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Towards improved food security in 20 OECD countries: Persistence of food imports using a fractional integration approach ^{☆, ☆ ☆}

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ABSTRACT

In this article, we aim to advance the literature on food security by examining the persistence of food imports in a group of 20 OECD nations. The analysis concentrates on two food import series for each nation: real food imports and real food imports per capita during 1963 and 2021. Using fractional integration techniques, the empirical findings show support for persistence of food imports in the OECD countries examined. Evidence of mean reversion is not found in any single case, and Korea Republic and Australia display the lowest degrees of integration, while Iceland the highest ones. Policy implications of the empirical findings are explained in the body of the manuscript.

1. Introduction

Food imports are crucial because food intake is essential for human survival and imports of different food items are required in many countries. Availability of food items is one of the cornerstones of food security, and food imports play a crucial role in the food availability in many countries (Food and Agriculture Organization, FAO, 2023a,b). Food imports are used to augment domestic production when domestic production fails to meet food demand in a country. The role of food imports is more conspicuous in countries that are often slow to increase domestic production because of the lack of agricultural resources in the face of rising food demand (Otsuka, 2013). Food imports can be used to tackle temporary food insecurity and chronic food insecurity. A key determinant of national food security is the amount of foreign exchange available to pay for food imports. During food crisis, such as the 2007–2008 food price crisis, export restrictions are used by exporting countries, thereby increasing import bills and subsidies on food importing countries (Brooks, 2014).

The globe continues to witness rising import bills in most of the recent years. For instance, the food import bill in the globe was about US \$ 2 trillion in 2022, which is the highest ever recorded figure and a rise of 10% (or an increase of US\$ 181 billion) from the 2021 figure (FAO, 2023a). The increase is as a result of simultaneous increase in both prices and volumes of different imported food items. Between 691 and 783 million people faced hunger in 2022 (FAO, 2023a). Developed nations continue to import from the entire spectrum of food products, while developing nations are progressively concentrating on staple items. Rich countries are responsible for most of the rise in the global food import bill in the world, while increasing food costs have been felt more in poor nations (FAO, 2023a).

As a result of the importance of food imports and its impact in both developed and developing countries, several aspects of the subject-matter have been discussed in the literature, including the determinants of food imports and the exchange rate as an important factor (Naylor and Falcon, 2010). Yang and Zehnder (2002) showed that water scarcity is one of the important factors of food imports and water

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scarcity-linked food imports will continue to grow. Zhan (2022) focussed on the socio-economic determinants and suggested that globalization has contributed to the soaring food imports. Kaitibie et al. (2023) also examined the factors of food imports. The results suggest a positive relationship between economic growth and food imports, while there is a negative relationship between real exchange rate, the price of fertilizers, and the opening of the Free Trade Agreement and food imports. Besides, new energy transportation has a negative impact on food imports (Ma and Zhao, 2024).

There are also papers on other aspects of food import. For instance, Sarris et al. (2011) focussed on the management of price instability and risks associated with food import and noted that hedging with futures provide considerable prospects for decreasing import cost unpredictability. In a related paper, Welburn et al. (2016) revealed that food import violations are prevalent in several economies. The current trend of food imports has been examined and it has been shown that under present trends and acute effects of climate change, food import dependency could increase by 3-fold between now and the year 2050 in some regions (Le Mouél et al., 2023). Some countries are expected to lose nearly half of their cultivable lands and becoming reliant on imports for almost 70% of their food requirements (Le Mouél et al., 2023). Focussing on the impact of food import, Huang et al. (2017) showed that limited food import might have insignificant impact on food security. In a related paper, Subramaniam et al. (2023) showed that food imports have a negative impact on food security in many countries. There are also studies on that that have used Autoregressive Moving Average (ARMA) or Autoregressive Integrated Moving Average (ARIMA) models to investigate several dimensions of food prices (Sallehuddin and Shamsuddin, 2009; Ohlyver and Pudjihastuti, 2018; Ray et al., 2023; etc.).

However, an issue ignored in the extant literature is the persistence of the food imports, upon which numerous important inferences can be established. Firstly, the existence of persistence of food imports implies that shocks arising from the blueprints or measures aimed at decreasing food imports to conserve foreign exchange earnings and improve food security (through the increase in local production of food) will be permanent. The measures aimed at increasing local production of food items require a cluster of technological innovations. These innovations include transitioning to advanced biotechnology-based farming, expanding on-farm yields of various food items, improvements of infrastructural facilities, input financing and improved smallholder farmer management skills. One of such blueprints is the Resilience and Sustainability Trust (RST) established in April 2022 by the International Monetary Fund to provide long-term funding to back countries' efforts to build economic resilience. This is to ensure that local production of food remains solid in the face of climate change and pandemics and therefore, decreasing food import. Other blueprints include Global Agriculture and Food Security Program of 2023 by the World Bank and Crisis Response Initiative of 2022 by International Fund for Agricultural Development (IFAD) which aimed at reducing food insecurity during the time of crises (FAO, 2023b).

Moreover, persistent food imports indicate that a sudden increase in food imports (due to sharp decline in local production or an increase in population or income) will linger unless there are far-reaching actions taken by governments to curb such an increase. The extent of the persistence of food imports will determine the scale of the remedial actions required to confront the adverse effect associated with any abrupt increase in food import that have adverse impact on the economy. The study is also useful to determine how reliant should food assistance programmes be on food imports. A persistent food imports suggests that it might take sometimes to correct food shortages caused by any disruption to food imports. Therefore, food assistance programmes should be less reliant on persistent food imports. Since food assistance programmes are present in several rural areas (Lu and Carter, 2024), it also means that it might take sometimes to effectively solve food disruption in the rural areas caused by decline in food imports.

Persistence of food imports also implies that long-term measures will be needed to ensure that rural dwellers are not affected by economic setback triggered any disruption in food imports.

Conversely, a mean reverting food imports suggests that policy shocks to food imports will have transient impacts. Therefore, rolling short term or medium-term blueprints will be more applicable with regards to decreasing (or increasing food imports). Testing persistence of food import is also associated with the dependency theory, which is connected to the Prebisch–Singer hypothesis. The Prebisch–Singer hypothesis states that the prices of primary commodities decline quicker than the prices of industrial products (Landajo and Presno, 2022). Although the theory is designed for developing countries, it can be extended to countries that conduct import-substitution strategies. Based on certain assumptions, the best course of development for countries is to implement import-substitution strategies. For these countries to record success with their import-substitution strategies, import series and especially food imports should be persistent. This is because persistence of food import series indicates that any shock to the series (resulting import substitution strategies) will have a long-term effect.

Moreover, persistence of food imports implies that it is not adequate to correctly predict future food imports figures by just counting on the previous values of food imports. In this case, there is a need to incorporate determinants of food imports in the prediction model. There are numerous organisations and bodies that are into forecasting of different food series such as the FAO of the United Nations (UN) and Organisation for Economic Co-operation and Development (OECD). A joint publication of FAO and OECD employs AGLINK-COSIMO model (which depends on numerous statistics including likely determinants of food imports) in the process of predicting the future figures of the food imports (OECD-FAO Agricultural Outlook, 2021). Furthermore, the existence of food imports persistence has valuable implications from a statistical viewpoint. Estimation methods such as the ordinary least squares (OLS) method depends on the stationarity assumption or the absence of persistence. If the food import series utilised in a model estimated through the OLS method are persistent, spurious results are likely to be generated (Noriega et al., 2016). There are studies that have been used OLS method to analyse food imports into rural areas (Wijesinghe and Kaushalya, 2022) and there are likely to be future studies on food imports into rural areas. Therefore, there is a need to test for persistence of food imports in rural areas before the series is analysed using econometric approaches, especially OLS methods.

The main research question that we seek to answer in this paper is "Does food import persistence exist in OECD countries?". Hence, the goal of this paper is to contribute to the literature on food imports in four ways. First, we investigate the persistence of food imports in 20 OECD countries for the period 1963–2021. According to our knowledge this is the first paper on the persistence of food imports. The second contribution is the use of a long-time span. With the use of 59 years of observations, the dependability of the results is improved, and the persistence of food imports can be assessed over a long period of time. The third contribution of this paper is the use of different series to represent food imports. Hence, the results generated from this paper will be more comprehensive relative to a single-variable analysis. Another contribution of this study is the fractional differentiation use in the methodology, which is better than the traditional methods that simply use first differentiation in case of nonstationary data.

We have studied OECD members for several reasons. OECD countries continue to be the largest food importers in the world. For instance, in 2021, the top food importers were United States (valued at US\$ 86.6 billion), Germany (valued at US\$ 44.3 billion), United Kingdom (valued at US\$ 34.2 billion), France (valued at US\$ 30.9 billion), and China (valued at US\$ 30.4 billion) (The Observatory of Economic Complexity, 2023). While food insecurity is more severe in developing nations, OECD countries are also affected. It has been estimated that about 7.5% of the population in OECD nations experienced food insecurity during 2018 and 2020. Moderate food insecurity prevalence across OECD nations

varied from 3% to 35% of the population. Severe food insecurity in OECD countries ranged between 0.5% and 13% of the OECD population during 2018 and 2020 (OECD, 2022).

This paper presents the following structure: Section 2 deals with the methodology; Section 3 details the main results and Section 4 provides some concluding remarks.

2. Methodology

As earlier mentioned, we use techniques based on fractional integration. Thus, instead of using first differentiation in case of nonstationary data, we permit the number of differences to be a fractional value. In other words, a process $\{x(t), t = 0, \pm 1, \dots\}$ is said to be fractionally integrated or integrated of order d where d is a real value if it can be represented as:

$$(1 - B)^d x(t) = u(t), t = 0, \pm 1, \dots \quad (1)$$

where B refers to the backshift operator, and $u(t)$ is a process integrated of order 0, also denominated short memory, and defined as a process where the infinite sum of the autocovariances is finite. The $I(0)$ processes include the white noise case but also models that allow for weak dependence such as the stationary ARMA-class of models. Thus, if $u(t)$ is ARMA(p, q), $x(t)$ is an AutoRegressive Fractionally Integrated Moving Average (ARFIMA(p, d, q)) process.

These processes based on fractional integration were proposed in the 80s by Granger (1980), Granger and Joyeux (1980) and Hosking (1981) based on the observation that many aggregate series that apparently required first differentiation, once they were differenced became over-differentiated, suggesting the need of an intermediate order of integration. In this context, Gil-Alana and Robinson (1997) examined 14 US macro series that were supposed to be $I(1)$ (Nelson and Plosser, 1982), finding support of $I(d)$ behavior with d constrained between 0 and 1. Since then, these models have been popularized in the analysis of economic time series data.

In the application carried out in the following section, we allow $x(t)$ to be the errors in a regression model that incorporates a constant and a linear time trend, i.e.,

$$y(t) = \alpha + \beta t + x(t), t = 1, 2, \dots \quad (2)$$

We estimate the parameters in the model given by Equations (1) and (2) by using the Whittle function, which is an approximation to the likelihood function and use the frequency domain in its implementation. More in particular, we use a version of a testing procedure (Robinson, 1994) that tests the null hypothesis:

$$H_0 : d = d_0, \quad (3)$$

for any real value d_0 , in a model given by (1) and (2). Among the many advantages of this method, we should indicate its standard null and local limit behavior unlike most unit root testing procedures (e.g., Dickey and Fuller, ADF, 1979) that display a non-standard behavior and must rely on numerical calculations based on simulation studies. Moreover, since d is real, it permits to consider the classical $I(0)$ and $I(1)$ approaches as particular cases of interest.

3. Data

Due to availability of data, we have used the data of food imports in 20 OECD countries from 1963 to 2021 in the analysis. Specifically, we have used real food imports (in 2010 US\$ prices) and real food imports per capita. The food imports in current values and the relevant consumer price index (which have been used to deflate food imports series in order to generate the real food imports) datasets have been obtained from *World Development Indicators* of the World Bank. The population data (which have been used to deflate real imports series to generate the real food imports per capita) have been obtained from *World Development*

Indicators of the World Bank. We have ended the coverage of our analysis in 2021, because the data was available until 2021 at the commencement of the writing of this paper. We have only considered 20 OECD countries out of a possible 38 OECD countries as only 20 OECD countries have full dataset for real food imports and real food imports per capita, for the 1963–2021 period.

The descriptive statistics of real food imports and real food imports per capita in 20 OECD countries are reported in Table 1. It is shown that Germany, New Zealand, Japan, Italy, France, and United Kingdom are the largest countries in terms of the size of real food imports. This is not surprising given that most of these countries have the largest economies. Iceland, United Kingdom, Denmark, Ireland, Greece, and Switzerland are largest countries in terms of the size of real food imports per capita. In order to have a clearer view, we have displayed the trend of real food imports and real food imports per capita in Figs. 1 and 2 respectively. There is an increase in real food imports in many countries in most of the years under review. There is also an increase in real food imports per capita in many countries, especially since the year 2000.

4. Empirical results

The examined model is the one given by Equations (1) and (2), i.e.,

$$y(t) = \alpha + \beta t + x(t); \quad (1 - L)^d x(t) = u(t), t = 1, 2, \dots, \quad (4)$$

where $u(t)$ is supposed to be a white noise process with zero mean and constant variance. The results in Tables 2 and 3 refer to the imports, while those in Tables 4 and 5 to the imports per capita. In Tables 2 and 4 we report the values of d and their associated confidence intervals at the 95% level, under three different assumptions.

- i) imposing that $\alpha = \beta = 0$ a priori, i.e., we do not include either a constant nor a time trend (results reported in the second column of the table),
- ii) imposing that $\beta = 0$ a priori, i.e., we include an intercept but not a time trend (results reported across the third column in the table), and
- iii) with a constant and a linear time trend, so α and β are estimated along with d (column 4).

We mark in bold in Tables 2 and 4 the selected specification for each series, this selection being made according to the t -values of the estimated coefficients, which are reported respectively in Tables 3 and 5.

Starting with the results for the imports, we observe that the estimates of the integration factor, d , are large in all cases, being close to 1 or above 1. The unit root null hypothesis, i.e., $d = 1$ cannot be rejected in 15 countries, being rejected in favor of $d > 1$ for the remaining 5 which are Iceland ($d = 1.49$), Canada (1.30), Italy (1.29), Portugal (1.26) and United Kingdom (1.22). On the other hand, seven countries display a positive trend: Austria, Australia, Germany, Japan, Korea, the Netherlands and Switzerland, the highest coefficient corresponding to the Netherlands (0.0425) and Japan (0.0423).

We see in the tables that Canada, Iceland, Italy, Portugal and United Kingdom are again the five countries where the unit root null hypothesis is rejected in favor of $d > 1$. In the rest of the cases we cannot reject $d = 1$. The time trends are found significant also in the same seven countries as with the previous case of imports: Austria, Australia, Germany, Japan, Korea, the Netherlands and Switzerland and the highest values correspond now to Japan.

The foregoing results have generally shown that the real food imports and real food imports per capita in OECD countries are highly persistent. Korea Republic and Australia display the lowest degrees of integration while Iceland the highest one in the two variables examined. The result of real food imports per capita for Iceland is not surprising given that the country appears to be among the largest in terms of real food imports per capita. According to Gil-Alana et al. (2023), shocks will

Table 1
Descriptive statistics of food imports series.

Panel A: Real food imports					Panel B: Real food imports per capita				
Series	Mean	Standard Deviation	Maximum Value	Minimum Value	Series	Mean	Standard Deviation	Maximum Value	Minimum Value
AUSTRIA	5670.46	4157.88	13252.32	1192.78	AUSTRIA	689.58	470.22	1532.47	160.30
AUSTRALIA	5916.28	3808.59	13542.94	2182.98	AUSTRALIA	309.66	126.10	567.55	195.43
CANADA	16534.06	9522.02	36213.13	5858.66	CANADA	547.48	217.04	963.19	288.79
DENMARK	7298.77	3304.44	13580.86	2919.63	DENMARK	1361.26	545.71	2472.11	596.83
FINLAND	2885.05	1389.07	5705.96	1360.33	FINLAND	562.19	238.01	1049.09	277.49
FRANCE	35703.58	13851.76	62236.15	15436.16	FRANCE	592.39	181.60	918.62	311.24
GERMANY	49129.36	25606.03	94291.53	10711.16	GERMANY	607.79	307.48	1155.81	143.36
GREECE	11119.06	5053.12	25146.08	5249.61	GREECE	1143.06	602.03	2816.20	482.45
ICELAND	5555.19	8367.98	24852.73	339.10	ICELAND	26785.01	42345.34	131446.02	1285.79
IRELAND	4859.13	2261.42	10184.59	2374.80	IRELAND	1241.90	359.86	2065.89	672.29
ITALY	38237.80	21757.87	79273.25	6137.28	ITALY	308.43	163.94	620.37	64.00
JAPAN	42663.60	12958.57	83586.56	24912.40	JAPAN	752.60	235.64	1526.66	437.26
KOREA	1982.83	1191.54	4671.36	837.22	KOREA	524.22	211.06	942.34	257.90
REPUBLIC					REPUBLIC				
NETHERLANDS	12227.59	7546.71	32117.45	2307.43	NETHERLANDS	271.97	131.11	620.69	80.39
NEW ZEALAND	48674.65	12701.06	76193.04	27222.86	NEW ZEALAND	828.64	227.29	1410.98	481.39
PORTUGAL	6247.34	3507.93	15112.45	1992.74	PORTUGAL	852.31	375.64	1736.38	328.42
SPAIN	7972.73	4218.69	16646.47	3697.18	SPAIN	885.01	394.12	1716.82	442.76
SWEDEN	23194.59	9199.92	40867.40	8409.72	SWEDEN	567.46	171.91	863.19	218.61
SWITZERLAND	9987.33	4541.79	27290.43	4104.98	SWITZERLAND	1032.49	530.12	3117.35	409.53
UNITED	31368.69	20524.09	75164.39	6554.34	UNITED	1980.70	1134.72	4287.01	547.75
KINGDOM					KINGDOM				

Real food imports are in per US million dollars. Real food imports per capita are in raw form.

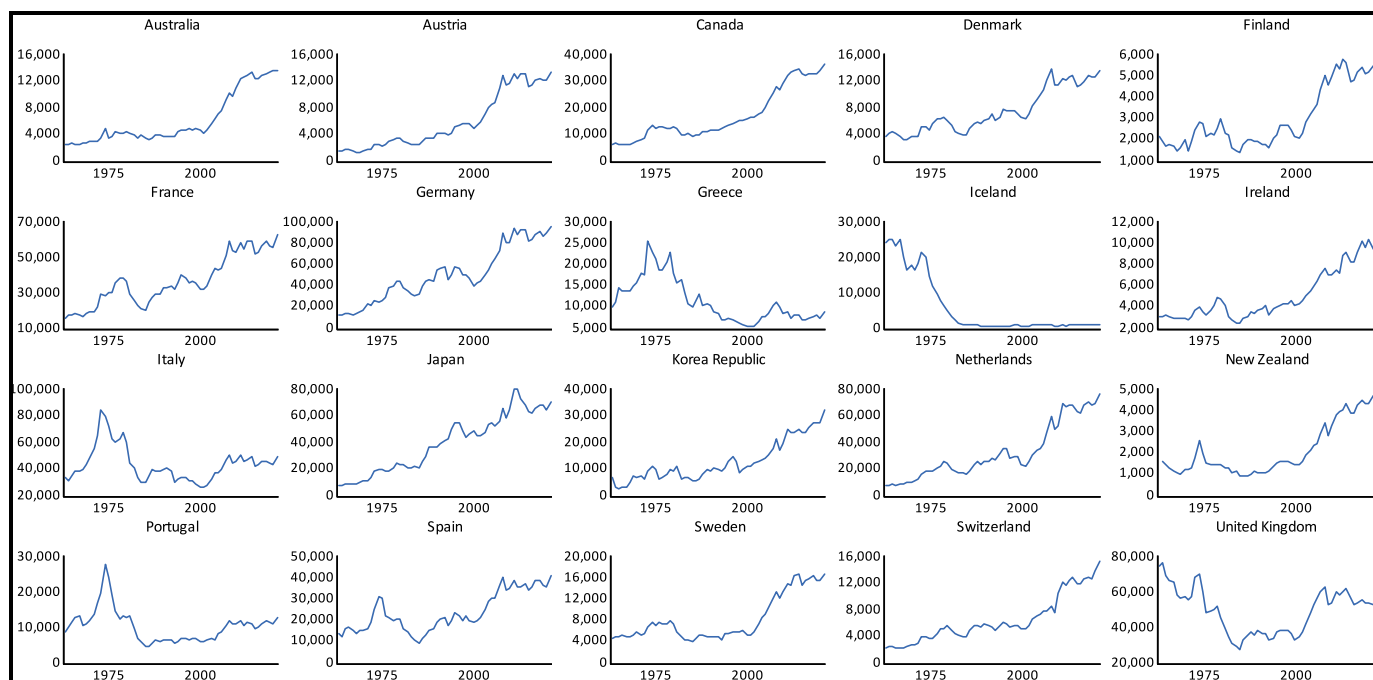


Fig. 1. Real food imports (per US million dollars) in 20 OECD countries, 1963–2021.

generate in a greater deviation from the long-run equilibrium path, as it is more difficult for big importers to quickly move back to long-run equilibrium.

A feasible rationale for the foregoing empirical results is that a majority of the events that determine food imports are persistent in nature. According to Solarin et al. (2022), a series which is dependent on other series that are persistent will absorb this persistence from these other series that might be or not be country-specific. Long-run income growth, domestic consumption of food items and rapid urbanization are among the prominent determinants of food imports (Ferjani et al., 2018; Olabisi et al., 2021). Studies such as Gil-Alana et al. (2023) and Aslanidis and

Fountas (2014) have shown that income growth is a persistent series, while Hong et al. (2021) argue in favor of the persistence of urbanization.

Another rationale for the persistence of the food imports is that apart from its past values, the series continues to be affected by a rising number of determining factors. Many additional series continue to influence food imports (Kaitibie et al., 2017). According to Hobday et al. (2016), the larger the number of the determinants of a series is, the more persistent and less predictable is the variable. In addition to several factors in the importing countries, inflation, corruption perception, trade openness in the food exporting economies are also determinants of

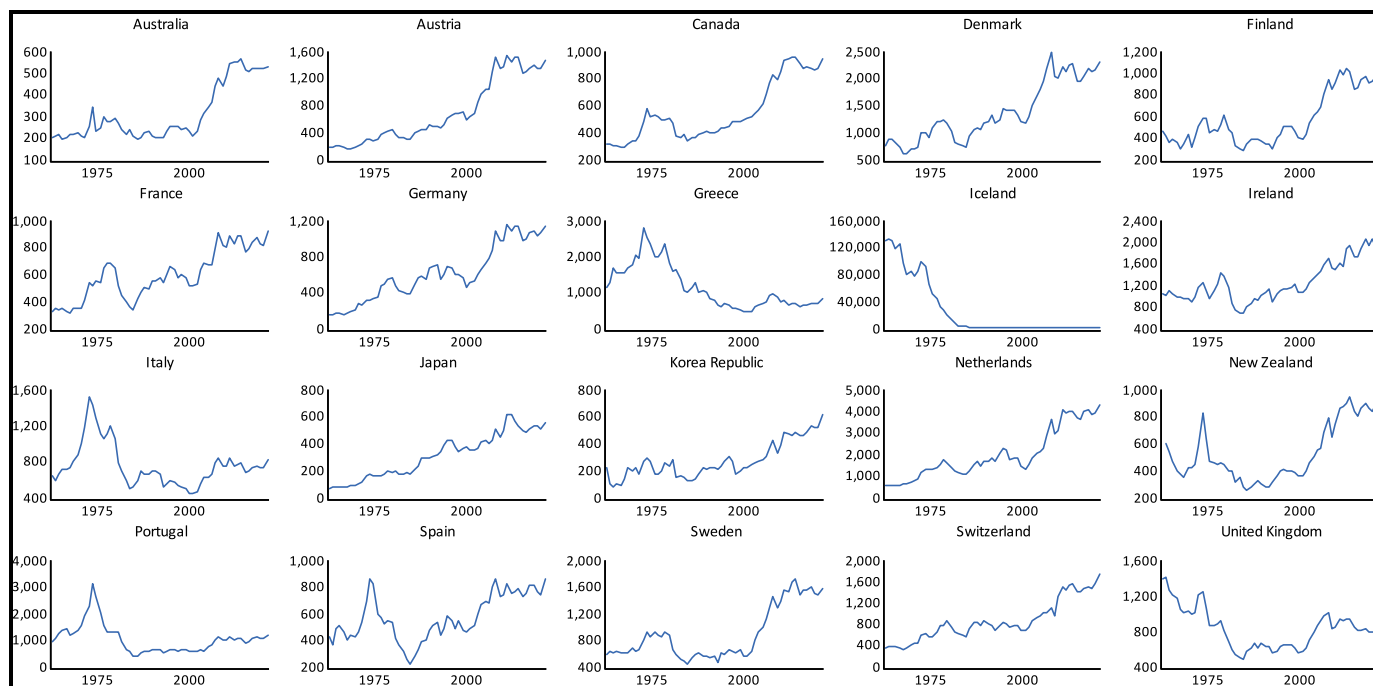


Fig. 2. Real food imports per capita in 20 OECD countries, 1963–2021.

Table 2
Estimates of d under three different scenarios. Real Imports.

Series	No terms	With an intercept	With a time trend
AUSTRIA	0.94 (0.77, 1.18)	1.09 (0.84, 1.51)	1.09 (0.81, 1.50)
AUSTRALIA	0.94 (0.77, 1.18)	0.90 (0.78, 1.10)	0.88 (0.74, 1.11)
CANADA	0.94 (0.77, 1.18)	1.30 (1.09, 1.61)	1.29 (1.09, 1.60)
DENMARK	0.94 (0.77, 1.18)	1.07 (0.81, 1.47)	1.07 (0.78, 1.47)
FINLAND	0.93 (0.76, 1.17)	0.96 (0.79, 1.26)	0.95 (0.75, 1.26)
FRANCE	0.94 (0.77, 1.18)	1.11 (0.84, 1.47)	1.11 (0.86, 1.45)
GERMANY	0.94 (0.78, 1.18)	0.97 (0.73, 1.25)	0.98 (0.80, 1.23)
GREECE	0.96 (0.80, 1.19)	1.06 (0.90, 1.31)	1.06 (0.89, 1.30)
ICELAND	0.94 (0.77, 1.17)	1.49 (1.33, 1.74)	1.48 (1.32, 1.74)
IRELAND	0.94 (0.77, 1.17)	1.02 (0.82, 1.40)	1.02 (0.78, 1.41)
ITALY	0.94 (0.78, 1.18)	1.29 (1.06, 1.66)	1.29 (1.06, 1.67)
JAPAN	0.94 (0.78, 1.18)	1.08 (0.80, 1.45)	1.07 (0.88, 1.39)
KOREA REP.	0.91 (0.75, 1.14)	0.79 (0.62, 1.22)	0.71 (0.42, 1.23)
NETHERLANDS	0.94 (0.77, 1.18)	1.09 (0.81, 1.46)	1.08 (0.84, 1.44)
NEW ZEALAND	0.93 (0.76, 1.17)	1.09 (0.93, 1.39)	1.10 (0.91, 1.39)
PORTUGAL	0.95 (0.77, 1.19)	1.26 (1.05, 1.59)	1.26 (1.05, 1.58)
SPAIN	0.94 (0.78, 1.18)	1.11 (0.87, 1.47)	1.11 (0.87, 1.47)
SWEDEN	0.94 (0.78, 1.18)	1.09 (0.94, 1.31)	1.09 (0.94, 1.32)
SWITZERLAND	0.94 (0.78, 1.18)	0.96 (0.73, 1.36)	0.98 (0.74, 1.35)
UNITED KINGDOM	0.94 (0.77, 1.17)	1.22 (1.02, 1.58)	1.22 (1.02, 1.57)

Note: The values reported in this table are the estimates of the differencing parameter (d) and those in bands are the non-rejection values of d . Column 2 refers to the case with no deterministic terms; in column 3, the estimates of d refer to a model with an intercept, while those in column 4 include a constant and a linear time trend. In bold, the most appropriate specification for each series.

food imports (Kaitibie et al., 2017).

5. Conclusions

We have examined the persistence of food imports series in 20 OECD countries using yearly data from 1963 to 2021. Two series to represent food imports series—real food imports and real food imports per capita—have been analysed in this study. Using fractional integration methods, the empirical results indicate that persistence of food imports exists in the examined countries. Although no evidence of mean

reversion is found in any single case, Korea Republic and Australia display the lowest degrees of integration.

An implication of the preceding results is that shocks to food imports are permanent or long-term in nature. Therefore, long-term measures are needed to address mounting food imports to improve food security including in the rural areas. Introduction and utilization of more cutting-edge technologies are among the measures that are long-term in nature. The latest sky farming techniques are part of the cutting-edge technologies that can be employed across different OECD countries to boost productivity, food production, and decrease food imports. Since food production takes place in many rural areas in OECD countries, the implementation of the long-term policies is expected to boost the prospects of the rural communities in the OECD countries. More allocations to rural areas in the government budgets are also expected because agriculture inclusive of food production is the dominant economic activity in many rural regions, and long-term policies require bigger capital allocations relative to short term measures. In other words, capital expenditures rather than revenue expenditures should dominate budgets allocations to food production (to reduce food imports) in OECD countries.

The results also suggest that standalone short-term policies to address food imports might have only a temporary effect on food production and food imports. Standalone short-term policies, which include direct subsidies (including fertilizer subsidies) will only have momentary impact on food imports if, they are not supplemented by long term policies. The results of the study also indicate that a reduction in the reliance on food imports to support food assistance programmes in the rural areas of OECD should be a viable policy option. Moreso, any disruption in food imports that will have a long-term effect on the viability of the food assistance programmes in the rural areas. Some of the existing food assistance programmes in the OECD countries include Supplemental Nutrition Assistance Program (formerly Food Stamps) in the United States; Nutrition North Canada in Canada, Food Voucher Assistance Programme (FVAP) in Korea Republic; and Healthy Start Scheme in the United Kingdom (OECD, 2022). The results also have implications for international policies as it suggests that relying solely on international trade policies that have short term outlooks (including import quota) might not effectively reduce or create viable local

Table 3
Estimated coefficients for the selected specifications in Table 2.

Series	D	Intercept (tvalue)	Time trend (tvalue)
AUSTRIA	1.09 (0.81, 1.50)*	20.886 (208.46)	0.0407 (3.15)
AUSTRALIA	0.88 (0.74, 1.11)*	21.474 (208.09)	0.0315 (3.59)
CANADA	1.30 (1.09, 1.61)	22.510 (366.43)	–
DENMARK	1.07 (0.81, 1.47)*	21.979 (213.83)	–
FINLAND	0.96 (0.79, 1.26)*	21.449 (157.79)	–
FRANCE	1.11 (0.84, 1.47)*	23.446 (249.91)	–
GERMANY	0.98 (0.80, 1.23)*	23.058 (206.92)	0.0374 (2.77)
GREECE	1.06 (0.90, 1.31)*	22.975 (176.98)	–
ICELAND	1.49 (1.33, 1.74)	23.897 (192.86)	–
IRELAND	1.02 (0.82, 1.40)*	21.729 (212.58)	–
ITALY	1.29 (1.06, 1.66)	24.231 (244.62)	–
JAPAN	1.07 (0.88, 1.39)*	22.485 (235.06)	0.0423 (2.62)
KOREA REP.	0.71 (0.42, 1.23)*	22.266 (110.96)	0.0317 (3.16)
NETHERLANDS	1.08 (0.84, 1.44)*	22.557 (198.83)	0.0425 (2.13)
NEW ZEALAND	1.09 (0.93, 1.39)*	21.175 (121.68)	–
PORTUGAL	1.26 (1.05, 1.59)	22.799 (167.02)	–
SPAIN	1.11 (0.87, 1.47)*	23.301 (179.79)	–
SWEDEN	1.09 (0.94, 1.31)*	22.188 (217.75)	–
SWITZERLAND	0.98 (0.74, 1.35)*	21.378 (224.03)	0.0348 (3.01)
UNITED KINGDOM	1.22 (1.02, 1.58)	25.042 (310.77)	–

Note: The values reported in column 2 are the estimated values of d and their associated 95% confidence bands. Those in columns 3 and 4 are the estimates of the constant and the linear time trend and their corresponding t-values. * indicates that the unit root null hypothesis ($d = 1$) cannot be rejected at the 5% level.

Table 4
Estimates of d under three different scenarios. Real Imports per capita.

Series	No terms	With an intercept	With a time tren
AUSTRIA	0.93 (0.75, 1.19)	1.10 (0.84, 1.51)	1.10 (0.81, 1.50)
AUSTRALIA	0.93 (0.77, 1.19)	0.89 (0.76, 1.10)	0.88 (0.74, 1.10)
CANADA	0.94 (0.76, 1.18)	1.28 (1.07, 1.60)	1.28 (1.07, 1.59)
DENMARK	0.95 (0.77, 1.20)	1.07 (0.81, 1.47)	1.07 (0.78, 1.47)
FINLAND	0.91 (0.74, 1.16)	0.96 (0.78, 1.26)	0.95 (0.75, 1.26)
FRANCE	0.95 (0.77, 1.20)	1.11 (0.83, 1.46)	1.11 (0.85, 1.45)
GERMANY	0.94 (0.78, 1.18)	0.97 (0.74, 1.25)	0.98 (0.80, 1.23)
GREECE	0.99 (0.84, 1.23)	1.07 (0.92, 1.31)	1.07 (0.91, 1.31)
ICELAND	0.98 (0.82, 1.21)	1.49 (1.33, 1.74)	1.48 (1.32, 1.73)
IRELAND	0.93 (0.76, 1.16)	1.00 (0.78, 1.39)	1.00 (0.74, 1.40)
ITALY	0.96 (0.78, 1.19)	1.28 (1.05, 1.65)	1.28 (1.05, 1.66)
JAPAN	0.96 (0.78, 1.22)	1.03 (0.74, 1.42)	1.03 (0.82, 1.38)
KOREA REP.	0.83 (0.67, 1.05)	0.78 (0.59, 1.22)	0.72 (0.44, 1.22)
NETHERLANDS	0.95 (0.78, 1.19)	1.08 (0.81, 1.46)	1.08 (0.83, 1.45)
NEW ZEALAND	0.91 (0.74, 1.16)	1.08 (0.90, 1.38)	1.08 (0.90, 1.37)
PORTUGAL	0.98 (0.79, 1.21)	1.27 (1.06, 1.58)	1.27 (1.06, 1.58)
SPAIN	0.93 (0.77, 1.18)	1.11 (0.88, 1.47)	1.11 (0.87, 1.47)
SWEDEN	0.94 (0.77, 1.19)	1.09 (0.93, 1.31)	1.09 (0.93, 1.31)
SWITZERLAND	0.94 (0.77, 1.19)	0.97 (0.73, 1.35)	0.97 (0.73, 1.34)
UNITED KINGDOM	0.93 (0.76, 1.18)	1.21 (1.01, 1.58)	1.21 (1.01, 1.57)

Note: The values reported in this table are the estimates of the differencing parameter (d) and those in bands are the non-rejection values of d. Column 2 refers to the case with no deterministic terms; in column 3, the estimates of d refer to a model with an intercept, while those in column 4 include a constant and a linear time trend. In bold, the most appropriate specification for each series.

Table 5
Estimated coefficients for the selected specifications in Table 4.

Series	d	Intercept (tvalue)	Time trend (tvalue)
AUSTRIA	1.10 (0.81, 1.50)*	5.104 (50.86)	0.0367 (1.94)
AUSTRALIA	0.88 (0.74, 1.10)*	5.278 (51.27)	0.0168 (1.92)
CANADA	1.28 (1.07, 1.60)	5.761 (92.65)	–
DENMARK	1.07 (0.81, 1.47)*	6.621 (64.54)	–
FINLAND	0.96 (0.78, 1.26)*	6.123 (44.96)	–
FRANCE	1.11 (0.83, 1.46)*	5.758 (61.43)	–
GERMANY	0.98 (0.80, 1.23)*	4.931 (44.00)	0.0355 (2.62)
GREECE	1.07 (0.92, 1.31)*	7.021 (52.83)	–
ICELAND	1.49 (1.33, 1.74)	11.774 (95.21)	–
IRELAND	1.00 (0.78, 1.39)*	6.935 (67.92)	–
ITALY	1.28 (1.05, 1.65)	6.481 (65.56)	–
JAPAN	1.03 (0.82, 1.38)*	4.117 (43.28)	0.0373 (2.69)
KOREA REPUBLIC	0.72 (0.44, 1.22)*	5.143 (25.30)	0.0206 (1.96)
NETHERLANDS	1.08 (0.83, 1.45)*	6.268 (54.75)	0.0345 (1.71)
NEW ZEALAND	1.08 (0.90, 1.38)*	6.411 (52.00)	–
PORTUGAL	1.27 (1.06, 1.58)	6.781 (49.20)	–
SPAIN	1.11 (0.88, 1.47)*	6.046 (46.88)	–
SWEDEN	1.09 (0.93, 1.31)*	6.335 (62.03)	–
SWITZERLAND	0.97 (0.73, 1.34)*	5.832 (60.84)	0.0263 (2.33)
UNITED KINGDOM	1.21 (1.01, 1.58)	7.246 (89.19)	–

Note: The values reported in column 2 are the estimated values of d and their associated 95% confidence bands. Those in columns 3 and 4 are the estimates of the constant and the linear time trend and their corresponding t-values. * indicates that the unit root null hypothesis ($d = 1$) cannot be rejected at the 5% level.

alternatives to food imports. Besides, the reliance on revenue tariff on food imports might not be sustainable as any disruption on food imports might lead to a long-term decrease in the revenue derived from food import duties. Many OECD countries have implemented several forms of protectionism policies to combat imports over the past decades.

The empirical findings also imply that it is not feasible to predict the subsequent figures of food imports by simply relying on their past values. There is a need to consider the role of other possible factors in projecting food imports. Hence the AGLINK-COSIMO model, which is used to predict different food series can be augmented by including more possible factors of food imports in the prediction of food imports. The empirical results also indicate that empirical papers involving food imports should use more advanced econometrics techniques beyond the OLS method in order to generate more reliable output.

This study is characterized by a few limitations. The study has only focused on food imports in selected OECD countries due to data limitation. With availability of relevant data in the future, subsequent studies can include more OECD countries as well as non-OECD countries in their analyses. Structural breaks can also be included in future papers. Note that fractional integration and potential breaks in the data are very much related (Granger and Hyung, 2004; Gil-Alana, 2008; etc.) and not taking them into account may produce spurious evidence of long memory. The inclusion of structural breaks will reveal the impact of different important events on the persistence of food imports. As an alternative to the existence of breaks, non-linear structures, either deterministic or stochastic, still in the context of fractional integration is

another line of future research with these data.

CRedit authorship contribution statement

Sakiru Adebola Solarin: Writing – review & editing, Writing – original draft, Supervision, Project administration, Data curation, Conceptualization. **Luis A. Gil-Alana:** Writing – original draft, Software, Methodology, Investigation, Formal analysis, Conceptualization.

Declaration of competing of interest

There is no conflict of interest with the publication of the present manuscript.

Data availability

Data will be made available on request.

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