Eggs first or chickens? A re-examination of Granger causality between increase in government spending and GDP growth.

PARK Seung-Joon[1]

Japanese original, 28 Jun. 2022

English translation, 06 Jul. 2022.

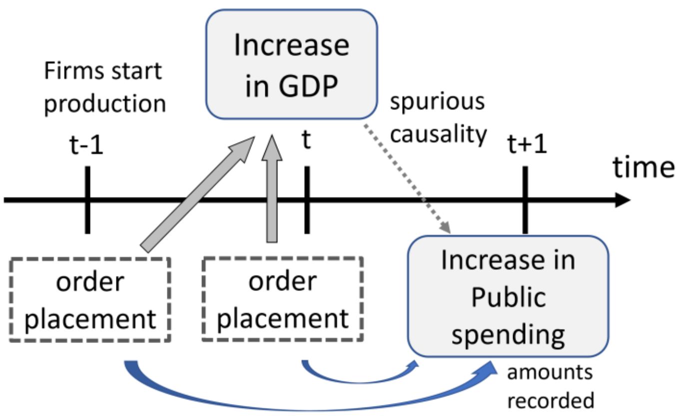
machine translation with author's correction

Draft, please do not quote

Abstract

Based on data from various countries, a strong correlation was noted between the growth rate of government expenditure and the growth rate of nominal and real GDP, but there was some debate about the direction of causality. In this paper, a simple theoretical simulation model was first constructed to show that scatter plots similar to those actually observed can be drawn in either direction we assume the causality. We then tested Granger causality between general government expenditure, nominal GDP and GDP deflators using data from 1980 to 2021 for 38 OECD countries, and found that the results differed significantly from country to country at different time periods, with many cases suggesting a causality from growth to government expansion. However, as government expenditure statistics such as in the SNA are produced on an accrual basis, the point in time when the amounts are recorded may be later than when the orders are placed, which means that 'spurious causality' may be observed. Therefore, we tried using the lead variable (a variable of later period) of public spending to test for Granger causality, and found that the results could change. To examine this point in more detail, we used quarterly data from the Japanese GDP statistics (1994-2021), namely nominal GDP, government fixed capital formation and government consumption. We found that in Japan since 2008 there was (practically) no causal relationship in neither direction without lead variables. However, with lead variables of government expenditure, one-way Granger causality from public spending to nominal GDP was observed.

Figure: possible spurious causality from change in GDP to public spending



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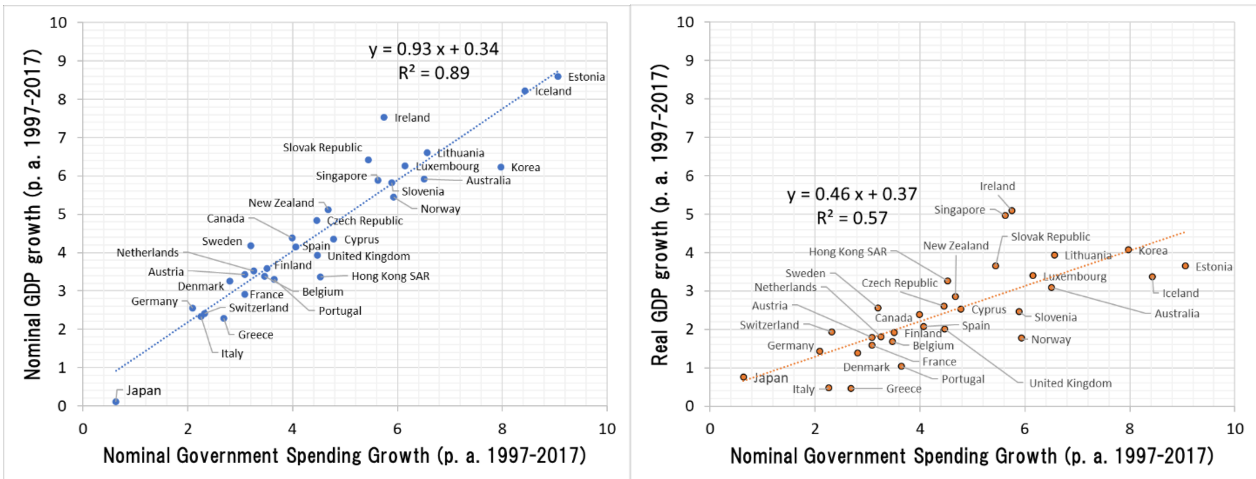
1. Introduction.

There is a clear correlation between the nominal/real GDP growth rates of countries and the growth rate of government expenditure (Shimakura 2018, Park & Shavetail 2020; Figure 1). Moreover, it is noteworthy in these figures that there are no dots significantly to the upper left or lower right of the regression line. This means that 'no country has high GDP growth without increasing government spending, and no country has low GDP growth with increased government spending' or 'no country increases public spending following GDP growth'. Here, Japan is among the lowest in the world, both in terms of the growth rate of government expenditure and in real/nominal economic growth. Therefore, the proponents of active fiscal policy (including the author) who are focused on getting Japan out of its current recession tells us that government spending should be increased.

In contrast, Atkinson (2022) casts doubt on this interpretation of causal direction, stating that "some people say that if you increase government spending the economy will grow, but this logic is too simplistic. Frankly, this claim is wrong" and cites a review by Nyasha et al. (2019) (summarised in Appendix 1) as an argument supporting his view.

Figure 1: Correlation between government spending growth and growth of nominal GDP (left) and real GDP (right)



Source: Park & Shavetail (2020), p. 173.
Note: Average annual growth rates over the last 20 years of real/nominal GDP and general government expenditure (nominal) for each country. The original data are from IMF *World Economic Outlook* (2019),

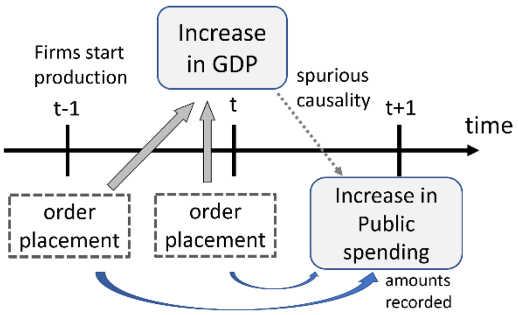
The review describes existing studies that address the causality between government spending and economic growth. According to the review, the results belong to 1 of four views: "(1) *Keynesian view*: the size of government is the cause of economic growth [6 studies]", "(2) *Wagner's Law*: government is inefficient and cannot promote economic growth [22 studies], "(3) *Bidirectional causality view*: there is a bi-directional causal relationship [10 studies]" and "(4) *Neutrality view*: there is no relationship [12 studies]". Various statistical methods are used with the main ones being Granger Causality tests (see Section 3), and studies using other methods practically applies the same concept of causality. On the basis of this review, Atkinson stated that it is wrong to say that the economy will grow if government spending is increased. But it is difficult to conclude this way.

Firstly, the results of causality tests (as the review concerned concludes) vary from country to country and from period to period. Although the view (2) seems at first glance reasonable on the basis of numbers, this is not something that should be decided by majority vote.

Secondly, a review of the papers included in this review shows that the overwhelming majority are based on data from developing countries such as Africa, and moreover, the studies are not necessarily new (none of them deal with sufficient data from developed countries since the global financial crisis in 2007).

Furthermore, GDP and fiscal statistics are recorded on an accrual or cash basis, which means that the amount of government expenditure is recorded long after orders have been placed, such as for public works[2]. Therefore, a spurious causal relationship can occur. That is, long before the statistical amount of government expenditure increases, orders may have been placed by the government to enterprises, and when the enterprises have started production the GDP would have been increased (Figure 2). Existing studies summarised in Nyasha et al. (2019) (Appendix 1) seems not explicitly take this issue this into account, but the authors of previous studies may need to revise their conclusions.

Figure 2: Timing issues of statistical government expenditure



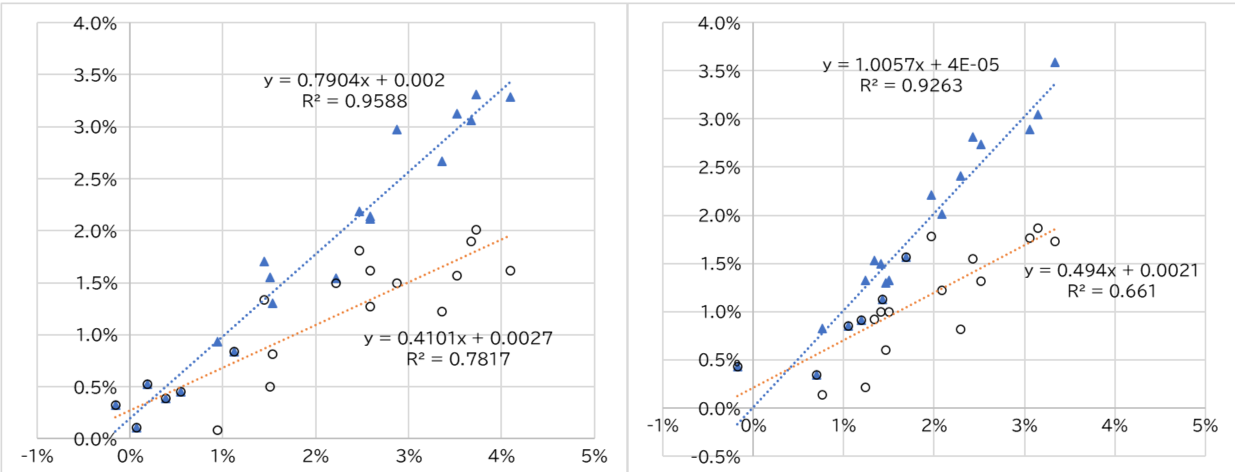
Source: prepared by the author.

[2] This problem was pointed out by Mukai (2010). Tanaka and Adachi (2003) found that a monthly comparison of consumer prices and the government budget balance in 1933, when the US economy improved, showed that the rise in prices progressed about six months faster than the rise in the budget deficit, making the argument that fiscal stimulus caused inflation untenable (ibid., p. 88, Fig. 4). However, while the fiscal balance is expenditure-based, the effects of fiscal stimulus occur when the order placed. As soon as a company receives an order, it places a bulk order for raw materials and construction machinery, contracts with labour and related companies and starts construction and production, which affects material prices and wages. On the other hand, the government's spending is delayed for some months after the order, and takes place ex post and in stages" (Mukai 2010, p. 299).

Finally, it is disconcerting (even though there are a number of studies based on this conceptualisation) to refer to the position that asserts a causal link from economic growth to increased government expenditure as 'Wagner's Law', since Wagner (1958, 1883) 'pointed to a law of expansion of public sector activity (especially state activity)' but did not point to a causal link from national income to government expenditure (-> Appendix 2).

The paper first examines the mechanism behind the appearance of the graphs shown in Figure 1 using a simple theoretical simulation model, taking into account both causalities 'from government expenditure to GDP (G->Y)' and 'from GDP to government expenditure (Y->G)'. Next, using annual data from 1990 to 2021 for 38 current OECD member countries, we perform Granger causality tests for the full period, pre-2007 and post-2008 (the available data period varies from country to country). Here, we also pay attention to how the results change when taking into account the issue of the timing of government spending orders and the point in time when the amounts are recorded in the statistics. Finally, a more detailed causality study is conducted based on quarterly data focusing on Japan from 2008 onwards. Based on these findings, we conclude.

Figure 3: Graphs with the direction of causality as 'G->GDP' (left) and 'GDP->G' (right)



Source: author's calculations.
Note: The horizontal axis is government expenditure growth, the ▲ vertical axis is nominal GDP growth and the ○ vertical axis is real commission GDP growth.

2. Simple simulation of the relationship between government expenditure and GDP

This section presents the results of simulations based on common-sense macroeconomic theory and discusses the causal relationship between government expenditure and nominal and real GDP (see Appendix 3 for details). The system of theoretical equations is made simple so that everyone can easily understand it, through simple one-way calculations with no feedback. Each country develops its own GDP supply capacity (Y^s, real), but GDP is actually generated in response to aggregate demand (Y^D, nominal aggregate demand = consumption + private capital investment + government expenditure). Y^D divided by the price index (P) is real aggregate demand. If this exceeds the supply capacity, price inflation will occur and real growth will be hampered. Under these common-sense assumptions, 20-year estimates were made for hypothetical countries (in this case 20 coutries), with varying parameters, and the results were compared.

The left-hand diagram in Figure 3 is produced based on the causality from government expenditure to GDP (G to GDP; i.e. each country's government expenditure continues to increase at a constant growth rate independent of GDP), while the right-hand diagram shows the results based on the causality from GDP to government expenditure (GDP to G; government expenditure is a constant percentage of nominal GDP in the previous year). The horizontal axis is the growth rate of public spending and the vertical axis is the growth rate of national income, where '▲' is nominal GDP and '◯' is real GDP. In both cases, it was found that the figures are broadly similar to Figure 1.

In practice, there may be a difference in the direction of short-term causality between periods when effective demand is lower than supply and periods when demand has reached the ceiling of supply capacity. In the next section, we use time-series data for several countries to apprehend causality in Granger's sense dividing the time period.

3. The Granger causality test with data from OECD countries

Granger causality tests are useful to ascertain whether increases in government expenditure precede GDP growth or vice versa. For example, Thurman et al. (1988) used time series data to test whether 'eggs come first or chickens come first' and published in *the Journal of Agricultural Economics*.

The review by Nyasha et al. (2019), presented in the Introduction (Appendix 1), includes a number of studies using this type of methodology. Focusing on recent data from developed countries, Granger causality tests are conducted here for 38 OECD Member States as of June 2022.

3.1. Data and analysis methods

Data are nominal GDP (*Y*), real GDP and general government expenditure (*G*) for 38 OECD member countries from the IMF's *World Economic Outlook Database* (April 2022).[3] The data period is 1980-2021, but varies from country to country. The GDP deflator (*P*) is obtained by dividing nominal GDP by real GDP.

Tests of Granger causality are generally based on the following formulas for regression analysis, with the null hypotheses $\beta_1 = \beta_2 = \cdots = \beta_l = 0$, and $\delta_1 = \delta_2 = \cdots = \delta_l = 0$, where $\varDelta$ is the symbol for the time difference of the respective variable, and the lowercase letter *l is* the number of lags of the explanatory variable

$$\varDelta y_t = \alpha_0 + \alpha_1 \varDelta y_{t-1} + \cdots + \alpha_l \varDelta y_{t-l} + \beta_1 \varDelta x_{t-1} + \cdots + \beta_l \varDelta x_{t-l} + \varepsilon_t \qquad \text{(Equation 1)}$$

[3] The General Government Gross Expenditure (GGX) in the relevant IMF database is from the IMF's *Government Finance Statistics* (GFS). It includes central government as well as local governments and social security funds, etc., but does not include government enterprises (IMF 2014, p. 18). It also includes social security-related transfer payments, unlike government expenditure in the GDP statistics (IMF GFS database). The author's intention was to use government expenditure (government consumption and public fixed capital formation only), which is included in the definition formula for expenditure-side GDP, but statistics matching it were difficult to obtain in the database which includes many countries, so this was used instead.

$$\Delta x_t = \gamma_0 + \gamma_1 \Delta x_{t-1} + \cdots + \gamma_l \Delta x_{t-l} + \delta_1 \Delta y_{t-1} + \cdots + \delta_l \Delta y_{t-l} + \mu_t \qquad \text{(Equation 2)}$$

In Equation 1, if the coefficients $\beta_1 = \beta_2 = \cdots = \beta_l$ are all zero, we can say that the past values of Δx do not affect Δy_t (not causal in the Granger sense), and in Equation 2 if $\delta_1 = \delta_2 = \cdots = \delta_l$ are all zero, we can say that the past values of Δy do not affect Δx_t (not causal in the Granger sense). This is confirmed by the F-test (Wald's test). Depending on the results of the test, not only one-way causality but also two-way causality may be confirmed, or there may be cases where no causality is found between each other (independent or neutral).

The reason for taking time-differences for each variable is that in many cases, the level values of time series data have a unit root (and therefore are not stationary) and should not be used in regression analysis, but by taking time-differences they become stationary (Enders 2019, p. 190). First, the unit root test for each variable is performed in the next section.

3.2. Unit root test

For the GDP deflator (P), general government expenditure (G) and nominal GDP (Y) for 38 countries, we first perform a unit root test using the ADF test method to check for stationarity of the variables (Enders 2019, p. 209). Here, we use a formulation that includes a drift (constant term) and a linear trend, as these variables are considered to have an increasing trend along time (equation 3).

$$\Delta y_t = \alpha_0 + \gamma y_{t-1} + \alpha_2 t + \beta_1 \Delta y_{t-1} + \cdots + \beta_k \Delta y_{t-k} + \varepsilon_t \qquad \text{(Equation 3)}$$

Here, if the null hypothesis of $\gamma = 0$ can be rejected, there is no unit root. Table 1 shows the results. [4]

[Table 1 at the end of this report corresponds here].

We find that most of the level variables cannot reject the existence of a unit root; taking the first-order difference (Δ) eliminates the unit root of most cases, but some still have a unit root; taking the second-order difference ($^2\Delta$) eliminates the unit root of most cases, but a few still have a unit root. In this paper, Granger causality tests are only performed on variables with first-order differences. For this reason, we gave the sign of I(0) for differenced variables which is already stationary, the sign I(1) which becomes stationary after a further first-order difference, and the sign I(2) which becomes stationary only after a difference of two or more orders. [5]

3.3. Conducting the Granger causality test

For each of the 38 countries, pairs of GDP deflators (P), general government expenditure (G) and nominal GDP

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[4] The calculations were performed using EViews (ver. 12), which was programmed to calculate all three variables for all countries at once. The number of lag variables to be included in the estimation equation for each variable was automatically selected based on the Akaike Information Criterion (AIC).

[5] Unit root tests were only performed up to second-order differences, and those here that may need to take more than third-storey differences are also denoted as I(2) for convenience.

(Y) were selected and fitted to Equations 1 and 2 to perform Granger causality tests. For each country, six types of Granger causality were tested, with the direction of causality as 'influencing variable -> influenced variable': 'ΔP->ΔG', 'ΔG->ΔP', 'ΔY->ΔG', 'ΔG->ΔY', 'ΔY->ΔP' and 'ΔP->ΔY'. In doing so, due to the limited number of time series data periods available, all lags of variables included in the equations were limited to two periods in order to ensure sufficient estimation periods. [6]

Estimates for the entire period available (1980-2021 at most) are presented in Table 2, broken down before and after the global financial crisis, Table 3 using data from before 2007 and Table 4 using data from 2008 onwards. The values shown in the tables are p-values for the F-test. In these studies, the following points should be noted.

[Tables 2, 3 and 4 at the end of this report correspond here].

First, when two of the three variables, ΔP, ΔG and ΔY, were selected and paired, and when both were I(0) variables with no unit root, the results of the F test of Granger causality were used as is, with a significance level of 5%. The sign and significance of the coefficients were checked and when there was one significant variable, its sign (+ or -) was attached in front of the value. When there were two significant variables and the signs were identical, the sign was shown (+ or -), and when they were different, the signs of the coefficients of the lag variables in the first and second period were checked in turn, and the sign (+ -) or (- +) was attached. Those for which no significant variables were found were marked with an '○' sign for caution, but the results of the F-test were used as they were.

Second, if one of the above pairs of two variables is an I(0) variable and the other is an I(1) variable, the F-test is not available, but the significance of the coefficients can be checked using a t-test (Enders 2019, p. 294). In this case, the '*' sign is prefixed to the value in the table. Regardless of the result of the F-test, the coefficient of lag of the paired partner variable (β_1 and β_2 in Equation 1) is determined by the t-test at a significance level of 5 %. As in the preceding paragraph, the signs and coefficients are checked and marked with a symbol.

Furthermore, when both in the couple of the variables are I(1), or when at least one of the variables is an I(2) or higher (a variable for which the unit root remains even if the second-order difference is taken), it was decided to exclude from consideration as causality testing is difficult and the cell was painted black.

According to Table 2, which summarises the results using data from the entire period, the cases of causality 'ΔP->ΔG' were in four of the 28 countries available for consideration, 'ΔG->ΔP' in three of the 28 countries, 'ΔY->ΔG' in 15 of the 28 countries, 'ΔG->ΔY' in 6 of 32 countries for 'ΔY->ΔP', 11 of 32 countries for 'ΔP->ΔY' and 6 of 32 countries for 'ΔP->ΔY'. Thus, if we focus on the causal relationship between nominal GDP and government expenditure, more results show causality from the former to the latter than vice versa.

Table 3, which summarises the results using pre-2007 data, shows that the 'ΔP->ΔG' causality was confirmed in 2 of the 27 countries available for consideration, 'ΔG->ΔP' in 4 of the 27 countries, 'ΔY->ΔG' in 12 of the 28

[6] The calculations were made using EViews (ver. 12), which was programmed to perform Granger Causality tests for all three pairs of all target countries, including two periods of lag, automatically. Note that EViews has a simple Granger Causality view command and this programme produces the same results.

countries, '*ΔG->ΔY*' in 2 of the 28 countries, '*ΔY->ΔP*' is 10 out of 31 countries and '*ΔP->ΔY*' is 4 out of 31 countries. If we focus on the causal relationship between nominal GDP and government expenditure, more results show causality from the former to the latter than vice versa.

Figure 4, which summarises the results using data from 2008 onwards, shows that the causality of '*ΔP->ΔG*' was confirmed in 3 of the 28 countries available for consideration, '*ΔG->ΔP*' in two of the 28 countries, '*ΔY->ΔG*' in three of the 28 countries, '*ΔG->ΔY*' in one of the 28 countries, '*ΔY -> ΔP*' is five out of 32 countries and '*ΔP -> ΔY*' is six out of 32 countries. Overall, the short sample period may have made it difficult to obtain statistically significant results. Again, if we focus on the causal relationship between nominal GDP and government expenditure, more results show causality from the former to the latter (three countries) than vice versa (one country).

The above results appear to correspond with the review's finding of Nyasha et al. (2019) that GDP is most often the determinant of government expenditure, irrespective of the periods. However, this may be due to the issue of the timing of statistical government expenditure (Figure 2), as discussed in the Introduction. This issue is examined in more detail in the next section.

3.4. Analysis with “lead” on general government expenditure

In the previous section, more cases showed Granger’s causality '*ΔY->ΔG*' than cases of '*ΔG->ΔY*' for any of the periods taken. However, this does not necessarily mean that '*ΔY->ΔG*' is the predominant direction of causality. The discussion here pays attention to the issue of the timing at which general government expenditure (in particular of public construction projects) is recorded in the statistics.

In the IMF-GFS, the timing is the same as in the national accounts (SNA) and is recorded on an accrual basis (IMF 2014, p. 352, A7.6). In the SNA, fixed assets are recorded when ownership is transferred to the user, not at the point of production or order. In the case of construction projects, for example, if payments are made in stages as progress is made, this is considered a partial purchase (European Communities et al. 2009, p. 201). Therefore, there must be a considerable time lag between when the government places an order for public works with a contractor and when the phased payments and deliveries are actually made and recorded in the statistics.

This means that, for example, public works projects that are recorded as government expenditure in amount in year t+1 may have been planned by the government and been placed the orders with contractors in period t or t-1. At that point, firms would have started work, so personnel would have been employed and materials etc. would have been purchased, and the impact on nominal/real GDP and prices would have occurred (an increase in Y_t and an increase in P_t). An spurious causal relationship from Y_t to G_{t+1} may occur if the amount of government expenditure (G_{t+1}) is recorded in year t+1 (Figure 2).

If this reasoning is correct, then even if the results of the causality tests conducted so far show that the direction of causality of "*ΔY->ΔG*" or "*ΔP->ΔG*" is dominant, this is merely a manifestation of the statistical timing problem of government expenditure. In this case, using values for general government expenditure at a later point in time (lead variables) may improve the results of the Granger causality test, as it would capture the effects occurring at the time of ordering government expenditure.

To check this point, we have therefore used the lead variables (G_{t+1} and G_{t+2}) for general government expenditure

G_t, taking the value at the relevant time (G_t) and the lead (k) for years 1 and 2, to see whether the results improve, based on Equations 4 and 5 below.

$$\Delta P_t = \alpha_0 + \alpha_1 \Delta P_{t-1} + \alpha_2 \Delta P_{t-2} + \beta_1 \Delta G_{t+k-1} + \beta_2 \Delta G_{t+k-2} + \varepsilon_t \qquad \text{(Equation 4)}$$

$$\Delta Y_t = \gamma_0 + \gamma_1 \Delta Y_{t-1} + \gamma_2 \Delta Y_{t-2} + \delta_2 \Delta G_{t+k-1} + \delta_2 \Delta G_{t+k-2} + \mu_t \qquad \text{(Equation 5)}$$

In these tables, the numbers in brackets around the symbols G(0), G(1) and G(2) are the number of lead periods. The columns denoted by 'G(0)->P', 'G(1)->P' and 'G(2)->P' confirm the impact (*ΔP->ΔY*) from government expenditure *G* to prices *P* (the number in brackets is the number of periods of lead). The columns denoted by 'G(0)->Y', 'G(1)->Y' and 'G(2)->Y' confirm the impact (*ΔG->ΔY*) from government expenditure *G* (number of lead periods in brackets) to nominal GDP *Y* (both calculations are based on first-order difference variables, but the *Δ* symbol is not marked in the table due to space constraints. In both cases, the calculations are based on first-order difference variables.)

[Tables 5, 6 and 7 at the end of this report correspond here].

First, Table 5 (data for the entire period) confirms the improvement in the results. Here, 'improvement' is defined as the sign being correctly positive and the p-value of the t-test being smaller than 5%, compared to the case where the lead (k) is 0. Note that in this table, a three-character country code was used for the country name. The country name code is marked with a symbol such as '0_*', '*_!' next to the country code. The symbol is '0' if the time series variables used in the analysis are I(0) variables, the symbol is '*' if they are a combination of I(1) and I(0) variables, and the symbol is '!' if both variables are I(0) or any is I(2). For example in "0_*", the first symbol relates to "*ΔG->ΔP*" and the second to "*ΔG->ΔY*". Cases with "!" symbols are not included in the study here (cells are blacked out).

The figures in the table show the *p*-values of the *t*-tests for the coefficients β_1 and β_2 or δ_1 and δ_2 for the variables G_{t+k-1} and G_{t+k-2} in equation 4 and equation 5 respectively. The sign in front of it is the sign of the coefficient, and the symbol '#' in front of it further indicates that the coefficient is significant at the 5% significance level (the cell is also brightened).

In the '*ΔG->ΔP*' test, it can be seen that when taking a one-period lead, the results improve in five (1+4) of the 28 (14+14) countries. In addition, when taking a two-period lead, the results improved in 8 of the 28 countries. In these cases, therefore, it is possible that an increase in prices may have occurred between the time the order was placed and the time it was recorded in the statistics, i.e. an 'spurious causality' may have occurred.

In the '*ΔG->ΔY*' test, it can be seen that when taking a one-period lead, the result improves in seven (3+4) of the 28 (13+15) countries. In addition, when taking a two-period lead, the results improve in 12 (5+7) of the 28 (13+15) countries. In other words, an 'spurious causal effect' may have occurred in these cases as well.

The interpretation is similar for Table 6 (pre-2007 data) and Table 7 (post-2008 data). In Table 6, the '*ΔG -> ΔP*' test shows that when taking a one-period lead, the results improve in four (3+1) of the 27 (13+14) countries. In addition, when taking a two-period lead, the results improved in seven of the 27 countries (2+5). In the '*ΔG->ΔY'* test, the results show that when a one-period lead is taken, the results improve in one country (1+0) out of 28 (13+15). In addition, when taking a two-period lead, results improve in 12 (7+5) out of 28 (13+15) countries. In these cases, 'spurious causality' may have occurred.

In Table 7, the '*ΔG->ΔP*' test shows that when taking a one-period lead, the results improve in three (1+2) of the 28 countries (14+14). In addition, when taking a two-period lead, the results improved in two of the 28 countries. In the ΔG->ΔY test, it can be seen that when taking a one-period lead, the result improves in two (1+1) of the 28 (13+15) countries. In addition, when taking a two-period lead, results improve in six (7+5) out of 28 (13+15) countries. It is possible that 'spurious causality' also occurred in these cases.

Thus, in many cases, taking the lead improved the results. It suggests that government expenditure that appears as a monetary amount at time *t* was ordered at an earlier point in time and that an economic effect had occurred. Studies using government expenditure will need to bear this in mind.

Of course, nothing definitive can be said here, as it is clear that if there is causality from GDP to *G*, taking *G*'s lead would reverse causality. This section will not go into further detail on the results for each country. A more detailed examination will be made only in the case of Japan in the next section.

4. Analysis using Japanese quarterly data

In this section, we use Japanese quarterly data to examine Granger causality and timing issues for government expenditure variables in more detail. The data used here are the Japanese GDP statistics (seasonally adjusted) for 109 periods from the first quarter of 1994 to the first quarter of 2021. As variables, we use GDP (*GDPn* in nominal terms and *GDPr* in real terms), aggregate demand excluding inventory investment (nominal *Yn* and real *Yr*), GDP deflator (*P*), government consumption expenditure (*GC*) and public fixed capital formation (*GI*) (here, unlike the IMF data treated in Section 3, government transfers such as social security benefits expenditure is not included in the considerations[7]). The reason why we consider not only GDP but also aggregate demand excluding inventory investment is that even when aggregate demand declines, GDP records unsold goods as output in the form of inventory investment, therefore GDP is considered insensitive to changes in aggregate demand.

4.1. The ADF test

First, the results of the ADF test for these variables (for all periods) are shown in Table 8. In the tests, the drift (constant term) and trend were included and the number of lag variables in the ADF test was automatically selected

[7] The interest of this paper is Granger causality between the variables included in the idintity of expenditure-side GDP, *Y=C+I+G+NX*, where *G* should be the government expenditure comprising GDP; *G* includes *GC* and *GI* but not transfer payments (which contributes aggregate demand through consumption). The IMF data in Section 3 on general government gross expenditure, including transfer payments, were used as is because it was not possible to obtain data on government consumption and government fixed capital formation alone from this database.

based on the AIC. According to the results, *GDPn*, *GDPr*, *Yn*, *Yr*, *P* and *GI* are I(1) variables, while *GC* is an I(2) variable. Therefore, when testing for Granger causality, first-order differenced variables are used.

[Table 8 at the end of this paper corresponds here].

4.2. Granger causality

Table 9 shows the results of the Granger causality test. In the upper panel, 'smpl' refers to the sample period, which is the whole period, pre-2007 and post-2008; 'lead' is the lead period (one or two years) for public fixed capital formation (*ΔGI*) or government consumption (*ΔGC*) (the sample period used for the test was restricted, taking into account the two-year lag and lead, and the impact of the October 2019 consumption tax increase). Furthermore, *Y* represents nominal or real gross output, with the following distinction. If we focus on the left column, *ΔGDPn* is the case using the difference of nominal GDP, while *ΔYn* is the case using the difference of nominal aggregate demand (excluding inventory investment). *ΔGDPr* is the case using the difference of real GDP and *ΔYr* is the case using the difference of real aggregate demand (excluding inventory investment). *ΔP* is the difference of the GDP deflator.

[Table 9 at the end of this report corresponds here.]

Explanatory variables included were of two years (eight periods). Results are determined by the *F*-test at a significance level of 10%, with significant results turning cells white. However, in analyses including the variable *GC*, which is an I(1) variable, null hypothesis of no Granger causality is rejected if the coefficient is *t*-tested at a significance level of 5% after checking the sign and *p*-values, even if the *F* value is slightly above 0.1.

First, the impact of *ΔGI* on GDP deflator (*ΔP*) was checked (GI->P), and the results for the period before 2007 improved when a one-year lead was taken, but not for the period after 2008. For the impact of *ΔGC* on *ΔP* (GC->P), the results for the whole period and for the pre-2007 period improved when taking a one- or two-year lead, but not when taking a lead from 2008 onwards. This suggests that before 2007, government consumption had an immediate impact on prices, but that this impact has disappeared since 2008.

Next, we look at the relationship between government expenditure and GDP, first using nominal GDP as it is (*ΔGDPn*). Looking at the 'GI->Y' column, *ΔGI* affects *ΔY* only for data from 2008 onwards, with a two-year lead; *ΔGC* affects *ΔY* for data from the whole period, with a one- or two-year lead. [8]

Next, we examine the results when using aggregate demand excluding inventory investment (*ΔYn*). Looking at the 'GI->Y' column, *ΔGI* affects *ΔY* when it has a two-year lead for data before 2007 and when it has a one- or two-year lead for data after 2008. Looking at the 'GC->Y' column, *ΔGC* affects *ΔY* when one or two years of leads are taken for any period.

The results so far suggest that government capital formation and consumption have had the effect of boosting (or

[8] With regard to the 'GC->Y' relationship, it was observed in some cases where *ΔGDPn* affected *ΔGI* and *ΔGC* leading two periods in the pre-2007 data, but the reasons for this are not clear.

reduced public spending had the effect of depressing) nominal aggregate demand in the Japanese economy since the collapse of Lehman Brothers.

The results improved when a lead of two years was taken for *ΔGC* for the case where data from the whole period was used.

Looking at the real *ΔYr* as the explained variable, for the relationship between *ΔGI* and *ΔY*, the results improved when taking a two-year lead on *ΔGI* for data from 2008 onwards; for the relationship between *ΔGC* and *ΔY*, when taking a one- or two-year lead on *ΔGC* for data from all time periods. In the case of pre-2007 data, results improved when taking a two-year lead on *ΔGC*.

These results suggest that government spending has actually had the effect of boosting nominal and real aggregate demand and GDP in Japan in recent years.

To examine this point in more detail, we focus on the estimated Granger causality for *ΔYn* and *ΔGI*, and *ΔYn* and *ΔGC*, based on data from 2008 onwards. Table 10 confirms the coefficients of the lag variable for *ΔY* (for the last two years, eight periods) to confirm the causality of 'ΔYn->ΔGI'.

[Table 10 at the end of this report corresponds here].

The '$' marks on the right-hand side of the table indicate the point in time of explained variable for which the lead was taken (K, 0 years = same point in time, 1 year = 4 periods ahead, 2 years = 8 periods ahead). It is assumed that the orders were placed at some point before the amounts were recorded in the statistics (to be seen in conjunction with Figure 2). The table clearly shows that past *ΔY* has no effect on either *ΔGI* or *ΔGC* (each coefficient is ±0.0 (one is +0.1) at every instance, and the *t*-test is not significant at the 5% significance level). This result is also true when *ΔGDPn* is used as an explanatory variable. Therefore, it can be said that in recent years, government expenditure has not increased (or decreased) in response to a preceding increase (or decrease) in aggregate demand or GDP, but has been independently and exogenously determined. This finding means that even if we use lead values of public spendings we will not produce spurious causality toward growth.

Table 11 confirms the Granger causality; *ΔGI* to *ΔYn* and *ΔGC* to *ΔYn*. None of the lagged explanatory variables *ΔGI* or *ΔGC* has significant effect on *ΔYn* in period *t*, the time represented by the symbol '$'. This means that government expenditure does not affect aggregate demand after it is recorded in the statistics.

However, when lead variables are used, *ΔGI* is statistically significant for the same period and for those taking the lead of one and two quaters. This can be interpreted that orders for public works and other projects that affect *ΔYn* in period t have been placed in or before period *t* and recorded after period *t* in terms of value, as shown in Figure 2.

In the case of government consumption *ΔGC*, it could be that the *ΔGC* recorded at time *t* affected the *ΔYn* at the same time, or that orders affecting the amount of *ΔGC* at time *t* were placed shortly before that. The *ΔGC* with a lead of exactly one year (four periods) is also significant. This may be due to the impact of the implementation of government expenditure items that are paid exactly one year later on *ΔYn* at period *t*.

The results of this section reveal that the direction of Granger causality is unambiguously from government expenditure to aggregate demand in the Japanese economy since 2008.

5. conclusion.

Based on data from various countries, a strong correlation was noted between the growth rate of government expenditure and the growth rate of nominal and real GDP, but there was some debate about the direction of causality. In this paper, a simple theoretical simulation model was first constructed to show that scatter plots similar to those actually observed can be drawn in either direction we assume the causality. We then tested Granger causality between general government expenditure, nominal GDP and GDP deflators using data from 1980 to 2021 for 38 OECD countries, and found that the results differed significantly from country to country at different time periods, with many cases suggesting a causality from growth to government expansion. However, as government expenditure statistics such as in the SNA are produced on an accrual basis, the point in time when the amounts are recorded may be later than when the orders are placed, which means that 'spurious causality' may be observed. Therefore, we tried using the lead variable (a variable of later period) of public spending to test for Granger causality, and found that the results could change. To examine this point in more detail, we used quarterly data from the Japanese GDP statistics (1994-2021), namely nominal GDP, government fixed capital formation and government consumption. We found that in Japan since 2008 there was (practically) no causal relationship in neither direction without lead variables. However, with lead variables of government expenditure, one-way Granger causality from government spending to nominal GDP was observed.

Table 1: Unit root tests (ADF test, drift and linear trend) for data from 38 OECD countries

	level			First order difference			Second order difference		
	P	G	Y	ΔP	ΔG	ΔY	$\Delta^2 P$	$\Delta^2 G$	$\Delta^2 Y$
Australia	0.258	1.000	0.985	[I(0)] 0.014	[I(0)] 0.070	[I(0)] 0.000	0.000	0.022	0.027
Austria	0.731	0.461	0.980	[I(0)] 0.018	[I(0)] 0.000	[I(0)] 0.001	0.000	0.001	0.001
Belgium	0.227	0.998	0.195	[I(0)] 0.002	[I(0)] 0.015	[I(0)] 0.009	0.026	0.036	0.026
Canada	0.169	1.000	0.856	[I(0)] 0.007	[I(1)] 0.957	[I(0)] 0.000	0.001	0.000	0.081
Chile	1.000	1.000	1.000	[I(0)] 0.042	[I(2)] 1.000	[I(0)] 0.004	0.053	1.000	0.012
Columbia	0.030	1.000	1.000	[I(0)] 0.042	[I(1)] 0.666	[I(0)] 0.040	0.476	0.072	0.032
Costa Rica	0.415	0.986	0.145	[I(1)] 0.673	[I(0)] 0.002	[I(0)] 0.891	0.000	0.883	0.956
Czech Rep.	0.210	0.525	0.024	[I(1)] 0.993	[I(0)] 0.043	[I(0)] 0.052	0.033	0.000	0.017
Denmark	0.225	0.901	0.830	[I(1)] 0.362	[I(0)] 0.013	[I(0)] 0.000	0.000	0.041	0.002
Estonia	0.017	0.674	0.611	[I(0)] 0.013	[I(1)] 0.287	[I(0)] 0.006	0.023	0.020	0.006
Finland	0.162	0.810	0.159	[I(0)] 0.031	[I(0)] 0.055	[I(0)] 0.001	0.000	0.000	0.000
France.	0.307	0.478	0.062	[I(1)] 0.195	[I(1)] 0.186	[I(0)] 0.000	0.000	0.000	0.050
Germany	0.522	1.000	0.678	[I(0)] 0.031	[I(0)] 0.004	[I(0)] 0.000	0.234	0.000	0.000
Greece	0.611	0.576	0.541	[I(1)] 0.437	[I(1)] 0.139	[I(1)] 0.288	0.000	0.000	0.000
Hungary	0.528	0.962	0.905	[I(1)] 0.183	[I(1)] 0.305	[I(0)] 0.034	0.001	0.000	0.106
Iceland	0.785	0.890	0.998	[I(0)] 0.062	[I(0)] 0.000	[I(0)] 0.010	0.000	0.000	0.037
Ireland	0.788	0.405	0.904	[I(0)] 0.005	[I(0)] 0.000	[I(2)] 0.158	0.000	0.000	0.216
Israel	0.363	0.999	0.853	[I(0)] 0.045	[I(1)] 0.108	[I(1)] 0.211	0.000	0.001	0.000
Italy	0.935	0.208	1.000	[I(0)] 0.002	[I(2)] 0.829	[I(0)] 0.068	0.001	0.895	0.000
Japan	0.001	0.696	0.722	[I(1)] 0.915	[I(1)] 0.437	[I(0)] 0.047	0.003	0.000	0.000
Latvia	0.189	0.231	0.055	[I(0)] 0.013	[I(1)] 0.240	[I(0)] 0.005	0.000	0.017	0.001
Lithuania	0.066	0.202	0.747	[I(0)] 0.053	[I(1)] 0.316	[I(0)] 0.013	0.006	0.004	0.001
Luxembourg	0.869	1.000	0.757	[I(0)] 0.000	[I(1)] 0.846	[I(0)] 0.000	0.004	0.027	0.005
Mexico	0.815	0.694	0.886	[I(0)] 0.090	[I(0)] 0.000	[I(1)] 0.190	0.000	0.000	0.007
Netherlands	0.222	0.342	0.661	[I(0)] 0.100	[I(0)] 0.025	[I(0)] 0.000	0.000	0.000	0.000
New Zealand	0.369	0.999	1.000	[I(1)] 0.694	[I(0)] 0.055	[I(0)] 0.002	0.002	0.104	0.054
Norway	0.622	1.000	0.822	[I(0)] 0.001	[I(1)] 0.735	[I(0)] 0.000	0.000	0.079	0.015
Poland	0.091	0.993	0.491	[I(1)] 0.137	[I(2)] 0.988	[I(1)] 0.788	0.000	0.984	0.016
Portugal	0.920	0.704	0.606	[I(0)] 0.009	[I(1)] 0.186	[I(2)] 0.602	0.000	0.000	0.549
Slovakia	0.846	0.114	0.741	[I(1)] 0.186	[I(0)] 0.011	[I(0)] 0.012	0.041	0.031	0.006
Slovenia	0.779	0.494	0.785	[I(1)] 0.155	[I(0)] 0.000	[I(0)] 0.017	0.002	0.000	0.001
S. Korea.	0.580	0.999	0.037	[I(0)] 0.003	[I(1)] 0.179	[I(0)] 0.022	0.003	0.000	0.044
Spain	0.405	0.004	0.903	[I(1)] 0.355	[I(0)] 0.003	[I(0)] 0.001	0.001	0.190	0.021
Sweden	0.212	0.943	0.987	[I(1)] 0.137	[I(1)] 0.592	[I(0)] 0.000	0.019	0.048	0.002
Switzerland	0.587	0.170	0.441	[I(1)] 0.705	[I(0)] 0.001	[I(0)] 0.000	0.000	0.000	0.000
Turkey	1.000	1.000	0.977	[I(2)] 1.000	[I(2)] 1.000	[I(2)] 1.000	1.000	0.573	1.000
United Kingdom	0.458	1.000	0.172	[I(1)] 0.324	[I(0)] 0.011	[I(0)] 0.010	0.000	0.530	0.000
United States of America	0.832	0.975	0.963	[I(1)] 0.762	[I(2)] 0.992	[I(0)] 0.000	0.000	0.377	0.004

Source: author's calculations.

Note: The numbers in the cells are the p-values of the ADF test results for the null hypothesis of $\gamma = 0$. Those that can be rejected at a significance level of 10% are represented by white cells. Only the first-order lag variables used in the analysis of this paper are marked with the symbols I(0), I(1) and I(2).

Table 2: Granger causality test for data from 38 OECD countries (entire period)

	Use data as long-term as possible					
	ΔP -> ΔG	ΔG -> ΔP	ΔY -> ΔG	ΔG -> ΔY	ΔY -> ΔP	ΔP -> ΔY
Australia	0.4801	0.0563	0.1388	(-+) 0.0041	0.2103	0.0896
Austria	0.1208	0.8085	(+) 0.0282	0.8546	0.7146	0.7352
Belgium	0.5969	0.9852	(+) 0.0011	0.7313	0.0557	0.3815
Canada	* 0.8664	* (+) 0.0000	* 0.2583	* (+) 0.0002	(-+) 0.0001	(-)0.0255
Chile					(-+) 0.0026	(+-) 0.0000
Columbia	* 0.0822	* 0.4970	* (+) 0.0000	*(-) 0.0000	(-+) 0.0006	0.2793
Costa Rica	* 0.3148	* (-) 0.0084				
Czech Rep.	* 0.6763	* 0.2867	(+) 0.0344	0.2484	* 0.2673	* 0.6277
Denmark	* 0.6404	* 0.9381	0.1018	0.4837	* 0.1202	* 0.3493
Estonia	*(+-)0.0037	* 0.3308	*(+-)0.0001	*(+) 0.0206	0.5800	○ 0.0466
Finland	0.5033	0.2843	(+) 0.0417	(-) 0.0318	(+-) 0.0168	0.2383
France.			* 0.0743	* 0.8667	* (+) 0.0452	* 0.4001
Germany	0.1119	0.3884	0.2627	0.5017	0.6880	0.4849
Greece						
Hungary			* (+) 0.0194	* 0.5977	* (+) 0.1808	* (+) 0.0516
Iceland	0.7371	0.2170	(+) 0.0002	0.1489	0.1811	0.2028
Ireland	0.1525	0.9491				
Israel	* 0.2995	* 0.9529			0.1291	0.5770
Italy					(+) 0.0094	0.1616
Japan			* 0.1587	* 0.5475	*(+) 0.0016	* 0.8747
Latvia	* 0.4402	* 0.9278	* (+) 0.1103	* 0.8234	0.4848	0.3415
Lithuania	* 0.5755	* 0.9448	* 0.1600	* 0.6667	0.9019	0.7574
Luxembourg	* 0.3028	* 0.7803	* 0.1487	* 0.5965	0.4391	0.6419
Mexico	0.8020	0.9751	* 0.7125	* 0.9335	* (-) 0.1101	* (+) 0.0437
Netherlands	(+) 0.0043	0.6068	(+) 0.0001	0.2933	(+) 0.0070	0.7236
New Zealand	* 0.4031	* 0.3420	(+) 0.0009	0.1368	* 0.8451	* (-) 0.0797
Norway	* (+) 0.0066	* 0.2426	* (+) 0.0002	* 0.0174	0.7104	0.8312
Poland						
Portugal	* 0.0650	* 0.1991				
Slovakia	* 0.9584	* 0.2747	0.3382	0.6405	* 0.3754	* 0.2535
Slovenia	* 0.6203	* 0.9508	0.0595	0.8195	* 0.1648	* 0.9976
S. Korea.	* 0.3413	* 0.4190	* 0.1449	* 0.8466	0.3228	0.1319
Spain	* 0.2230	* (-) 0.0530	(+) 0.0001	0.2610	* 0.4959	* 0.2520
Sweden			* (+) 0.0299	* 0.5548	* 0.9707	* 0.2439
Switzerland	* 0.0040	* 0.3037	(+) 0.0003	0.6664	* 0.9297	* 0.2864
Turkey						
United Kingdom	* 0.8904	* 0.6193	0.0591	0.2904	* 0.3493	* 0.4468
United States of America					* (-) 0.0022	* (-) 0.0112
SIgnificant results	4/28	3/28	15/28	6/28	11/32	6/32

Source: author's calculations.

Note: The value in each cell is the p-value of the *F*-test, with cells with p>0.1 coloured white. For each country 1980-2020, the maximum available period of data was used for the paired variables to be included in the analysis, excluding missing before and after available data. Estimated periods may therefore differ between countries and pairs of variables.

Table 3: Granger causality test for data from 38 OECD countries (pre-2007 data)

	Using pre-2007 data.					
	ΔP -> ΔG	*ΔG -> ΔP*	*ΔY -> ΔG*	*ΔG -> ΔY*	*ΔY -> ΔP*	*ΔP -> ΔY*
Australia	0.3007	(+) 0.0018	o 0.0379	0.1854	0.3797	0.4240
Austria	(+) 0.0072	0.5140	0.8396	0.3658	0.9465	0.7429
Belgium	0.4804	0.3712	(+) 0.1311	0.3486	0.0459	0.0963
Canada	* 0.5778	* 0.3779	* (+) 0.0205	* 0.2977	0.6982	0.2934
Chile					0.4154	0.4835
Columbia	* 0.1717	* 0.7421	* (+) 0.0002	* 0.3222	(-+) 0.0215	0.1505
Costa Rica	* 0.3844	* 0.3344				
Czech Rep.	* 0.9222	* 0.3530	0.8311	0.9016	* 0.4227	* 0.1124
Denmark	* 0.7498	* 0.8703	0.1585	0.8835	* 0.8365	* 0.7639
Estonia	* 0.4745	* 0.4480	* (+) 0.0017	* 0.5646	(+) 0.0105	0.1856
Finland	0.7550	0.1791	0.5938	0.4266	(+-) 0.0017	(-) 0.0038
France.			* (+) 0.0040	* 0.6488	* 0.0523	* 0.3586
Germany	0.2172	0.8930	0.3847	0.4750	0.2080	0.3554
Greece						
Hungary			* 0.3100	* 0.4513	* 0.7698	* 0.1728
Iceland	0.3596	0.9912	(+) 0.0068	0.5960	0.9674	0.0259
Ireland	0.6079	(+-) 0.0597				
Israel						
Italy					0.1301	0.5595
Japan			*** 0.0066	* (+) 0.0830	* (+) 0.0001	* 0.2007
Latvia	* 0.4336	* 0.6579	* 0.1559	* 0.9063	0.0001	0.0787
Lithuania	* 0.1511	* 0.1692	* (+) 0.0109	* 0.5407	(+) 0.0447	(-) 0.0683
Luxembourg	* 0.3696	* 0.8510	* 0.2360	* 0.7704	0.4712	0.1101
Mexico	0.2517	0.7126	* 0.5964	* (+) 0.0433	* 0.9929	* 0.5136
Netherlands	(+) 0.0081	0.3244	o 0.0115	0.2046	o 0.0084	0.0859
New Zealand	* 0.7953	* 0.3505	(+) 0.0008	0.7336	* 0.6441	* 0.3990
Norway	* 0.0387	* 0.2467	* (+) 0.0011	* 0.1765	0.6044	0.1185
Poland						
Portugal	* 0.8091	* 0.7862				
Slovakia	* 0.0816	* 0.4684	0.5527	0.6672	* 0.8306	* 0.1700
Slovenia	* 0.5677	* 0.5985	0.5160	0.6355	* 0.3154	* 0.0197
S. Korea.	* 0.9961	* 0.9533	* 0.3092	* 0.3923	(+-) 0.0477	0.8117
Spain	* 0.2634	* (+) 0.1200	(+) 0.0027	0.7585	* 0.4526	* 0.1522
Sweden			* 0.4904	* 0.2601	* 0.6035	* (-) 0.0134
Switzerland	* 0.0155	* 0.3771	(+) 0.0030	0.8264	* (+) 0.0102	* 0.6361
Turkey						
United Kingdom	* 0.8891	*(+-)0.0360	0.1274	0.5637	* 0.4755	* 0.1062
United States of America					*** 0.0105	* 0.6713
Significant results	2/25	4/25	12/25	2/25	9/27	4/27

Source: author's calculations.

Note: The value in each cell is the p-value of the F-test, with cells with p>0.1 coloured white. For each country 1980-2007, the maximum available period of data was used for the paired variables to be included in the analysis, excluding missing before and after available data. Estimated periods may therefore differ between countries and pairs of variables.

Table 4: Granger causality test for data from 38 OECD countries (data from 2008 onwards)

	Using data from 2008 onwards					
	ΔP -> ΔG	ΔG -> ΔP	ΔY -> ΔG	ΔG -> ΔY	ΔY -> ΔP	ΔP -> ΔY
Australia	0.8217	0.3155	0.6026	(-) 0.1089	0.2149	0.1922
Austria	0.9579	0.6383	0.0760	0.5616	0.8929	0.7435
Belgium	0.4586	0.3699	(+) 0.1132	0.1404	0.5299	0.8107
Canada	* 0.8896	* (+) 0.0059	* 0.7258	* 0.1822	(-) 0.0227	0.5514
Chile					0.1116	(+) 0.0009
Columbia	* 0.3894	* 0.6336	* 0.4881	* (-) 0.0074	(-) 0.0164	0.8015
Costa Rica	* 0.7153	* (-) 0.0623				
Czech Rep.	* 0.6366	* 0.7048	0.1619	0.2666	* 0.1013	* 0.6795
Denmark	* 0.4925	* 0.8559	0.4376	0.3748	* 0.2697	* (-) 0.0591
Estonia	*(+-) 0.0181	* 0.3239	* (+) 0.0202	* (+) 0.1025	0.1444	(-) 0.0034
Finland	0.4208	0.2248	0.3160	0.1831	0.1813	0.1529
France.			* 0.4839	* 0.9343	* 0.5876	* 0.5730
Germany	(+) 0.0666	0.4504	(+) 0.0464	0.6526	0.1586	0.8733
Greece						
Hungary			* 0.2522	* 0.7412	* 0.3694	* 0.2424
Iceland	0.7474	0.7136	0.1578	0.7701	0.8868	0.4405
Ireland	0.4729	0.8206				
Israel	* 0.5344	* 0.7550			* 0.3233	* 0.8012
Italy					(+) 0.0180	0.9955
Japan	! 0.8699	! 0.4142	* 0.9958	* 0.2836	* 0.1061	* 0.6354
Latvia	* 0.5815	* 0.9894	* 0.2952	* 0.4410	0.9622	0.2650
Lithuania	* 0.5453	* 0.9839	* 0.4752	* 0.6170	0.9218	0.3599
Luxembourg	* 0.4473	* 0.9365	* 0.1329	* 0.5950	0.7483	0.1053
Mexico	0.7502	0.6728	* 0.4975	* 0.2931	* 0.1940	* 0.6140
Netherlands	(+) 0.0218	0.8874	(+) 0.0017	0.6788	0.3306	0.9436
New Zealand	* 0.4151	* 0.3737	0.1637	0.1936	* 0.7411	* 0.1990
Norway	* 0.8207	* 0.8163	* 0.4704	* 0.5021	0.3209	0.7286
Poland						
Portugal	* 0.2136	* 0.1310				
Slovakia	* 0.1099	* 0.4216	0.5568	0.4714	* 0.4986	* 0.2628
Slovenia	* 0.5486	* 0.9984	0.2418	0.8840	* 0.1384	* 0.5992
S. Korea.	* 0.1693	* 0.3313	* 0.0701	* 0.4057	0.6812	(+) 0.0251
Spain	* 0.1526	* 0.3059	0.0693	0.4902	* 0.0877	* 0.7189
Sweden			* (+) 0.1273	* 0.4963	* 0.7852	* 0.8814
Switzerland	* 0.0245	* 0.4846	0.1434	0.7078	* (-) 0.0450	* (+) 0.0686
Turkey						
United Kingdom	* 0.6038	* 0.9988	0.2608	0.1486	* 0.6577	* 0.2628
United States of America					* (-) 0.0265	* (-) 0.0487
Significant results	3/29	2/29	3/28	1/28	5/29	6/29

Source: author's calculations.

Note: The value in each cell is the p-value of the F-test, with cells with p>0.1 coloured white. For each country 2008-2020, the maximum available period of data was used for the paired variables to be included in the analysis, excluding missing before and after available data. Estimated periods may therefore differ between countries and pairs of variables.

Table 5: Improved results with lead variables for government expenditure (data for entire period)

	G(0)->P	G(1)->P	G(2)->P	G(0)->Y	G(1)->Y	G(2)->Y
AUS 0,0	(-) 0.188 # (+) 0.019	(+) 0.270 (+) 0.736	(+) 0.335 (+) 0.498	# (-) 0.003 # (+) 0.007	(+) 0.131 (+) 0.171	# (+) 0.027 (+) 0.239
AUT 0,0	(-) 0.762 (-) 0.520	(+) 0.334 (+) 0.611	# (+) 0.014 (+) 0.065	(-) 0.592 (-) 0.719	(-) 0.449 (-) 0.312	(+) 0.730 (-) 0.911
BEL 0,0	(-) 0.870 (+) 0.945	(+) 0.651 (-) 0.874	(+) 0.649 (+) 0.730	(-) 0.635 (-) 0.579	(-) 0.588 (-) 0.796	# (+) 0.006 (-) 0.292
CAN *,*	# (+) 0.000 (-) 0.817	(-) 0.338 (+) 0.158	(-) 0.999 (+) 0.495	# (+) 0.000 (-) 0.163	# (-) 0.001 (+) 0.102	(+) 0.258 (+) 0.803
CHL ! ,!						
COL *,*	(+) 0.739 (-) 0.258	(+) 0.633 (-) 0.977	(+) 0.709 (+) 0.656	(+) 0.524 # (-) 0.000	(+) 0.065 (+) 0.179	(+) 0.423 (+) 0.056
CRI *,!	# (-) 0.002 (+) 0.331	(+) 0.271 # (-) 0.015	(-) 0.686 (+) 0.552			
CZE *,0	(+) 0.179 (-) 0.441	(+) 0.209 (+) 0.240	(+) 0.586 (+) 0.407	(-) 0.469 (-) 0.118	(+) 0.550 (+) 0.850	(+) 0.121 (+) 0.538
DNK *,0	(-) 0.929 (+) 0.726	(+) 0.293 (+) 0.964	(+) 0.504 (+) 0.423	(-) 0.242 (-) 0.793	# (-) 0.024 (-) 0.294	(-) 0.256 (-) 0.052
EST *,*	(+) 0.161 (-) 0.927	(-) 0.780 (-) 0.655	# (+) 0.023 (+) 0.959	# (+) 0.006 (-) 0.787	(+) 0.864 (+) 0.756	# (+) 0.000 (+) 0.294
FIN 0,0	(-) 0.151 (+) 0.189	(+) 0.132 (-) 0.130	(+) 0.271 (+) 0.890	# (-) 0.021 (+) 0.958	(-) 0.234 (-) 0.140	# (+) 0.013 # (-) 0.001
FRA ! , *				(+) 0.931 (+) 0.684	# (-) 0.001 (+) 0.489	# (+) 0.012 (-) 0.462
DEU 0,0	(+) 0.174 (+) 0.820	(+) 0.119 (+) 0.736	(+) 0.113 (+) 0.055	(+) 0.346 (+) 0.454	(-) 0.451 (-) 0.926	(+) 0.282 (+) 0.314
GRC ! ,!						
HUN ! ,*				(-) 0.338 (-) 0.652	# (+) 0.001 (-) 0.830	# (+) 0.027 # (+) 0.001
ISL 0,0	(+) 0.096 (+) 0.346	# (+) 0.006 (+) 0.072	(-) 0.142 # (+) 0.019	(-) 0.053 (-) 0.789	# (+) 0.013 # (-) 0.012	# (+) 0.001 # (+) 0.000
IRL 0,!	(-) 0.865 (-) 0.761	(-) 0.306 (-) 0.802	(-) 0.095 (-) 0.108			
ISR *,!	(+) 0.930 (+) 0.806	(+) 0.057 (-) 0.790	(-) 0.148 # (+) 0.036			
ITA ! ,!						
improvement	base	1/14 cases	4/14 cases	base	3/13 cases	5/13 cases

	G(0)->P	G(1)->P	G(2)->P	G(0)->Y	G(1)->Y	G(2)->Y
JPN ! ,*				(+) 0.625 (+) 0.281	(-) 0.504 (-) 0.929	(+) 0.573 (-) 0.738
LVA *,*	(+) 0.909 (+) 0.766	# (+) 0.000 (-) 0.271	(+) 0.878 # (+) 0.000	(-) 0.582 (-) 0.977	# (+) 0.000 (-) 0.297	# (+) 0.033 # (+) 0.000
LTU *,*	(-) 0.986 (+) 0.740	# (+) 0.001 (+) 0.665	(+) 0.179 # (+) 0.002	(-) 0.477 (-) 0.634	# (+) 0.004 (-) 0.468	# (+) 0.008 # (+) 0.023
LUX *,*	(+) 0.791 (+) 0.654	(-) 0.695 (+) 0.481	(-) 0.235 (+) 0.472	(-) 0.484 (+) 0.335	(-) 0.145 (+) 0.273	(-) 0.476 (-) 0.413
MEX 0,*	(-) 0.844 (+) 0.919	(+) 0.115 (-) 0.702	(+) 0.649 (+) 0.119	(+) 0.805 (+) 0.763	(+) 0.149 (-) 0.100	(+) 0.215 # (+) 0.003
NLD 0,0	(-) 0.421 (+) 0.556	# (+) 0.023 (-) 0.478	# (+) 0.004 # (+) 0.026	(-) 0.364 (-) 0.237	(-) 0.951 (-) 0.356	# (+) 0.042 (+) 0.625
NZL *,0	(+) 0.240 (+) 0.952	# (+) 0.032 (-) 0.379	(-) 0.525 # (+) 0.031	(-) 0.120 (-) 0.775	# (+) 0.019 (-) 0.122	(+) 0.739 (+) 0.161
NOR *,*	(+) 0.388 (+) 0.998	(-) 0.867 (-) 0.740	(+) 0.064 (-) 0.150	(+) 0.069 (-) 0.681	(-) 0.584 (+) 0.763	# (+) 0.011 (-) 0.178
POL ! ,!						
PRT *,!	(-) 0.124 (-) 0.498	(+) 0.287 (-) 0.108	(+) 0.126 (+) 0.579			
SVK *,0	(-) 0.146 (-) 0.427	(-) 0.710 (-) 0.171	(+) 0.806 (-) 0.718	(-) 0.426 (-) 0.590	(-) 0.960 (-) 0.611	(+) 0.277 (+) 0.967
SVN *,0	(-) 0.756 (-) 0.876	(+) 0.226 (-) 0.755	(+) 0.689 (+) 0.051	(+) 0.629 (-) 0.862	(-) 0.607 (-) 0.522	(+) 0.772 (+) 0.477
KOR *,*	(-) 0.220 (-) 0.647	(+) 0.766 (-) 0.596	(-) 0.652 (+) 0.372	(+) 0.646 (-) 0.730	(-) 0.609 (+) 0.320	(+) 0.114 (-) 0.817
ESP *,0	(+) 0.644 # (-) 0.018	(-) 0.619 (-) 0.910	(+) 0.094 (-) 0.267	(-) 0.537 (-) 0.212	# (-) 0.047 (-) 0.349	# (+) 0.002 (-) 0.143
SWE ! ,*				(+) 0.358 (-) 0.332	(+) 0.115 (-) 0.719	# (+) 0.039 (+) 0.505
CHE *,0	(-) 0.951 (-) 0.126	(-) 0.504 (+) 0.976	(+) 0.091 (-) 0.621	(-) 0.425 (-) 0.749	(-) 0.541 (-) 0.355	(+) 0.141 (-) 0.948
TUR ! ,!						
GBR *,0	(+) 0.360 (-) 0.425	(+) 0.497 (-) 0.854	(+) 0.287 (-) 0.953	(-) 0.120 (+) 0.293	(+) 0.948 (-) 0.264	(+) 0.621 (-) 0.395
USA ! ,!						
improvement	base	4/14 cases	4/14 cases	base	4/15 cases	7/15 cases

Source: author's calculations.

Note: The figures in the table are the *p*-values of the *t*-tests; white colour in the cells (with # sign) indicates significance at the 5% level of significance. (+) or (-) indicates the sign of the coefficient on the counterpart lag variable (top row: first period lag, bottom row: second period lag). The bottom row is the number of countries where the sign or significance of the coefficient has improved. Cells that are not used in the study are in dark grey.

Table 6: Improved results with lead variables for government expenditure (pre-2007)

	G(0)-->P	G(1)-->P	G(2)-->P	G(0)-->Y	G(1)-->Y	G(2)-->Y		G(0)-->P	G(1)-->P	G(2)-->P	G(0)-->Y	G(1)-->Y	G(2)-->Y
AUS 0,0	#(+) 0.043	(-) 0.994	(+) 0.114	(+) 0.140	(+) 0.531	#(+) 0.045	JPN ! ,*				(+) 0.606	(-) 0.458	(+) 0.361
	#(+) 0.012	#(+) 0.044	(-) 0.960	(+) 0.420	(+) 0.057	(+) 0.562					#(+) 0.035	(-) 0.336	(+) 0.675
AUT 0,0	(-) 0.939	(+) 0.589	#(+) 0.007	(-) 0.225	(+) 0.717	(+) 0.947	LVA *,*	(-) 0.431	(+) 0.169	#(-) 0.012	(+) 0.815	(+) 0.243	(-) 0.223
	(-) 0.376	(+) 0.461	(+) 0.118	(+) 0.889	(-) 0.239	(+) 0.387		(-) 0.416	(-) 0.573	#(+) 0.005	(+) 0.925	(+) 0.727	(+) 0.097
BEL 0,0	(+) 0.356	(+) 0.282	(+) 0.658	(+) 0.732	(-) 0.983	#(+) 0.005	LTU *,*	(+) 0.146	(+) 0.116	(+) 0.253	(-) 0.331	(+) 0.068	#(+) 0.007
	(+) 0.193	(+) 0.380	(+) 0.381	(+) 0.155	(-) 0.868	(+) 0.436		(+) 0.515	(+) 0.293	(+) 0.487	(+) 0.574	(+) 0.975	#(+) 0.030
CAN *,*	(+) 0.671	#(+) 0.017	(+) 0.070	(-) 0.124	(+) 0.320	#(+) 0.003	LUX *,*	(+) 0.925	(+) 0.706	(-) 0.398	(-) 0.770	(-) 0.902	(-) 0.156
	(+) 0.313	(-) 0.846	(+) 0.206	(+) 0.322	(-) 0.123	(-) 0.070		(+) 0.622	(+) 0.602	(+) 0.487	(+) 0.496	(+) 0.768	(+) 0.960
CHL ! ,!	(+) 0.382	(-) 0.496	(+) 0.066	(-) 0.755	(-) 0.320	#(+) 0.023	MEX 0,*	(+) 0.516	(+) 0.550	(+) 0.980	#(+) 0.033	(+) 0.154	(-) 0.799
	(-) 0.173	(+) 0.463	(-) 0.101	(-) 0.552	(-) 0.999	(-) 0.052		(-) 0.543	(+) 0.792	(+) 0.535	(-) 0.500	#(+) 0.023	(+) 0.094
COL *,*	(+) 0.491	(+) 0.455	(-) 0.138	(+) 0.341	(+) 0.107	(+) 0.471	NLD 0,0	(-) 0.677	(+) 0.125	#(+) 0.003	(-) 0.118	(-) 0.362	#(+) 0.022
	(-) 0.585	(+) 0.875	(+) 0.124	(-) 0.315	(+) 0.128	(+) 0.169		(+) 0.254	(-) 0.812	#(+) 0.010	(+) 0.896	#(-) 0.049	(+) 0.508
CRI *,!	(+) 0.357	(+) 0.118	(-) 0.982	(+) 0.540	(+) 0.823	(-) 0.580	NZL *,0	(+) 0.446	(+) 0.480	(+) 0.881	(+) 0.470	(+) 0.474	#(+) 0.013
	(+) 0.278	(+) 0.129	(+) 0.058	(+) 0.238	(+) 0.541	(+) 0.925		(+) 0.754	(+) 0.804	(+) 0.576	(-) 0.681	(+) 0.897	(-) 0.729
CZE *,0	(+) 0.638	(+) 0.927	(-) 0.862	(+) 0.671	(-) 0.662	(-) 0.868	NOR *,*	(+) 0.901	(+) 0.225	#(+) 0.022	(+) 0.599	(+) 0.369	#(+) 0.000
	(-) 0.256	(+) 0.459	(-) 0.766	(+) 0.943	(+) 0.838	(-) 0.552		(+) 0.187	(+) 0.879	(+) 0.878	(+) 0.232	(+) 0.368	(+) 0.371
DNK *,0	(-) 0.977	(+) 0.288	(-) 0.639	(-) 0.704	(+) 0.943	#(-) 0.048	POL ! ,!						
	(-) 0.616	(-) 0.739	(+) 0.297	(+) 0.692	(-) 0.765	(+) 0.689							
EST *,*	(+) 0.494	#(+) 0.018	(+) 0.455	(+) 0.382	(+) 0.345	#(+) 0.010	PRT *,!	(-) 0.585	(+) 0.231	(+) 0.356			
	(+) 0.476	(+) 0.809	(+) 0.065	(+) 0.713	(+) 0.201	(+) 0.985		(+) 0.544	(-) 0.254	(+) 0.590			
FIN 0,0	(-) 0.125	(+) 0.756	(+) 0.569	(-) 0.323	(-) 0.169	(+) 0.121	SVK *,0	(-) 0.452	(+) 0.785	(-) 0.297	(+) 0.467	(+) 0.733	(-) 0.212
	(+) 0.129	(-) 0.285	(-) 0.798	(+) 0.302	(-) 0.734	#(-) 0.038		(-) 0.233	(-) 0.844	(+) 0.912	(-) 0.962	(+) 0.485	(-) 0.947
FRA ! , *				(-) 0.359	(-) 0.905	#(+) 0.042	SVN *,0	(-) 0.340	#(+) 0.001	(+) 0.605	(-) 0.404	(+) 0.268	(+) 0.102
				(+) 0.656	(-) 0.475	(-) 0.420		(-) 0.931	(-) 0.349	#(+) 0.001	(+) 0.597	(-) 0.761	(+) 0.249
DEU 0,0	(-) 0.764	(+) 0.265	(+) 0.803	(-) 0.255	(+) 0.775	(+) 0.137	KOR *,*	(-) 0.980	(+) 0.551	(-) 0.979	(+) 0.255	(+) 0.513	(+) 0.369
	(-) 0.659	(+) 0.700	(+) 0.287	(-) 0.356	(-) 0.653	(+) 0.313		(-) 0.769	(+) 0.983	(+) 0.556	(-) 0.644	(+) 0.141	(+) 0.632
GRC ! ,!							ESP *,0	#(+) 0.042	(+) 0.152	(-) 0.379	(-) 0.468	(-) 0.719	#(+) 0.034
								(-) 0.228	(+) 0.949	#(+) 0.050	(+) 0.887	(-) 0.595	(-) 0.177
HUN ! ,*				(-) 0.252	(+) 0.144	(+) 0.220	SWE ! ,*				(-) 0.927	(+) 0.381	(+) 0.288
				(+) 0.816	(-) 0.536	#(+) 0.035					(-) 0.214	(-) 0.177	(-) 0.712
ISL 0,0	(-) 0.897	#(+) 0.046	#(-) 0.011	(-) 0.691	#(+) 0.000	(+) 0.370	CHE *,0	(+) 0.527	(-) 0.979	#(+) 0.032	(+) 0.774	(-) 0.306	(-) 0.946
	(+) 0.996	(-) 0.365	#(+) 0.003	(-) 0.315	(+) 0.108	#(+) 0.000		(-) 0.265	(+) 0.408	(+) 0.782	(-) 0.577	(-) 0.966	(-) 0.303
IRL 0,!	#(+) 0.025	(-) 0.869	(+) 0.529				TUR ! ,!						
	#(-) 0.037	(+) 0.431	(-) 0.895										
ISR *,!							GBR *,0	#(+) 0.014	(+) 0.835	(-) 0.975	(+) 0.489	(+) 0.546	(+) 0.815
								#(-) 0.017	(+) 0.720	(+) 0.590	(+) 0.893	(+) 0.712	(+) 0.416
ITA ! ,!							USA ! ,!						
improvement	base	3/13 cases	2/13 cases	base	1/13 cases	7/13 cases	improvement	base	1/14 cases	5/14 cases	base	0/15 cases	5/15 cases

Source: author's calculations.

Note: The figures in the table are the p-values of the t-tests, with white (with # sign) in the cells indicating significance at the 5% level of significance. (+) or (-) indicates the sign of the coefficient on the paired partner lag variable (top row: first period lag, bottom row: second period lag). The bottom row is the number of countries where the sign or significance of the coefficient has improved. Cells that are not used in the study are in dark grey.

Table 7: Improved results with lead variables for government expenditure (since 2008)

	G(0)->P	G(1)->P	G(2)->P	G(0)->Y	G(1)->Y	G(2)->Y
AUS 0,0	(-) 0.474	(+) 0.418	(+) 0.879	#(-) 0.049	(+) 0.260	(+) 0.425
	(+) 0.142	(+) 0.642	(+) 0.269	(+) 0.135	(+) 0.642	(+) 0.592
AUT 0,0	(-) 0.414	(+) 0.349	(-) 0.872	(-) 0.770	(-) 0.078	(+) 0.597
	(+) 0.615	(-) 0.305	(+) 0.383	(-) 0.308	(-) 0.288	(-) 0.317
BEL 0,0	(+) 0.766	(+) 0.718	(+) 0.448	(-) 0.969	(-) 0.660	(+) 0.391
	(-) 0.179	(-) 0.714	(-) 0.835	(-) 0.073	(-) 0.659	(-) 0.228
CAN *,*	#(+) 0.003	(-) 0.570	(+) 0.756	(+) 0.073	#(-) 0.032	(+) 0.334
	(+) 0.617	(+) 0.603	(-) 0.544	(-) 0.502	(+) 0.682	(-) 0.295
CHL ! ,!						
COL *,*	(-) 0.985	(+) 0.699	(+) 0.654	(+) 0.588	(+) 0.250	(+) 0.596
	(-) 0.380	(+) 0.907	(+) 0.478	#(-) 0.006	(+) 0.301	(+) 0.164
CRI *,!	#(-) 0.024	(+) 0.948	(-) 0.866			
	(-) 0.373	(-) 0.181	(+) 0.874			
CZE *,0	(+) 0.584	#(+) 0.040	(+) 0.639	(-) 0.479	(+) 0.400	(+) 0.109
	(+) 0.519	(+) 0.676	(+) 0.125	(-) 0.144	(-) 0.926	(+) 0.557
DNK *,0	(+) 0.824	(+) 0.476	(+) 0.144	(-) 0.203	(-) 0.130	(-) 0.730
	(+) 0.606	(+) 0.642	(+) 0.641	(-) 0.447	(-) 0.263	(-) 0.222
EST *,*	(+) 0.157	#(-) 0.029	(+) 0.322	#(+) 0.043	(-) 0.795	#(+) 0.006
	(+) 0.870	(+) 0.264	(-) 0.374	(-) 0.813	(+) 0.907	(+) 0.452
FIN 0,0	(+) 0.510	(+) 0.283	(-) 0.935	(-) 0.911	(+) 0.782	(+) 0.216
	(+) 0.241	(+) 0.972	(+) 0.353	(-) 0.228	(-) 0.272	(-) 0.167
FRA ! , *				(-) 0.724	#(-) 0.021	(+) 0.156
				(+) 0.832	(-) 0.998	(-) 0.369
DEU 0,0	(+) 0.234	(+) 0.863	(+) 0.071	(-) 0.933	(-) 0.067	(-) 0.760
	(-) 0.840	(-) 0.263	(-) 0.720	(+) 0.438	(+) 0.266	(+) 0.466
GRC ! ,!						
HUN ! ,*				(-) 0.496	#(+) 0.014	(+) 0.207
				(-) 0.628	(+) 0.738	#(+) 0.024
ISL 0,0	(+) 0.456	(+) 0.183	(-) 0.423	(-) 0.528	(+) 0.192	#(+) 0.003
	(+) 0.593	(+) 0.419	(+) 0.623	(+) 0.863	(-) 0.227	#(+) 0.000
IRL 0,!	(-) 0.616	(-) 0.474	(-) 0.271			
	(-) 0.618	(-) 0.628	(-) 0.267			
ISR *,!	(-) 0.577	(-) 0.506	(-) 0.615			
	(-) 0.764	(-) 0.604	(-) 0.573			
ITA ! ,!						
improvement	base	1/14 cases	0/14 cases	base	1/13 cases	3/13 cases

	G(0)->P	G(1)->P	G(2)->P	G(0)->Y	G(1)->Y	G(2)->Y
JPN ! ,*				(+) 0.125	(-) 0.066	(-) 0.117
				(+) 0.771	(+) 0.251	#(-) 0.006
LVA *,*	(-) 0.887	#(+) 0.004	(-) 0.191	(-) 0.529	#(+) 0.004	(+) 0.339
	(+) 0.957	(-) 0.358	#(+) 0.006	(-) 0.430	(-) 0.242	#(+) 0.005
LTU *,*	(+) 0.912	(+) 0.057	(+) 0.705	(-) 0.499	(+) 0.162	(+) 0.128
	(+) 0.879	(+) 0.718	(+) 0.073	(-) 0.513	(-) 0.568	(+) 0.182
LUX *,*	(+) 0.783	(-) 0.999	(-) 0.601	(-) 0.328	(-) 0.343	(+) 0.706
	(+) 0.927	(-) 0.976	(+) 0.712	(+) 0.998	(-) 0.758	(-) 0.168
MEX 0,*	(-) 0.391	(+) 0.468	(+) 0.587	(-) 0.163	(-) 0.769	(+) 0.185
	(-) 0.614	(-) 0.561	(+) 0.258	(-) 0.198	(-) 0.054	(+) 0.067
NLD 0,0	(-) 0.910	(+) 0.092	(+) 0.255	(-) 0.926	(+) 0.855	#(+) 0.015
	(-) 0.752	(-) 0.394	(+) 0.351	(-) 0.600	(-) 0.693	(-) 0.268
NZL *,0	(+) 0.180	#(+) 0.038	(-) 0.703	(-) 0.282	(+) 0.119	(-) 0.738
	(-) 0.795	(+) 0.972	#(+) 0.043	(-) 0.398	(-) 0.185	(+) 0.430
NOR *,*	(+) 0.539	(+) 0.903	(+) 0.351	(+) 0.262	(-) 0.950	(+) 0.219
	(-) 0.792	#(-) 0.035	(-) 0.224	(-) 0.427	(-) 0.061	(-) 0.248
POL ! ,!						
PRT *,!	(-) 0.251	(+) 0.416	(+) 0.244			
	(-) 0.107	(-) 0.383	(+) 0.541			
SVK *,0	(-) 0.203	(-) 0.932	(+) 0.106	(-) 0.334	(+) 0.853	(+) 0.345
	(+) 0.999	(-) 0.170	(+) 0.665	(-) 0.489	(-) 0.456	(+) 0.983
SVN *,0	(+) 0.968	(+) 0.241	(+) 0.941	(+) 0.864	(-) 0.618	(-) 0.998
	(-) 0.987	(+) 0.941	(+) 0.168	(-) 0.735	(-) 0.502	(+) 0.789
KOR *,*	(-) 0.151	(-) 0.694	(-) 0.413	(-) 0.227	(-) 0.344	(+) 0.183
	(-) 0.921	(-) 0.475	(+) 0.629	(-) 0.611	(-) 0.515	(-) 0.588
ESP *,0	(+) 0.388	(+) 0.827	(+) 0.089	(-) 0.722	(-) 0.294	(+) 0.236
	(-) 0.207	(+) 0.470	(+) 0.720	(-) 0.340	(-) 0.477	(-) 0.556
SWE ! ,*				(+) 0.265	(+) 0.098	#(+) 0.042
				(+) 0.949	(+) 0.272	#(+) 0.050
CHE *,0	(-) 0.529	(+) 0.665	(+) 0.465	(-) 0.580	(+) 0.535	(+) 0.390
	(-) 0.303	(-) 0.762	(+) 0.232	(-) 0.642	(-) 0.578	(+) 0.271
TUR ! ,!						
GBR *,0	(-) 0.965	(+) 0.204	(+) 0.137	(-) 0.109	(-) 0.572	(-) 0.644
	(-) 0.994	(+) 0.768	(+) 0.374	(-) 0.385	#(-) 0.036	(-) 0.391
USA ! ,!						
improvement	base	2/14 cases	2/14 cases	base	1/15 cases	3/15 cases

Source: author's calculations.

Note: The figures in the table are the *p*-values of the *t*-tests; white colour in the cells (with # sign) indicates significance at the 5% level of significance. (+) or (-) indicates the sign of the coefficient on the paired partner lag variable (top row: first period lag, bottom row: second period lag). The bottom row is the number of countries where the sign or significance of the coefficient has improved. Cells that are not used in the study are in dark grey.

Table 8: Results of the ADF test

	level	lags	1st diff.	lags	2nd diff.	lags
GDPn	0.5170	0	0.0000	0		
GDPr	0.0990	0	0.0000	0		
Yn.	0.7212	1	0.0000	0		
Yr.	0.0478	0	0.0000	0		
p	0.9994	0	0.0000	0		
GC	0.6263	6	0.1055	5	0.0000	4
GI	0.9904	9	0.0015	8		

Source: author's calculations.
Note: ADF tests using the whole period data including the drifts and trends in the equation, the number of lag variables for the ADF test is automatically selected based on the AIC.

Table 9: Results of Granger causality tests using Japanese quarterly data (first-order differences)

	smpl	lead	GI->P	P->GI	GC->P	P->GC
ΔP	1996Q1 2017Q2	0	0.463	0.180	0.184	0.571
		1	0.569	0.824	0.057	0.535
		2	0.148	0.544	0.073	0.248
	1996Q1 2007Q4	0	0.159	0.094	0.595	0.674
		1	0.089	0.132	0.021	0.602
		2	0.125	0.560	0.037	0.007
	2008Q1 2017Q2	0	0.850	0.266	0.152	0.598
		1	0.587	0.986	0.864	0.827
		2	0.365	0.917	0.737	0.913
	smpl	lead	GI->Y	Y->GI	GC->Y	Y->GC
ΔGDPn	1996Q1 2017Q2	0	0.662	0.508	0.602	0.268
		1	0.357	0.754	0.045	0.880
		2	0.387	0.522	0.008	0.377
	1996Q1 2007Q4	0	0.366	0.044	0.465	0.349
		1	0.287	0.272	0.250	0.824
		2	0.198	0.074	0.308	0.007
	2008Q1 2017Q2	0	0.413	0.184	0.832	0.509
		1	0.165	0.729	0.145	0.598
		2	0.078	0.936	0.100	0.960
	smpl	lead	GI->Y	Y->GI	GC->Y	Y->GC
ΔYn	1996Q1 2017Q2	0	0.779	0.387	0.246	0.041
		1	0.276	0.644	0.003	0.916
		2	0.324	0.495	0.001	0.679
	1996Q1 2007Q4	0	0.504	0.063	0.425	0.076
		1	0.359	0.155	0.038	0.887
		2	0.093	0.042	0.061	(+)0.116
	2008Q1 2017Q2	0	0.718	0.161	0.458	0.422
		1	0.084	0.521	0.074	0.665
		2	0.071	0.853	0.070	0.829
	smpl	lead	GI->Y	Y->GI	GC->Y	Y->GC
ΔGDPr	1996Q1 2017Q2	0	0.900	0.503	0.353	0.235
		1	0.503	0.793	0.289	0.871
		2	0.585	0.665	0.076	0.650
	1996Q1 2007Q4	0	0.692	0.097	0.649	0.322
		1	0.512	0.322	0.743	0.284
		2	0.436	0.120	0.228	0.045
	2008Q1 2017Q2	0	0.766	0.049	0.668	0.827
		1	0.046	0.490	0.314	0.920
		2	0.011	0.818	0.374	0.955
	smpl	lead	GI->Y	Y->GI	GC->Y	Y->GC
ΔYr	1996Q1 2017Q2	0	0.990	0.437	0.105	0.162
		1	0.754	0.738	0.091	0.761
		2	0.630	0.637	0.030	0.641
	1996Q1 2007Q4	0	0.702	0.126	0.472	0.282
		1	0.491	0.114	0.347	0.283
		2	0.329	0.054	0.094	0.160
	2008Q1 2017Q2	0	0.988	0.128	0.224	0.864
		1	0.155	0.342	0.253	0.873
		2	0.064	0.799	0.286	0.832

Source: author's calculations.

Note: Values in the table are *F* values for the *F* test, judged at a significance level of 10%. Results of tests involving the I(1) variable ΔGC were confirmed based on *t*-values for the coefficients.

Table 10: Effect of nominal aggregate demand (ΔYn) on public fixed capital formation and government consumption (ΔGI, ΔGC)

Lags and leads	-8	-7	-6	-5	-4	-3	-2	-1	0 (=t)	1	2	3	4	5	6	7	8
ΔY -> ΔGI (K=0)	+0.0	-0.0	+0.0	+0.0	-0.0	-0.0	+0.0	-0.0	$								
ΔY -> ΔGI (K=1)	+0.0	-0.0	+0.0	-0.0	+0.0	+0.0	+0.0	-0.0					$				
ΔY -> ΔGI (K=2)	+0.0	+0.0	-0.0	-0.0	+0.0	-0.0	-0.0	-0.0									$
ΔY -> ΔGC (K=0)	-0.0	+0.0	-0.0	-0.0	+0.1	-0.0	+0.0	-0.0	$								
ΔY-> ΔGC(K=1)	-0.0	+0.0	+0.0	-0.0	-0.0	+0.0	-0.0	+0.0					$				
ΔY -> ΔGC (K=2)	+0.0	-0.0	+0.0	-0.0	-0.0	+0.0	+0.1	-0.0									$

Source: author's calculations.
Note: Values are coefficient values. Grey cells mean that the coefficient is not significant at the 5% significance level.

Figure 11: Effect of public fixed capital formation (ΔGI) and government consumption (ΔGC) on nominal aggregate demand (ΔYn)

Lags and leads	-8	-7	-6	-5	-4	-3	-2	-1	0 (=t)	1	2	3	4	5	6	7
ΔYn									$							
ΔGI (K=0)	+1.6	+0.0	+1.8	+0.1	+1.6	+1.7	-1.0	-3.2								
ΔGI (K=1)					+1.7	-0.2	+1.8	-1.7	+5.1*	-6.4*	+4.2*	-1.8				
ΔGI (K=2)									+4.4*	-5.4*	+3.4*	-2.0	-0.6	-0.6	+1.5	+1.4
ΔYn									$							
ΔGC (K=0)	+2.3	-2.0	-1.1	+0.2	-2.2	+3.1	+0.7	-1.5								
ΔGC (K=1)					-1.9	+2.2	+2.9	+1.3	+3.7*	-0.3	+0.4	-3.7				
ΔGC (K=2)									+3.4*	-0.3	+0.2	-2.3	+4.2*	+0.8	-0.8	+1.0

Source: author's calculations.
Note: Values are for coefficients of explanatory variables. Grey cells mean that the coefficient is not significant at the 5% significance level.

Appendix 1: List of existing studies examining the causality between government expenditure and GDP (1/4, continued)

Y -> G	Author.	obtaining	Country/region	Method.	data period	variable	Considerations about the time of government's order placing
1	Bohl (1996).		G7 nations	Causality Test			
2	Ansari et al. (1997).	*	Ghana, Kenya, South Africa.	Granger causality test, Holmes-Hutton test	IFS, annual, Ghana 1963-88, Kenya 1964-89, South Africa 1957-90.	Real per capita government expenditure and national income	None.
3	Abizadeh et al. (1988).	*	United States of America	Regression analysis (not a causality test)	US authorities, annual, 1950-1984.		
4	Islam (2001).	*	United States of America	Error correction model (ECM)	US authorities, annual, 1929-1996.	Nominal gross government expenditure GNP ratio, real GNP per capita	None.
5	Tang (2001).	*	Malaysia	Cointegration and Granger tests.	IFS, annual, 1960-1998.	Real per capita GDP, real per capita government expenditure	None.
6	Al-Faris (2002).	*	Gulf Cooperation Council countries	Cointegration and Granger tests.	1970-1997	Real per capita GDP, government expenditure as % of GDP, current expenditure per capita, capital expenditure per capita	None.
7	Abu-Bader et al. (2003).	*	Egypt, Israel and Syria.	Cointegration test, variance decomposition	IFS, WDI, US-ACDA, annual	Nominal gross government expenditure as % of GDP, military expenditure as % of GDP	None.
8	Dritsakis (2004).		Greece, Turkey.	Causality Test			
9	Loizides et al. (2005).	*	Greece, UK, Ireland.	Error correction model (ECM)	National statistics, annual, longest 1948-1995	Real GDP per capita, real government expenditure, government expenditure as % of GDP, etc.	None.
10	Akoitoby et al. (2006).	*	Developing countries 51 countries	Causality Test	GFS&IFS, annual, 1970-2002.	Real GDP, real government expenditure each	None.
11	Sideris (2007).	*	Greece	Granger Causality Test	Existing literature, annual, 1832-1938.	Real GDP, real government expenditure, population	None.

Source: prepared by the author with reference to the respective tables contained in Nyasha et al. (2019). Those of them for which a paper was available are denoted by an '*' symbol.
Abbreviations: ADI: African Development Indicators; ADB: Asian Development Bank; EO: Economic Outlook (OECD); GFS: Government Financial Statistics (IMF); IFS: International Financial Statistics, IFY: International Financial Yearbook, NA: National Accounts, PWT6.2: Penn World Table 6.2, WBDI: World Bank Development Indicators, WDI: World Development Indicator, ACDA: Arms Control and Disarmament Agency.

Appendix 1: List of existing studies examining the causality between government expenditure and GDP (2/4, continued)

Y -> G	Author.	obtaining	Country/region	Method.	data period	variable	Considerations about the time of government's order placing
12	Narayan et al. (2008).		Chinese provinces	Granger Causality Test	Chinese authorities (1952-1989) and existing literature (1990-2003).	Real GDP, real GDP per capita, real government expenditure	None.
13	Mohammadi et al. (2008).	*	Turkey	ARDL Bounds Test	Home authorities, annual, 1951-2005.	Real GNP, real government expenditure, population	None.
14	Samudram et al. (2009).	*	Malaysia	ARDL Bounds Test	Home authorities, annual, 1970-2004.	Real GDP, real government expenditure	None.
15	Tang (2009).		Malaysia	Cointegration Bounds test and others.			
16	Taban (2010).		Turkey	Bounds test and others.			
17	Lamartina et al. (2011).	*	OECD 23 countries	panel data analysis	EO, GFS & AMECO, longest 1970-2006.	Nominal GDP per capita, nominal gross government expenditure	None.
18	Kumar et al. (2012).		New Zealand	ARDL Bounds test and others.	IFS, annual, 1960-2007.	Real government expenditure, real GDP and GNP, government expenditure-GDP ratio or GNP ratio (both growth rates)	None.
19	Srinivasan (2013).	*	India	Cointegration and error-correction models	Home authorities, annual, 1973-2012.	Real GDP, real gross central government expenditure	None.
20	Akinlo (2013)		Nigeria	Multivariate time series analysis.			
21	Biyase et al. (2015).	*	Africa 30 countries	panel data analysis	ADI, annual, 1990-2005.	Government expenditure as % of GDP, economic growth (nominal or real unknown)	None.
22	Thabane et al. (2016).	*	Lesotho	ARDL Bounds Test	WBDI, annual, 1980-2012.	Real GDP, gross government expenditure (nominal?)	None.

Appendix 1: List of existing studies examining the causality between government expenditure and GDP (3/4, continued)

G to Y	Author.	obtaining	Country/region	Method.	data period	GDP variables and government expenditure variables	Considerations about the time of government's order placing
1	Ghali(1988).	*	OECD countries	Vector error correction model (VECM)	IFS , Quarterly, 1970:1-1994:3.		None.
2	Loizides et al. (2005).	*	Greece, UK, Ireland.	Error correction model (ECM)	National statistics, annual, longest 1948-1995	Real GDP per capita, real government expenditure, government expenditure as % of GDP, etc.	None.
3	Dogan et al. (2006).		Philippines, Indonesia, Malaysia, Singapore, Thailand.	Granger Causality Test			
4	Blankenau et al. (2007).	* Undecided manuscript	Developed and developing countries (83 countries)	Endogenous growth models, and their panel data analysis.	WDI, annual, 1960-2000.	Real per capita GDP growth, real education expenditure as % of GDP, real government expenditure as % of GDP, etc.	Consideration? Adopt a five-year average
5	Chandran et al. (2011).	*	Malaysia	Autoregressive distributed lag method (ARDL)	ADB, 1970-2006.	Real GDP, real gross government expenditure, real education expenditure, etc.	None.
6	Ebaidalla (2013).	*	Sudan	Granger causality test, error correction model.	Home authorities, annual, 1970-2008.	Real GDP, real gross government expenditure	None.
Y↔G.	Author.	obtaining	Country/region	Method.	data period	variable	Considerations at the time of placing a government order
1	Singh et al. (1984).	*	India	Granger Causality Test	Home authorities, annual, 1950-1981.	GDP per capita, government expenditure per capita (nominal and real)	None.
2	Cheng et al. (1997).		Korea	Vector autoregression (VAR)	IFY, annual, 1959-1993.	Real GDP, government spending, money supply	None.
3	Abu-Bader et al. (2003).	*	Egypt, Israel and Syria.	Cointegration test, variance decomposition	IFS, WDI, US-ACDA, annual	Nominal gross government expenditure as % of GDP, military expenditure as % of GDP	None.
4	Ahmad et al. (2005).		D-8 Member States	Granger Causality Test			
5	Samurdram et al. (2009).	*	Malaysia	ARDL Bounds Test	Home authorities, annual, 1970-2004.	Real GDP, real government expenditure	None.
6	Tang (2009).		Malaysia	Cointegration Bounds test and others.			

Appendix 1: List of existing studies examining the causality between government expenditure and GDP (4/4, continued)

Y↔G.	Author.	obtaining	Country/region	Method.	data period	variable	Considerations about the time of government's order placing
7	Wu et al. (2010).	*	182 countries worldwide	Panel Granger Causality Test	PWT 6.2, annual, 1950-2004.	Real GDP, real GFDP per capita, real government expenditure, government expenditure-GDP ratio	None.
8	Taban (2010).		Turkey	Bounds test and others.			
9	Abu-Eideh (2015).		Palestine	Granger Causality Test			
Y: G	Author.	obtaining	Country/region	Method.	data period	variable	Considerations at the time of placing a government order
1	Singh et al. (1984).	*	India	Granger Causality Test	Home authorities, annual, 1950-1981.	GDP per capita, government expenditure per capita (nominal and real)	None.
2	Afxentiou et al. (1296).	*	Enlargement of the European Union	Causality Test	OECD-NA, annual, 1961-1991.	Government final consumption, transfers and subsidies, GDP (per capita, nominal or real not known)	None.
3	Ansari et al. (1997).	*	Ghana, Kenya, South Africa.	Granger causality test, Holmes-Hutton test	IFS, Ghana 1963-88, Kenya 1964-89, South Africa 1957-90.	Real per capita government expenditure and national income	None.
4	Bagdigen et al. (2003).		Turkey	Cointegration and Granger Tests			
5	Ahmad et al. (2005).		D-8 Member States	Granger Causality Test			
6	Dogan et al. (2006).		Indonesia, Malaysia, Philippines, Singapore, Thailand.	Granger Causality Test			
7	Frimpong et al. (2009).		Gambia, Ghana, Nigeria.	Cointegration and Granger Tests			
8	Verma and Arora (2010).	*	India	Error correction model (ECM)	IFS-GFS, 1950/51-2008/09.	Real government expenditure, real GDP, population	None.
9	Taban (2010).		Turkey	Bounds test and others.			
10	Afzal et al. (2010).		Pakistan.	Granger & Sims Test			
11	Rauf et al. (2012).		Pakistan.	Autoregressive distributed lag method (ARDL)			
12	Ray et al. (2012).		India	Causality Test			
13	Huang (2006).	*	China, Taiwan.	Bounds test for UECM estimation.	IFS and Taiwanese authorities, 1979-2002.	Real GDP, real government expenditure, population	None.

Appendix 2: About Wagner's Law

In Nyasha et al. (2019), Wagner (1958, 1883) was referred to, so we sought in this article the references to fiscal expansion, and found it only in the following paragraph. It states that tax revenues are also described as a constraint on the expansion of the state, but basically it is argued that the desire of progressive people for greater government overcomes their financial difficulties. This has nothing to do with a causal direction from increased national income to higher government expenditure.

"The 'law of increasing expansion of public, and particularly state, activities' becomes for the fiscal economy the law of the increasing expansion of fiscal requirements. Both the State's requirements grow and, often even more so, those of local authorities, when administration is decentralized and local government well organized. Recently there has been a marked increase in Germany in the fiscal requirements of municipalities, especially urban ones. That law is the result of empirical observation in progressive countries, at least in our Western European civilization; its explanation, justification and cause is the pressure for social progress and the resulting changes in the relative spheres of private and public economy, especially compulsory public economy. Financial stringency may hamper the expansion of state activities, causing their extent to be conditioned by revenue rather than the other way round, as is more usual. But in the long run the desire for development of a progressive people will always overcome these financial difficulties." Wagner (1958, 1883), p. 8 [underlined by the author]

Appendix 3: On a simple simulation of the relationship between government expenditure and GDP

This section describes the design, set values and results of a simple simulation of the relationship between government expenditure and GDP.

A3.1. system of equations

Real gross domestic product is determined by both supply-side GDP (supply capacity) and demand-side GDP (effective demand) equations. It considers that the production of real GDP is realised as minimum of supply side or the demand side. In this case, government expenditure G_t as a policy variable plays an important role. Taxes are not taken into account (we assume that taxes are implicitly deducted before consumption and private investment are determined). It also does not explicitly take into account the fiscal balance (it considers that the fiscal deficit is compensated by the issuing of money by the government, which, if excessive, will cause nominal GDP to exceed the supply capacity and prices to rise).

- Supply-side real GDP (supply capacity)

$$Y^S_t = Y^S_0 \times (1+r)^t$$

where Y^S_t is the supply capacity, Y^S_0 is the initial value and r is the growth rate of supply capacity. In this model, the supply capacity is assumed to be exogenously determined and varies from country to country. Critics who deny the effects of government spending and argue that 'productivity should be increased' are, in this interpretation of the model, saying that r should be increased.

- Nominal GDP (effective demand)

$$Y_t = C_t + I_t + G_t$$

where Y_t is nominal GDP (effective demand), C_t is consumption, I_t is private capital investment and G_t is government expenditure.

- Nominal consumption

$$C_t = c \times Y_{t-1}$$

Where consumption (C_t) shall be determined by the consumption propensity c and GDP in the previous period (Y_{t-1}).

- Nominal private-sector capital investment

$$I_t = h \times Y_{t-1} \times P_{t-1} + \varepsilon_t$$

where private capital investment (I_t) is assumed to be determined by the investment propensity h, GDP in the previous period (Y_{t-1}) and prices (P_{t-1}). In other words, if the economy expands in the previous period, capital investment will increase proportionally. ε_t is a disturbance term representing changes in investment due to economic shocks.

- Nominal government expenditure

$$G_t = G_0 \times (1+g)^t$$

where G_t is government expenditure, G_0 is the initial value and g is the growth rate of government expenditure ($0 \leq g < 1$). g varies from country to country.

- Price index

$$P_t = P_{t-1} \times \max(1, Y_t / (P_{t-1} \times Y^S_t))$$

In terms of nominal GDP based on prices in the previous period, prices are assumed to rise accordingly when there is excess demand ($Y_t > (P_{t-1} \times Y^S_t)$) and prices remain as in the previous period when there is excess supply ($Y_t < (P_{t-1} \times Y^S_t)$). In other words, deflation is not assumed.

- Real GDP

$${}^RY_t = Y_t \div P_t$$

Actual GDP (${}^RY_t$) is nominal GDP (Y_t) divided by the price index. Rising prices cause the real value of consumption, capital investment and government expenditure to shrink in the same way.

A3.2 Simulation when the direction of causality is 'G->GDP'.

In this setting, the growth rate (r) of each country's supply capacity (Y^S_t) and the growth rate (g) of government expenditure (G_t), an item of effective demand, are exogenously determined first, and real and nominal GDP are consequently determined. In other words, government expenditure G_t is assumed here to grow at an initially determined rate of growth, unaffected by the resulting nominal and real GDP (Y_t, ${}^RY_t$). This assumes that the direction of causality is 'G -> GDP'. This is a reasonable approach considering that government expenditure is exogenous: by setting four levels of r (0%, 0.5%, 1% and 1.5%) and assuming five levels of government expenditure growth g (0%, 1%, 2%, 3% and 4%), 4 x 5 = 20 countries are assumed (country number is i). However, a random number is added to g so that calculations are made with more diverse growth rates (Figure A3-1).

Table A3-1: Set government expenditure growth (g) and supply capacity growth (r) for 20 countries

I	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
R	0	0	0	0	0	.5	.5	.5	.5	.5	1	1	1	1	1	1.5	1.5	1.5	1.5	1.5
g	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4

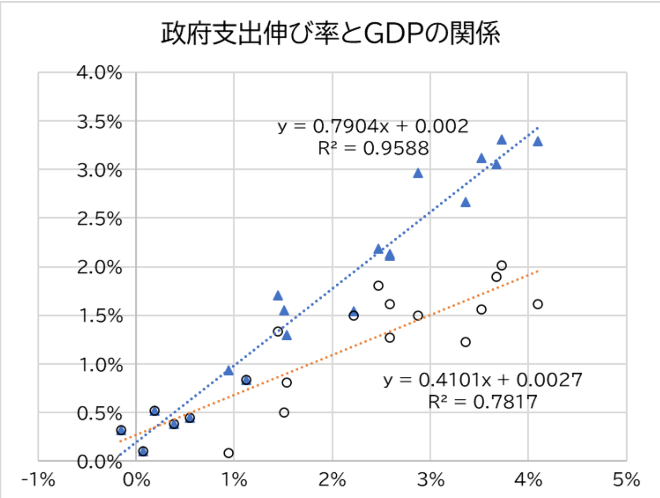
Source: author's settings. However, a uniform random number between minus 0.5 and plus 0.5 is added to g.

For each country, the initial values for each GDP item are set as $c_0 = 6$, $I_0 = 2$, $G_0 = 2$, $Y^D{}_0 = Y^S{}_0 = Y_0 = 10$. The consumption propensity is set to c = 0.6 and the investment propensity to h = 0.2. The growth rate of supply capacity is set to r and the growth rate of government expenditure is set to g, which varies from country to country. Furthermore, for capital investment I_t, in addition to the part determined by multiplying the previous year's Y_{t-1} by the investment propensity of 0.2, a uniform random number that takes a range from minus 0.4 to plus 0.6 is added. For each of these, a 20-year simulation was performed from t = 1 to 20.

Shown in Figure A2 is a scatterplot for the 20-year average. The first thing that can be read from the '▲' scatterplot is the (naturally) strong correlation between the growth rate of government expenditure and nominal GDP (the coefficient in the regression equation is about 0.79). The vertical scatter is due to changes in capital investment (not shown here, but if no random numbers were added to capital investment, the ▲ points would line up in a straight line). The '○' scatter plot shows the relationship between the growth rate of government expenditure and the growth rate of real GDP. This one shows a positive correlation, but the fit is much worse than in the case of nominal GDP. The vertical divergence between the '▲' and '○' figures is the difference between nominal and real GDP growth for the same rate of government expenditure growth. It can be seen that when the growth of supply capacity (Y^S) is low and nominal government expenditure is increased excessively, real GDP is suppressed because prices rise, even if nominal GDP grows. The regression equations for growth of real GDP and government expenditure also show that the coefficient of determination is much lower than for nominal GDP.

Figure A3-1 shows a similar trend to Figure 1 and is considered to capture some of the mechanisms that led to the relationships shown in Figure 1 in the main text. In the next section, the reverse causal relationship is considered.

Figure A3-1: Graph with the direction of causality as 'G -> GDP'



Source: author's calculations.

Note: The horizontal axis is government expenditure growth, the ▲ vertical axis is nominal GDP growth and the ○ vertical axis is real GDP growth.

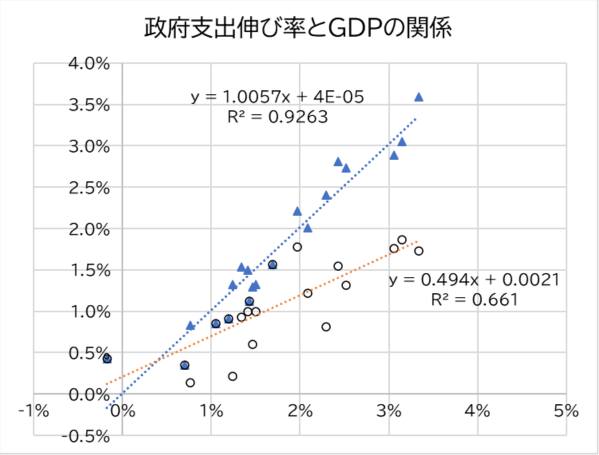
A2.3. when the direction of causality is 'GDP -> G'

In this setting, government expenditure shall be determined passively on the basis of nominal GDP in the previous period, as a fixed percentage of this. This has a certain validity given the actual budgetary decision-making mechanism. This means that the direction of causality is assumed to be ‘nominal GDP -> G’.

For the growth rate of supply capacity r, as in the previous section, four levels are set: 0%, 0.5%, 1% and 1.5%. For the growth rate of government expenditure, no prior assumptions are made and $G_t=0.2\times Y_{t-1}$ is assumed passively. Again, 20 countries are assumed (country number i). For all countries, the initial values for each GDP item are set as $C_0=6$, $I_0=2$, $G_0=2$, $Y^D_0=Y^S_0=Y_0=10$. The consumption and investment propensities are set to c = 0.6 and h = 0.2 respectively. For capital investment I_t, in addition to the part determined by multiplying the previous year's Y_{t-1} by the investment propensity of 0.2, a uniform random number that ranges from minus 0.8 to plus 1.2 is added to account for shocks due to economic fluctuations. In this case, capital investment is the driving force behind economic growth and, as a result of chance, there will be large differences in nominal and real GDP and government expenditure depending on the different rates of growth of capital investment.

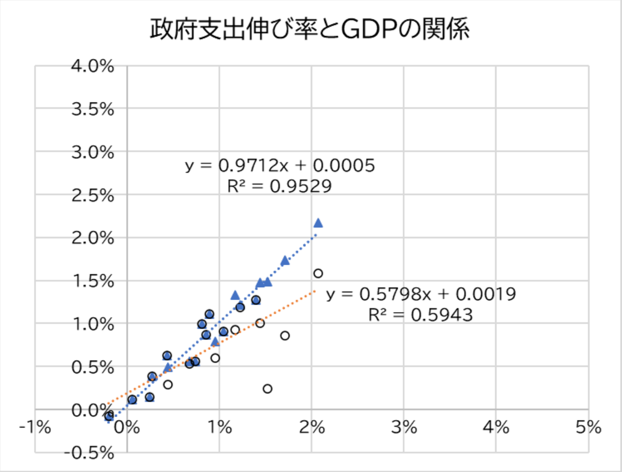
The results of a 20-year simulation for each of these, from $t = 1$ to 20, are shown in Figure A3-2. For this one, a similar relationship can be drawn for the government expenditure growth rate and nominal and real GDP as in Figure 1 in the main text. In this case, private capital investment drives GDP growth and government expenditure growth, with the country with the largest growth rate (4.50% per annum) having a Y growth rate of 3.59%, G growth rate of 3.34% and ${}^{R}Y$ growth rate of 1.73% and P growth rate of 1.83%. If the growth rate of private investment is large for all countries, the distribution of the graph is broad both vertically and horizontally; conversely, if the growth rate of private investment is small for all countries, the distribution of the graph is narrow both vertically and horizontally (for reference, see Figure A3-3).

Figure A3-2: Graph with the direction of causality 'GDP -> G'



Source: author's calculations.
Note: The horizontal axis is government expenditure growth, for the ▲ vertical axis is nominal GDP growth and the ○ vertical axis is real GDP growth. A uniform random number taking a range of -0.8 to 1.2 is added to the formula for private capital investment. The country with the largest capital investment growth rate was 4.50% per annum, with Y growth at 3.59% and G growth at 3.34%. The growth rate of ${}^{R}Y$ and P was 1.73% and 1.83%, respectively.

Figure A3-3: Graph with the direction of causality 'GDP->G' (when capital investment growth is small)



Source: author's calculations.
Note: The horizontal axis is government expenditure growth, for the ▲ vertical axis is nominal GDP growth and the ○ vertical axis is real GDP growth. A uniform random number taking a range of -0.4 to 0.6 is added to the formula for private capital investment. The country with the largest capital investment growth rate is 2.55% per annum, at which Y growth is 2.17%, G growth is 2.07%, ${}^{R}Y$ growth is 1.58% and P growth is 0.58%.

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