	0.45 → H_0
Norway	23.8289	23.0985	12.4356	8.2334	0.01 → $H_A{}^{***}$
Portugal	13.9020	26.8409	14.3682	10.0393	0.06 → $H_A{}^{*}$
Spain	0.0037	38.2585	19.7929	13.3334	0.98 → H_0
Sweden	35.0152	31.6064	17.9438	11.9494	0.01 → $H_A{}^{***}$
Switzerland	0.0474	62.7892	36.0616	25.3582	0.95 → H_0
UK	3.1047	46.5452	25.2914	17.4810	0.49 → H_0
USA	3.1096	41.8270	22.8301	15.6436	0.45 → H_0

Note: ***, ** and * indicate significance at the 1, 5 and 10 percent levels, respectively.

Finally, it is important to mention that Granger causality between exports and GDP does not necessarily mean that the ELG or GDE hypothesis is valid. The signs of the regression coefficients involved in the causality tests are also crucial since the ELG and GDE hypotheses imply *positive* effects. Hence, in (2a) and (3a) the $\gamma_{1,i,1}$, while in (2b) and (3b) the $\beta_{2,i,1}$ ($i = 1, ..., N$) parameters are expected to be positive. Indeed, the estimates of $\gamma_{1,i,1}$ in the preferred specifications are positive in all those cases when causality is detected from exports to GDP, with the exception of the Netherlands. However, in four out of the nine cases when causality is detected from GDP to exports, namely Canada, Finland, Norway and Portugal, the estimates of $\beta_{2,i,1}$ are negative.

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Appendix

For the i^{th} panel member (2a) and (2b) can be written in matrix form as

$$\mathbf{Y}_i = \alpha_{1,i}\boldsymbol{\iota} + \mathbf{Y}^*_{1,i}\boldsymbol{\beta}_{1,i} + \mathbf{X}^*_{1,i}\boldsymbol{\gamma}_{1,i} + \boldsymbol{\varepsilon}_{1,i} \tag{2a*}$$

and
$$\mathbf{X}_i = \alpha_{2,i}\boldsymbol{\iota} + \mathbf{Y}^*_{2,i}\boldsymbol{\beta}_{2,i} + \mathbf{X}^*_{2,i}\boldsymbol{\gamma}_{2,i} + \boldsymbol{\varepsilon}_{2,i} \tag{2b*}$$

where $\boldsymbol{\iota}$ is a $T \times 1$ vector of ones, $\mathbf{Y}_i$ and $\mathbf{X}_i$ are $T \times 1$ vectors of the observed values of Y and X, $\mathbf{Y}^*_{1,i}$, $\mathbf{X}^*_{1,i}$, $\mathbf{Y}^*_{2,i}$ and $\mathbf{X}^*_{2,i}$ are $T \times 1$ vectors of the values of the error variables, $\alpha_{1,i}$ and $\alpha_{2,i}$ are the intercept terms, and $\boldsymbol{\beta}_{1,i}$, $\boldsymbol{\gamma}_{1,i}$, $\boldsymbol{\beta}_{2,i}$ and $\boldsymbol{\gamma}_{2,i}$ are $mly_1 \times 1$, $mlx_1 \times 1$, $mly_2 \times 1$ and $mlx_2 \times 1$ vectors of the slope coefficients, all for country i.

Stacking the equations for all i ($i = 1,..., N$), the two sets of equations can be written as

$$\mathbf{Y} = \boldsymbol{\alpha}_1 + \mathbf{Y}^*_1\boldsymbol{\beta}_1 + \mathbf{X}^*_1\boldsymbol{\gamma}_1 + \boldsymbol{\varepsilon}_1 \tag{2a**}$$

and
$$\mathbf{X} = \boldsymbol{\alpha}_2 + \mathbf{Y}^*_2\boldsymbol{\beta}_2 + \mathbf{X}^*_2\boldsymbol{\gamma}_2 + \boldsymbol{\varepsilon}_2 \tag{2b**}$$

where

$$\mathbf{Y} = \begin{bmatrix} \mathbf{Y}_1 \\ \mathbf{Y}_2 \\ \vdots \\ \mathbf{Y}_N \end{bmatrix}, \quad \mathbf{X} = \begin{bmatrix} \mathbf{X}_1 \\ \mathbf{X}_2 \\ \vdots \\ \mathbf{X}_N \end{bmatrix}, \quad \boldsymbol{\alpha}_1 = \begin{bmatrix} \alpha_{1,1}\boldsymbol{\iota} \\ \alpha_{1,2}\boldsymbol{\iota} \\ \vdots \\ \alpha_{1,N}\boldsymbol{\iota} \end{bmatrix}, \quad \boldsymbol{\alpha}_2 = \begin{bmatrix} \alpha_{2,1}\boldsymbol{\iota} \\ \alpha_{2,2}\boldsymbol{\iota} \\ \vdots \\ \alpha_{2,N}\boldsymbol{\iota} \end{bmatrix}, \quad \boldsymbol{\varepsilon}_1 = \begin{bmatrix} \boldsymbol{\varepsilon}_{1,1} \\ \boldsymbol{\varepsilon}_{1,2} \\ \vdots \\ \boldsymbol{\varepsilon}_{1,N} \end{bmatrix}, \quad \boldsymbol{\varepsilon}_2 = \begin{bmatrix} \boldsymbol{\varepsilon}_{2,1} \\ \boldsymbol{\varepsilon}_{2,2} \\ \vdots \\ \boldsymbol{\varepsilon}_{2,N} \end{bmatrix}$$

are $N\,T \times 1$ vectors,

$$\mathbf{Y}^*_1 = \begin{bmatrix} \mathbf{Y}^*_{1,1} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{0} & \mathbf{Y}^*_{1,2} & \dots & \mathbf{0} \\ \vdots & \vdots & \vdots & \vdots \\ \mathbf{0} & \mathbf{0} & \dots & \mathbf{Y}^*_{1,N} \end{bmatrix}, \quad \mathbf{X}^*_1 = \begin{bmatrix} \mathbf{X}^*_{1,1} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{0} & \mathbf{X}^*_{1,2} & \dots & \mathbf{0} \\ \vdots & \vdots & \vdots & \vdots \\ \mathbf{0} & \mathbf{0} & \dots & \mathbf{X}^*_{1,N} \end{bmatrix}$$

$$\mathbf{Y}^*_2 = \begin{bmatrix} \mathbf{Y}^*_{2,1} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{0} & \mathbf{Y}^*_{2,2} & \dots & \mathbf{0} \\ \vdots & \vdots & \vdots & \vdots \\ \mathbf{0} & \mathbf{0} & \dots & \mathbf{Y}^*_{2,N} \end{bmatrix}, \quad \mathbf{X}^*_2 = \begin{bmatrix} \mathbf{X}^*_{2,1} & \mathbf{0} & \dots & \mathbf{0} \\ \mathbf{0} & \mathbf{X}^*_{2,2} & \dots & \mathbf{0} \\ \vdots & \vdots & \vdots & \vdots \\ \mathbf{0} & \mathbf{0} & \dots & \mathbf{X}^*_{2,N} \end{bmatrix}$$

are $N\,T \times N\,mly_1$, $N\,T \times N\,mlx_1$, $N\,T \times N\,mly_2$ and $N\,T \times N\,mlx_2$ matrices, and

$$\boldsymbol{\beta}_1 = \begin{bmatrix} \boldsymbol{\beta}_{1,1} \\ \boldsymbol{\beta}_{1,2} \\ \vdots \\ \boldsymbol{\beta}_{1,N} \end{bmatrix}, \quad \boldsymbol{\gamma}_1 = \begin{bmatrix} \boldsymbol{\gamma}_{1,1} \\ \boldsymbol{\gamma}_{1,2} \\ \vdots \\ \boldsymbol{\gamma}_{1,N} \end{bmatrix}, \quad \boldsymbol{\beta}_2 = \begin{bmatrix} \boldsymbol{\beta}_{2,1} \\ \boldsymbol{\beta}_{2,2} \\ \vdots \\ \boldsymbol{\beta}_{2,N} \end{bmatrix}, \quad \boldsymbol{\gamma}_2 = \begin{bmatrix} \boldsymbol{\gamma}_{2,1} \\ \boldsymbol{\gamma}_{2,2} \\ \vdots \\ \boldsymbol{\gamma}_{2,N} \end{bmatrix}$$

are $N\,mly_1 \times 1$, $N\,mlx_1 \times 1$, $N\,mly_2 \times 1$ and $N\,mlx_2 \times 1$ vectors.