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Abstract

The paper investigates the revenue-expenditure nexus in the case of Japan by using five variables of revenues and four variables of expenditures. The techniques to analyze the causal relationship depend on the properties of the series. This paper utilizes three kinds of approaches; a VAR model setting by adding the extra lags, which is provided by Toda and Yamamoto (1995), a differenced VAR modeling, where there is no cointegrating relationship between non-stationary series, and a threshold error correction specification, which is proposed by Enders and Siklos (2001).

It is found that when we focus on the total expenditures excluding debt services and the total revenues excluding bond issues respectively, there is no causal relationship between them and the institutional separation hypothesis is supported in Japan. However, the expenditures excluding debt services Granger cause bond revenues. Especially regarding expenditures for social security and pensions, there exists the bidirectional causality between bond revenues and them. However, there is no causality that runs from expenditures for social security and pensions to tax revenues though there exists the causality that runs expenditures for public works to tax revenues. In addition, it is not observed such causality that when tax revenues increase, bond issues decrease. Therefore it concludes that the reason for accumulating the debt outstanding of the central government in Japan would be the increase in expenditures for social security and pensions by aging of Japanese society without taking account of the level of the revenues.

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Furthermore, when more controllable variables are set as expenditures like the national land conservation and development, it is found that the MTAR setting is statistically chosen, asymmetries in the adjusting process of the deviation from the long-run equilibrium is found, and in the case of worsening changes of budget deficits the adjustment process works well to avoid the deficit crisis. But it seems to be unsustainable, since deficits are reduced by utilizing non-tax revenues in Japan.

JEL classification: C32, C54, H50, H60

Key Words: Revenues; expenditures; central government; asymmetries; Granger non-causality; error correction model; TAR/MTAR model; structural break; aging economy; social security and pensions

1 Introduction

The paper examines the intertemporal relationship between the Japan's central government revenues and expenditures by using Granger non-causality test for these time series. According to Payne (2003), which reviews comprehensively the revenue-expenditure nexus and the related empirical literature, four behavioral hypotheses on the relationship between revenues and expenditures have been verified in a large number of literature. These hypotheses are based on the existence and the direction of the causal relationship between government revenues and expenditures. First, the tax-spend hypothesis is that the causality runs from revenues to expenditures, which is given by Friedman (1978) and Buchanan and Wagner (1977). Second, Barro (1979) and Peacock and Wiseman (1979) propose the spend-tax hypothesis which argues that the causality runs in opposite direction, from expenditures to revenues. Third, the fiscal synchronization hypothesis is that revenues and expenditures have bidirectional causality, which is provided by Musgrave (1960) and Meltzer and Richard (1981). Fourth, the institutional separation hypothesis is that revenues and expenditures have no causality; see, in detail, Wildavsky (1964, 1988) and Baghestani and McNown (1994).

Our main objective is to investigate a matter of generating budget deficits in the Japan's central government by using Granger non-causality test for several kinds of the

revenues and expenditures series. Furthermore, the long-run sustainability of budget deficits is examined by testing the significance of coefficients on the error correction term. Figure 1 shows that general bonds, which is the main part of the long-term debt of Japan's central government, outstanding is 636 trillion yen and its share of GDP runs up 133% at the end of FY 2010. Adding to local governments, the long-term debt outstanding in the whole government is 862 trillion yen and its share of GDP reaches 179% at the end of FY 2010, which is the worst level in OECD countries. Although Japan's fiscal deficits have been financed by abundant domestic savings, the Japan's government might meet repayment problems and seriously decide whether cutting in expenditures or rising tax rate in the future. In fact the Japan's government decided to expand public expenditures by issuing of the government bonds adding to monetary easing measures toward the economic recovery in 2013 and the consumption tax was increased from 5% to 8% on April of 2014. The impacts of these policies on the debt outstanding and business cycles depend on domestic and international macroeconomic situations as well as the Japan's government decision making process, which would be expressed as causality between the central government revenues and expenditures.

Figure 1 should be inserted around here.

In the revenue-expenditure nexus, early studies have checked the causal relationship between revenues and expenditures by Granger non-causality test based on vector autoregressive (VAR) models or error correction models. Recently, many researches have employed to threshold autoregressive (TAR) and momentum threshold autoregressive (MTAR) models provided by Enders and Siklos (2001). Ewing et al. (2006) is the first paper which applied TAR and MTAR models to the causal analysis on revenues and expenditures. This approach has an advantage that it is possible to test whether the adjusting process toward the log-run equilibrium is symmetry and to estimate the threshold which determines whether policymakers adjust revenues and expenditures toward the log-run equilibrium. The threshold is defined by levels of budget surplus or deficit in the case of TAR model, and in the case of MTAR model, it is defined by changes in budget surplus or deficit. When the TAR model is statistically significant, it indicates that the government adjusts revenues and expenditures by reacting to levels of budget surplus or deficit. When the MTAR model is chosen, it implies that the government adjusts revenues

and expenditures by reacting to changes of budget surplus or deficit. In the case that both models are statistically valid, policymakers would respond to both of levels and changes of budget surplus or deficit toward the long-run equilibrium. In this way, it is possible to gain a more insight into the government behavior by utilizing TAR and MTAR models than by using a symmetric modeling.

The paper is organized as follows. Section 2 describes the set of data used in this paper and our estimation strategy. Section 3 provides the properties of the data by using the unit root tests and the cointegration tests. In Section 4 the causal relationships between the series are investigated by using three kinds of techniques. For checking the robustness of results, Section 5 reinvestigates the causal relationships among the revenues and expenditures variables by using different types of variables; nominal and real variables, which are adjusted by GDP deflator, Consumer Price Index (CPI), and Corporate Goods Price Index (CGPI). Section 6 provides concluding remarks.

2 Data and estimation strategy

2.1 Data

Our data set consists of annual observations for Japan over the period FY 1955 to FY 2009 except for the bond issues, which was not allowed from FY 1965 to FY 2009. All data on revenues and expenditures are taken from the settlement of the general accounts based on “Financial Statistics of Japan” by Ministry of Finance. We use four different types of data on central government revenues;

1. the total revenues minus the bond issues ($CGR1$),
2. the bond issues ($CGR2$),
3. the bond issues and the tax and stamp revenues ($CGR3$),
4. non-tax revenues ($CGR4$) such as revenues on the sale of government assets and from government enterprises.

The $CGR1$ is the sum of $CGR3$ and $CGR4$. Regarding the data on government expenditures, we consider five different types according to controllability of expenditures by policymakers;

1. the total central government expenditures minus the debt services ($CGE1$),

2. $CGE1$ minus the expenditures for the local government finance which are mainly local allocation tax grants to local governments ($CGE2$),
3. the expenditures for the national land conservation and development, namely public works ($CGE3$),
4. $CGE2$ minus the expenditures for the social security and pensions ($CGE4$),
5. the expenditures for the social security and pensions ($CGE5$).

The series of $CGE3$ and $CGE4$ would be more controllable than $CGE1$, $CGE2$ and $CGE5$ for the central government. In the following G denotes the GDP ratio data; for example, $CGR1_G$ indicates that $100 \times CGR1$ is divided by GDP. Tables 1 and 2 summarize the relationships among each variables we will use in the following investigation.

Tables 1 and 2 should be inserted around here.

The data on GDP comes from “Annual Report on National Accounts” by Cabinet Office in Japan. Although National Accounts in Japan is currently based on SNA93 (System of National Accounts, 1993), the data created by retrospective adjustment is available since FY 1980 only. Therefore, we create the series of GDP from FY 1955 to FY 2009 by calculating the ratio of GDP by SNA93 to GDP by SNA68 in FY 1980 and multiplying the series of GDP from FY 1955 to FY 1979 by this ratio.

The series for revenues and expenditures in Japan are displayed in Figure 2 and their basic statistics are given by Table 3.

Figure 2 and Table 3 should be inserted around here.

2.2 Estimation strategy

To test four behavioral hypotheses of the Japan’s central government, the paper adopts the following estimation strategy:

Step 1: Check the stationarity of each series by unit root tests with/without a break.

Step 2: If the series are $I(1)$ processes, check the cointegrating relationships between them by cointegration tests with/without a break and with/without a threshold. If the integrated order of the series is not determined by unit root tests or larger than one, test Granger non-causality by Toda and Yamamoto (1995)’s approach.

Step 3: Based on the error correction representation, including no cointegration, test Granger non-causality between the series.

3 Preliminary tests

3.1 Unit root tests

First of all, the order of integration for each series is determined by ADF, PP, and KPSS tests. The former two test the null hypothesis of a unit root, and the last one tests the null hypothesis of stationarity. Table 4 reports the results of these unit root tests. This table shows that, taking into account three testing procedures, all series seem to be $I(1)$ process except for $CGR4_G$ under no structural break. In addition to the whole sample case, we deal with three cases where the last one, two, and three years in the sample are deleted for checking the robustness of the unit root test results, since Figure 2 shows some of variables are increasing steeply, especially in the last three years. But this treatment did not affect the test results.

Table 4 should be inserted around here.

3.2 Unit root tests with a break

Although the orders of integration are chosen by ADF, PP, and KPSS tests, it is necessary to check them with an endogenously determined structural break. By using the method by Zivot and Andrews (1992), consider the following three models:

$$\text{Model A: } y_t = \mu + \theta DU_t(\lambda) + \beta t + \alpha y_{t-1} + \sum_{j=1}^k c_j \Delta y_{t-j} + e_t,$$

$$\text{Model B: } y_t = \mu + \beta t + \gamma DT_t^*(\lambda) + \alpha y_{t-1} + \sum_{j=1}^k c_j \Delta y_{t-j} + e_t,$$

$$\text{Model C: } y_t = \mu + \theta DU_t(\lambda) + \beta t + \gamma DT^*(\lambda) + \alpha y_{t-1} + \sum_{j=1}^k c_j \Delta y_{t-j} + e_t,$$

where

$$DU_t(\lambda) = \begin{cases} 1 & \text{if } t > T\lambda \\ 0 & \text{if } t \leq T\lambda \end{cases},$$

$$DT_t^*(\lambda) = \begin{cases} t - T\lambda & \text{if } t > T\lambda \\ 0 & \text{if } t \leq T\lambda \end{cases},$$

$e_t \sim i.i.d.(0, \sigma_e^2)$, and T indicates the sample size. Each model is estimated by ordinary least squares with the break fraction λ , using the middle 70% of the whole sample. For each value of λ , t statistic on $\hat{\alpha}$ is evaluated, and the minimum t statistic among them is set as $t_{\hat{\alpha}}^*$;

$$t_{\hat{\alpha}}^* = \inf_{\lambda \in \Lambda} t_{\hat{\alpha}}(\lambda).$$

Zivot and Andrews (1992) provide the critical values of $t_{\hat{\alpha}}^*$, where the null hypothesis is given by $H_0 : \alpha = 1$. In this paper, Λ is set as $[0.15, 0.85]$, that is, the middle 70% of the whole data is used to search the break point. Table 5 reports t statistics and a break year for each model and indicates that $CGR1_G$, $CGR3_G$, $CGE3_G$, and $CGE4_G$ are still $I(1)$ variables, but the order of integration of $CGR2_G$, $CGE1_G$ and $CGE5_G$ is two under an endogenously determined structural break. Also the order of integration of $CGE2_G$ is undetermined by Table 5. In the case of $CGR4_G$, the order of integration is zero, which is not related with the presence of breaks.

Table 5 should be inserted around here.

Following our estimation strategy, we divide the set of the series into 24 groups:

- Group 1: $CGR1_G$ and $CGE3_G$
- Group 2: $CGR1_G$ and $CGE4_G$
- Group 3: $CGR3_G$ and $CGE3_G$
- Group 4: $CGR3_G$ and $CGE4_G$
- Group 5: $CGR1_G$ and $CGE1_G$
- Group 6: $CGR1_G$ and $CGE2_G$
- Group 7: $CGR1_G$ and $CGE5_G$
- Group 8: $CGR2_G$ and $CGE1_G$
- Group 9: $CGR2_G$ and $CGE2_G$

- Group 10: $CGR2_G$ and $CGE3_G$
- Group 11: $CGR2_G$ and $CGE4_G$
- Group 12: $CGR2_G$ and $CGE5_G$
- Group 13: $CGR3_G$ and $CGE1_G$
- Group 14: $CGR3_G$ and $CGE2_G$
- Group 15: $CGR3_G$ and $CGE5_G$
- Group 16: $CGR4_G$ and $CGE1_G$
- Group 17: $CGR4_G$ and $CGE2_G$
- Group 18: $CGR4_G$ and $CGE3_G$
- Group 19: $CGR4_G$ and $CGE4_G$
- Group 20: $CGR4_G$ and $CGE5_G$
- Group 21: $CGR2_G$ and $CGR1_G$
- Group 22: $CGR2_G$ and $CGR3_G$
- Group 23: $CGR4_G$ and $CGR2_G$
- Group 24: $CGR4_G$ and $CGR3_G$

Regarding Groups 1 to 4, we will check the existence of cointegrating relationships between the series, since the order of integration of each series in Groups 1 to 4 is one. The causal relationships between the series in Groups 5 to 24 will be investigated based on the method by Toda and Yamamoto (1995), where the merits of Toda and Yamamoto's approach are that it is not necessary to identify the order of integration of each series and the cointegrating relationship between them, and it can deal with the case that each series has the different order of integration. Groups 21 and 24 examine causal relationships among revenues variables to examine a policy maker's decision on the amount of bound issues and non-tax revenues.

If the policymaker issued bonds without increasing tax and non-tax revenues to finance public services and social infrastructures, the debt outstanding in the Japan's central government would expand unlimitedly.

3.3 Cointegration tests

As each group is constructed of just two series in the paper, the method by Engle and Granger (1987) is utilized to test the existence of cointegration between the series in each

group. For checking the robustness of the cointegration test, estimate the model twice by replacing the dependent variable with the independent one. Table 6 reports the results of the cointegration tests and implies that there is no long-run relationship between the series. In Groups 1 and 3, when $CGE3_G$ is set as the dependent variable the test statistics are statistically significant, but by replacing the role of the variable these significances disappear. We conclude that there is no cointegrating relationship between the series in each group.

Table 6 should be inserted around here.

3.4 Cointegration tests with a break

Although the previous subsection shows no cointegration, we consider the cointegration test by Gregory and Hansen (1996), where endogenous breaks are taken into account. Following Gregory and Hansen (1996), three kinds of models are examined:

$$\text{Level shift (C): } y_{1t} = \mu_1 + \mu_2\phi_{t\lambda} + \alpha y_{2t} + e_t,$$

$$\text{Level shift with trend (C/T): } y_{1t} = \mu_1 + \mu_2\phi_{t\lambda} + \beta t + \alpha y_{2t} + e_t,$$

$$\text{Regime shift (C/S): } y_{1t} = \mu_1 + \mu_2\phi_{t\lambda} + \alpha_1 y_{2t} + \alpha_2 y_{2t}\phi_{t\lambda} + e_t,$$

where $e_t \sim (0, \sigma_e^2)$ and

$$\phi_{t\lambda} = \begin{cases} 1 & \text{if } t > T\lambda \\ 0 & \text{if } t \leq T\lambda \end{cases}.$$

The above cointegrating equation is estimated by ordinary least squares, and a unit root test is applied to the regression errors. For each $\lambda \in \Lambda = [0.15, 0.85]$, evaluate $ADF(\lambda)$, $Z_\alpha(\lambda)$, and $Z_t(\lambda)$ statistics, and test the null hypothesis of no cointegration based on the minimum $ADF(\lambda)$, $Z_\alpha(\lambda)$, and $Z_t(\lambda)$ statistics. The $ADF(\lambda)$ is given by t statistic on $\hat{e}_{t-1\lambda}$, where $\Delta\hat{e}_{t\lambda}$ is regressed on $\hat{e}_{t-1\lambda}, \Delta\hat{e}_{t-1\lambda}, \dots, \Delta\hat{e}_{t-K\lambda}$;

$$ADF(\lambda) = t_{\hat{\rho}_\lambda}.$$

The $Z_\alpha(\lambda)$ and $Z_t(\lambda)$ are given by

$$Z_\alpha(\lambda) = T(\hat{\rho}_\lambda^* - 1),$$

$$Z_t(\lambda) = (\hat{\rho}_\lambda^* - 1)/s.e.(\hat{\rho}_\lambda),$$

where $\hat{\rho}_\lambda^*$ is the bias-corrected first-order serial correlation coefficient estimate. The final statistics we use are given by

$$\begin{aligned} ADF^* &= \inf_{\lambda \in \Lambda} ADF(\lambda), \\ Z_\alpha^* &= \inf_{\lambda \in \Lambda} Z_\alpha(\lambda), \\ Z_t^* &= \inf_{\lambda \in \Lambda} Z_t(\lambda). \end{aligned}$$

Asymptotic distribution of each test statistics are provided by Gregory and Hansen (1996), and Table 7 gives test statistics, break years, and selected lags order for ADF statistics. Table 7 implies that there is no cointegrating relationship between the series in each group even in the presence of endogenously determined structural breaks.

Table 7 should be inserted around here.

3.5 Threshold cointegration tests

Although the cointegrating relationship between the series is not found irrespective of the existence of structural breaks, it seems to be possible that there is a threshold cointegrating relationship between the series, which is given by Enders and Siklos (2001). The paper investigates the threshold autoregressive (TAR) and momentum TAR (MTAR) model to test the existence of the cointegration, where in the TAR model the degree of autoregressive decay depends on the state of the variable concerned, and in the MTAR model a variable to display differing amounts of autoregressive decay depends on whether it is increasing or decreasing. To deal with the case of unknown threshold, Chan (1993)'s method is utilized in this paper. Consider the following model:

$$y_{1t} = \beta_0 + \beta_1 y_{2t} + e_t, \quad (3.1)$$

$$\Delta e_t = I_t \rho_1 e_{t-1} + (1 - I_t) \rho_2 e_{t-1} + \sum_{j=1}^k \gamma_j \Delta e_{t-j} + \varepsilon_t, \quad (3.2)$$

where $e_t \sim i.i.d.(0, \sigma_e^2)$, $\varepsilon_t \sim i.i.d.(0, \sigma_\varepsilon^2)$, and the Heaviside indicator I_t is given by

$$I_t = \begin{cases} 1 & \text{if } e_{t-1} \geq \tau \\ 0 & \text{if } e_{t-1} < \tau \end{cases}, \quad (3.3)$$

where τ is a threshold. As another identification of adjustment process, consider

$$I_t = \begin{cases} 1 & \text{if } \Delta e_{t-1} \geq \tau \\ 0 & \text{if } \Delta e_{t-1} < \tau \end{cases}. \quad (3.4)$$

When I_t is defined by (3.3), it is called to be the TAR model, and in the case (3.4) is set as I_t it is the MTAR model. By using the residuals obtained in the cointegration equation (3.1), estimate (3.2). Enders and Siklos (2001) provide two test statistics, that is, the one is to use maximum value between t statistics on $\hat{\rho}_1$ and on $\hat{\rho}_2$, which is called to be t -Max test, and another one is Φ test based on F statistic of $\rho_1 = \rho_2 = 0$. When the null hypothesis of $\rho_1 = \rho_2 = 0$ is rejected, test the null hypothesis of $\rho_1 = \rho_2$ based on F distribution; see, for example, Ewing et al. (2006) and Payne et al. (2008). The distribution of t -Max and Φ statistics are provided by Enders and Siklos (2001). Although it is well known that the necessary and sufficient conditions for the stationarity of $\{e_t\}$ is $\rho_1 < 0, \rho_2 < 0$ and $(1 + \rho_1)(1 + \rho_2) < 1$ for any value of τ , this paper just confirms whether final estimates of ρ_1 and ρ_2 satisfy the conditions. In all cases the estimates of ρ_1 and ρ_2 for TAR models do not meet the conditions, while the stationary conditions are satisfied in all MTAR settings. Table 8 reports MTAR estimation results and indicates in the case of Groups 1 and 2 the null hypothesis of $\rho_1 = \rho_2 = 0$ is rejected and this result does not depend on how to choose the dependent variable. Furthermore, the null hypothesis of $\rho_1 = \rho_2$ is rejected in both cases. It concludes that there is a threshold cointegration in Groups 1 and 2 respectively, that is, by taking asymmetry adjustments into account we can find a long-run relationship between the series. But in the case of Groups 3 and 4, the result of threshold cointegration tests depends on the selected dependent variable, and it concludes that the null hypothesis of $\rho_1 = \rho_2 = 0$ is not rejected in each group. In the following, the causal relationship in Groups 1 and 2 are examined by using threshold error correction representations and differenced VAR models are used to identify Granger causality in Groups 3 and 4.

Table 8 should be inserted around here.

4 Empirical results

4.1 Causal analyses by VAR model

As Groups 5 to 24 include the variables whose orders of integration are not one, we use Toda and Yamamoto's approach, where we estimate a $(p + d_{\max})$ th order VAR model, where d_{\max} is the maximal order of integration that we suspect might occur in the series.

The d_{\max} is set by two in this paper. For Groups 5 to 24, the likelihood ratio tests select one, two, and four as the lag orders for each model, that is, by taking account of extra two lags we estimate VAR(3), VAR(4) and VAR(6) models respectively to test Granger non-causality. Consider the bivariate VAR(3) model, which is constructed of x_t and y_t . To test the null hypothesis of Granger non-causality from $\{y_t\}$ to $\{x_t\}$, it needs to test whether the coefficient on y_{t-1} is significantly different from zero or not by using its t -statistic. In the cases of VAR(4) and VAR(6) models, the number of zero restrictions on coefficients is not equal to one, the *Wald* test is available to test Granger non-causality. Tables 9 and 10 report t -statistics, *Wald* statistics and their p -values, and it concludes that the null hypotheses of Granger non-causality from $CGE1_G$ to $CGR2_G$, from $CGE1_G$ and $CGR3_G$, and from $CGR4_G$ to $CGR3_G$ are rejected at 10%, 5%, and 1% significance levels respectively, that is, $CGE1_G$ Granger causes $CGR2_G$ and $CGR3_G$, and $CGR4_G$ causes $CGE3_G$ in the sense of Granger. Furthermore, in the cases of Group 12 and 23, the null hypotheses of non-causality for both directions are rejected at 5% and 10% significance levels respectively, and these results indicate that the fiscal synchronization hypothesis is valid for the pair of $CGR2_G$ and $CGE5_G$, and the one of $CGR4_G$ and $CGR2_G$.

Tables 9 and 10 should be inserted around here.

4.2 Causal analyses by differenced VAR models

As there is no cointegrating relationship between the series in Groups 3 and 4, we apply the differenced VAR estimation approach to test Granger non-causality. Consider the bivariate VAR model constructed of x_t and y_t as in the previous subsection. The null hypothesis of Granger non-causality from y_t to x_t is identified by zero restrictions of all coefficients on the lagged y_t variables, and Granger non-causality tests are conducted by the *Wald* statistics. Table 11 gives the results of causal analyses based on differenced VAR models. In the case that $CGR3_G$ is set as the dependent variable in 3 to 5th lag order VAR models, the null hypothesis of zero restrictions are rejected and it is found that $CGE3_G$ causes $CGR3_G$ in the sense of Granger.

Table 11 should be inserted around here.

4.3 Causal analyses by threshold error correction model

As asymmetries in the adjustment process under the cointegrating relationship are found between the series in Groups 1 and 2, a momentum threshold error correction model is estimated to identify the causal relationship between them. The error correction term is defined by

$$\begin{aligned} R_t &= \beta_0 + \beta_1 G_t + e_t, \\ \Delta \hat{e}_t &= I_t \rho_1 \hat{e}_{t-1} + (1 - I_t) \rho_2 \hat{e}_{t-1} + \sum_{j=1}^k \gamma_j \Delta \hat{e}_{t-j} + \varepsilon_t, \\ I_t &= \begin{cases} 1 & \text{if } \Delta \hat{e}_{t-1} \geq \tau \\ 0 & \text{if } \Delta \hat{e}_{t-1} < \tau \end{cases}, \end{aligned}$$

where $e_t \sim i.i.d.(0, \sigma_e^2)$, $\varepsilon_t \sim i.i.d.(0, \sigma_\varepsilon^2)$, $\{\hat{e}_t\}$ is the residual sequence, and R_t and G_t indicate the revenues and the expenditures respectively. The error term \hat{e}_t implies the level of the surplus if e_t is positive, and the level of deficits otherwise. We estimate the corresponding asymmetric error correction model which is given by

$$\begin{aligned} \Delta R_t &= \mu_0 + \sum_{i=1}^p \alpha_i \Delta R_{t-i} + \sum_{i=1}^p \beta_i \Delta G_{t-i} + \rho_1 I_t \hat{e}_{t-1} + \rho_2 (1 - I_t) \hat{e}_{t-1} + u_{1t}, \\ \Delta G_t &= \tilde{\mu}_0 + \sum_{i=1}^p \tilde{\alpha}_i \Delta R_{t-i} + \sum_{i=1}^p \tilde{\beta}_i \Delta G_{t-i} + \tilde{\rho}_1 I_t \hat{e}_{t-1} + \tilde{\rho}_2 (1 - I_t) \hat{e}_{t-1} + u_{2t}. \end{aligned}$$

Table 12 gives the *Wald* statistics to test the Granger non-causality, their p -values, estimates of ρ_i for $i = 1, 2$, their p -values, and estimated thresholds $\hat{\tau}$ for the lag order from 1 to 5.

Table 12 should be inserted around here.

In Group 1, there is no proof to imply the short-run Granger causality from $\Delta CGR1_G$ to $\Delta CGE3_G$, and from the error correction term to $\Delta CGE3_G$. However in the opposite direction, the null hypothesis of no Granger causality from $\Delta CGE3_G$ to $\Delta CGR1_G$ is rejected for all lag orders, and, furthermore, ρ_2 is significantly different from zero at 1% significance level for all the specifications. The result of Group 2 is that Granger causality from the variable $CGR1_G$ of revenues to the variable $CGE4_G$ of expenditures is not found at all, and this is the same as in Group 1. Although the short-run causality

from $\Delta CGE4_G$ to $\Delta CGR1_G$ is not found and ρ_1 is not significantly different from zero, the null hypothesis of $\rho_2 = 0$ is rejected at 1% significance level for all the lag orders. In both cases of Groups 1 and 2, the estimates of ρ_2 are negative and their absolute values are less than one, and the estimated signs of thresholds τ are negative.

4.4 Implication

Our main result is that there is no causal relationship between $CGR1_G$ (the total revenues excluding the bond issues) and $CGE1_G$ (the total expenditures excluding the debt services) as well as $CGE2_G$ ($CGE1_G$ minus expenditures for grants to local governments). This result supports for the institutional separation hypothesis in the Japan's central government. Thus, $CGR1_G$ and $CGE1_G$ (or $CGE2_G$) would be decided independently. However it seems that the level of deficits in Japan is not still in the critical phase. This implies that there exist some relationships between the revenues and expenditures variables, and by dividing the revenues variable into three variables it is found that $CGE1_G$ Granger causes $CGR2_G$ (the revenues by the bond issues) and $CGE3_G$ (public works) one-sidedly. Although these mechanisms, that is, issuing bonds and raising the tax, have been working well to avoid the deficit crisis in Japan so far, the budget deficits have been increasing because of not enough increase in tax. To investigate the reason of expanding deficits, it is required to consider each item of the expenditures variable.

Regarding more controllable expenditures, $CGE3_G$ and $CGE4_G$ (government expenditures except the debt services, grants to local governments, and social security with pensions), the threshold cointegration relationships between $CGE3_G$ (or $CGE4_G$) and $CGR1_G$ are found. When these expenditures increase and then the deviation from the long-run equilibrium expands beyond a certain negative threshold, $CGR1_G$ will be adjusted to the long-run equilibrium, but $CGR3_G$ (tax and stamp revenues) will not. This asymmetric finding implies that $CGR4_G$ (non-tax revenues such as revenues on the sale of government assets and revenues from government enterprises) would be adjusted to the long-run equilibrium because $CGR1_G$ consists of $CGR3_G$ and $CGR4_G$. The absolute values of estimates of ρ_2 in the M-TAR specifications for Groups 1 and 2 are less than one, this indicates in the long-run the relationship between $CGR4_G$ and $CGE3_G$ (or $CGE4_G$) is sustainable. But as the order of integration of $CGR4_G$ is determined by zero, we could not apply TAR specifications to $CGR4_G$. Furthermore, it is found that $CGR4_G$ and

$\Delta CGE3_G$ Granger cause $CGE3_G$ and $\Delta CGR3_G$ respectively. It might indicate that to increase the public work, the policy maker consider to sell government assets and when the budget is not enough to do the public work, in the short run she or he will increase the tax, but the level of tax rates are not enough to avoid the debt crisis in the long run. As a result, it concludes that Japan's central government utilizes non-tax revenues for improving the budget deficits when controllable expenditures expand. However, this policy seems to be a lack of plan, since Spend-Tax hypothesis is valid only in the short run and it would be impossible to continue it forever, since government's assets are not unlimited.

Which components of expenditures generate fiscal deficits in Japan crucially? While there is no causality between $CGE3_G$ and $CGR2_G$ as well as between $CGE4_G$ and $CGR2_G$, there exists the bidirectional causality between $CGE5_G$ (social security and pensions) and $CGR2_G$. In addition, there is no causal relationship between $CGR3_G$ (or $CGR4_G$) and $CGE5_G$, and there exists the causality that runs from $CGE3_G$ to $CGR3_G$ in the short run. Although tax revenues react to expenditures for public works, these do not react to expenditures for social security and pensions. This results show that the expenditure for social security and pensions is financed by not raising tax but issuing bonds and that issuing bonds would also generate expenditures for social security and pensions inversely.

In pairs of revenues variables, although there exists the bidirectional causal relationship between $CGR2_G$ and $CGR4_G$, $CGR2_G$ does not Granger cause $CGR1_G$ and $CGR3_G$ and vice versa, that is, when raising tax revenues, bond issues do not decrease necessarily. Accordingly, it concludes that expanding expenditures for social security and pensions by aging of Japanese society results in more increasing the debt outstanding of Japan's central government, and the way of financing more controllable expenditures is not sustainable.

5 Robustness checks

To check the robustness of our results based on the GDP ratio data, we reestimate the causal relationship between revenues and expenditures by using four types of variables; nominal and three versions of real variables defined by using GDP deflator, CPI, and CGPI, since there is no consensus about the measures of revenues and expenditures in

the empirical literature. See, for example, Ram (1988) and Baghestani and McNown (1994). By using not only GDP deflator but also CPI and CGPI as in Ram (1988), we transform nominal data to real data. In the following, r_1 , r_2 and r_3 indicate that the series is adjusted by GDP deflator, CPI and CGPI respectively. The data on GDP deflator comes from “Annual Report on National Accounts” by Cabinet Office in Japan, and the data on CPI and CGPI is available on Bank of Japan’s website. All variables are transformed into natural logs. Table 13 shows basic statistics for them.

Table 13 should be inserted around here.

Following the same estimation procedures in the previous analysis, Tables 14 to 28 shows Granger non-causality test results. For the same reason in Section 3, we report MTAR specification results when there exists a threshold cointegration between variables. In all the cases, it is observed that $CGE1$, $CGE5$ and $CGR4$ Granger cause $CGR2$, and the causality runs from $CGE3$ to $CGR3$. These results indicate that the public work is financed healthily, but other expenditures, especially social security and pensions, depend on issuing the bonds. These findings are observed consistently in Japan. However, there are considerably various results, which depend on the setting as in Ram (1988). When real variables are used, it is necessary to consider which type of real variables are suitable to the purpose of the research. Although Tables 14 to 28 cannot provide consistent results, it is found that the spend-tax hypothesis is valid when there is any causal relationship between revenues and expenditures.

Tables 14 to 28 should be inserted around here.

6 Concluding remarks

The paper investigated the revenue-expenditure nexus in the case of Japan by using five variables of revenues and three variables of expenditures. The techniques to analyze the causal relationship depend on the properties of the series. This paper utilizes three kinds of approaches; VAR models by adding the extra lags, differenced VAR models, and threshold error correction models.

It is found that when we focus on the total expenditures excluding debt services and the total revenues excluding bond issues respectively, there is no causal relationship between them and the institutional separation hypothesis is supported in Japan. However, the expenditures excluding debt services Granger cause bond revenues. Especially regarding expenditures for social security and pensions, there exists the bidirectional causality between bond revenues and them. However, there is no causality that runs from expenditures for social security and pensions to tax revenues though there exists the causality that runs expenditures for public works to tax revenues. In addition, it is not observed such causality that when tax revenues increase, bond issues decrease. Therefore it concludes that the reason for accumulating the debt outstanding of the central government in Japan would be the increase in expenditures for social security and pensions by aging of Japanese society.

Furthermore, when more controllable variables are set as expenditures, it is found that the MTAR setting is statistically chosen, asymmetries in the adjusting process of the deviation from the long-run equilibrium is found, and in the case of worsening changes of budget deficits the adjustment process works well to avoid the deficit crisis. But financial resources for reducing the budget deficit are mainly from revenues on the sale of government assets and from government enterprises, and it seems to be unsustainable. It is necessarily to construct the link between expenditures and tax revenues to avoid the deficit crisis with absolute certainty.

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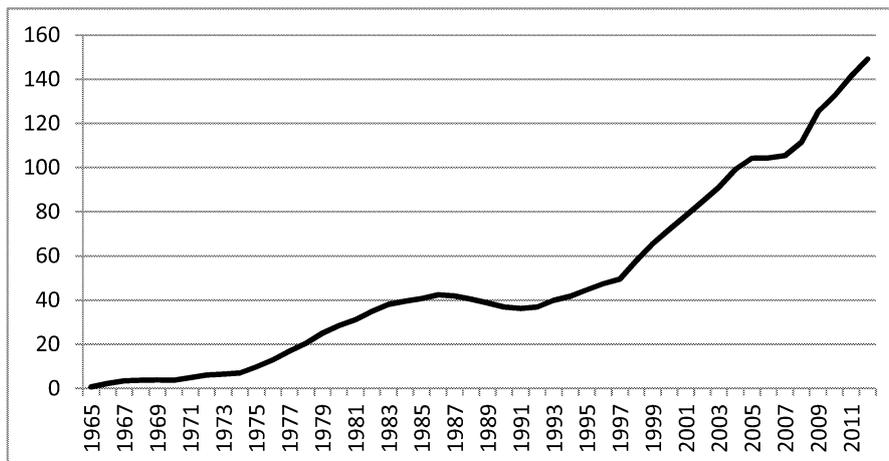
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Figure 1: General bonds outstanding/GDP ratio (%) in Japan



Source: Ministry of Finance, Japan's Fiscal Condition.

Figure 2: Revenues and expenditures in Japan

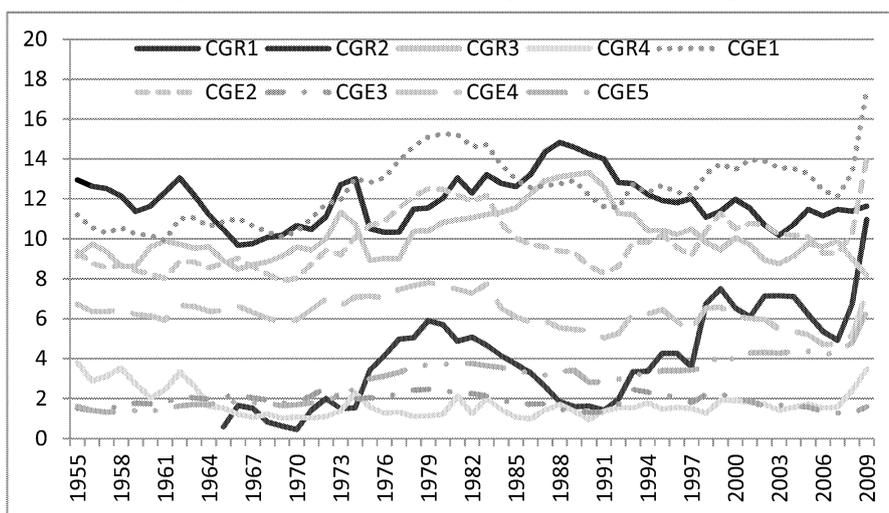


Table 1: Revenue variables

| Item | <i>CGR1</i> | <i>CGR2</i> | <i>CGR3</i> | <i>CGR4</i> | % |
|------------------------|-------------|-------------|-------------|-------------|-------|
| Bond issues | - | ● | - | - | 48.5 |
| Tax and stamp revenues | ● | - | ● | - | 36.2 |
| Other revenues | ● | - | - | ● | 15.3 |
| Total | | | | | 100.0 |

1. % is evaluated in FY2009.
2. The symbols of ● and - indicate that each variable in the column contains and does not contain the corresponding item in the row respectively.

Table 2: Expenditure variables

| Item | <i>CGE1</i> | <i>CGE2</i> | <i>CGE3</i> | <i>CGE4</i> | <i>CGE5</i> | % |
|--|-------------|-------------|-------------|-------------|-------------|-------|
| Debt services | - | - | - | - | - | 18.3 |
| Local finance | ● | - | - | - | - | 16.4 |
| Social security, etc. | ● | ● | - | - | ● | 29.9 |
| National land conservation and development | ● | ● | ● | ● | - | 7.5 |
| Agencies' administration | ● | ● | - | ● | - | 5.0 |
| National defense | ● | ● | - | ● | - | 4.8 |
| Industrial development | ● | ● | - | ● | - | 7.6 |
| Education and culture | ● | ● | - | ● | - | 5.8 |
| Pensions for former military | ● | ● | - | ● | - | 0.8 |
| Others | ● | ● | - | ● | - | 3.9 |
| Total | | | | | | 100.0 |

1. % is evaluated in FY2009.
2. The symbols of ● and - indicate that each variable in the column contains and does not contain the corresponding item in the row respectively.

Table 3: Basic Statistics

| Variables | Mean | Median | Max | Min | S.D. | Skew | Kurt | JB | <i>p</i> -value | Obs. |
|-------------------------|--------|--------|--------|-------|-------|--------|-------|---------------------|-----------------|------|
| <i>CGR1_G</i> | 11.885 | 11.798 | 14.820 | 9.679 | 1.242 | 0.364 | 2.640 | 1.511 | 0.470 | 55 |
| <i>CGR2_G</i> | 3.990 | 4.147 | 10.960 | 0.456 | 2.365 | 0.473 | 2.906 | 1.694 | 0.429 | 45 |
| <i>CGR3_G</i> | 10.137 | 9.751 | 13.307 | 8.171 | 1.288 | 0.910 | 3.139 | 7.632 ^b | 0.022 | 55 |
| <i>CGR4_G</i> | 1.747 | 1.541 | 3.799 | 0.949 | 0.709 | 1.320 | 3.960 | 18.089 ^a | 0.000 | 55 |
| <i>CGE1_G</i> | 12.456 | 12.556 | 17.410 | 9.918 | 1.624 | 0.473 | 3.048 | 2.053 | 0.358 | 55 |
| <i>CGE2_G</i> | 9.833 | 9.589 | 14.011 | 7.916 | 1.360 | 0.871 | 3.329 | 7.202 ^b | 0.027 | 55 |
| <i>CGE3_G</i> | 1.886 | 1.943 | 2.540 | 1.275 | 0.341 | -0.055 | 2.098 | 1.893 | 0.388 | 55 |
| <i>CGE4_G</i> | 6.294 | 6.311 | 7.814 | 4.700 | 0.773 | 0.076 | 2.490 | 0.648 | 0.723 | 55 |
| <i>CGE5_G</i> | 2.982 | 3.230 | 6.370 | 1.320 | 1.134 | 0.242 | 2.718 | 0.719 | 0.698 | 55 |

1. The Skew, Kurt, JB and Obs. indicate skewness, kurtosis, Jarque-Bera statistic, and the number of observations respectively.
2. ^a, ^b, ^c indicate significance at the 1%, 5%, 10% level respectively.

Table 4: Unit root Tests

| Variables | ADF(C) | ADF(T) | PP(C) | PP(T) | KPSS(C) | KPSS(T) |
|-------------------|-------------------------|-------------------------|----------------------|----------------------|--------------------|--------------------|
| $CGR1_G$ | -2.205(0) | -2.212(0) | -2.346 | -2.349 | 0.135 | 0.123 ^c |
| $\Delta CGR1_G$ | -6.142 ^a (0) | -6.085 ^a (0) | -6.111 ^a | -6.032 ^a | 0.101 | 0.099 |
| $\Delta^2 CGR1_G$ | -7.024 ^a (2) | -6.955 ^a (2) | -24.010 ^a | -23.595 ^a | 0.177 | 0.177 ^b |
| $CGR2_G$ | -0.525(1) | -1.965(1) | -0.613 | -1.711 | 0.538 ^b | 0.086 |
| $\Delta CGR2_G$ | -3.644 ^a (0) | -3.644 ^b (0) | -3.508 ^b | -3.602 ^b | 0.139 | 0.090 |
| $\Delta^2 CGR2_G$ | -6.306 ^a (1) | -6.335 ^a (1) | -7.650 ^a | -7.728 ^a | 0.267 | 0.092 |
| $CGR3_G$ | -1.787(1) | -1.601(1) | -1.619 | -1.272 | 0.246 | 0.183 ^b |
| $\Delta CGR3_G$ | -5.744 ^a (0) | -5.780 ^a (0) | -5.569 ^a | -5.608 ^a | 0.228 | 0.090 |
| $\Delta^2 CGR3_G$ | -6.950 ^a (2) | -6.915 ^a (2) | -23.247 ^a | -28.462 ^a | 0.220 | 0.219 ^a |
| $CGR4_G$ | -3.108 ^b (0) | -2.520(0) | -2.957 ^b | -2.011 | 0.292 | 0.210 ^b |
| $\Delta CGR4_G$ | -7.462 ^a (0) | -7.759 ^a (0) | -7.699 ^a | -11.301 ^a | 0.504 ^b | 0.208 ^b |
| $\Delta^2 CGR4_G$ | -5.181 ^a (5) | -8.113 ^a (2) | -22.905 ^a | -24.278 ^a | 0.194 | 0.191 ^b |
| $CGE1_G$ | -1.060(1) | -2.213(1) | -0.810 | -1.503 | 0.548 ^b | 0.120 ^c |
| $\Delta CGE1_G$ | -2.897 ^c (0) | -2.885(0) | -2.801 ^c | -2.837 | 0.150 | 0.122 ^c |
| $\Delta^2 CGE1_G$ | -7.371 ^a (0) | -7.417 ^a (0) | -7.324 ^a | -7.386 ^a | 0.212 | 0.118 |
| $CGE2_G$ | -1.512(1) | -2.138(1) | -0.878 | -1.819 | 0.318 | 0.100 |
| $\Delta CGE2_G$ | -3.227 ^b (0) | -3.236 ^c (0) | -3.199 ^b | -3.225 ^c | 0.192 | 0.119 |
| $\Delta^2 CGE2_G$ | -5.870 ^a (1) | -5.897 ^a (1) | -7.333 ^a | -7.388 ^a | 0.209 | 0.117 |
| $CGE3_G$ | -3.190 ^b (1) | -3.393 ^c (1) | -2.588 | -2.542 | 0.184 | 0.129 ^c |
| $\Delta CGE3_G$ | -5.499 ^a (1) | -5.528 ^a (1) | -5.774 ^a | -5.781 ^a | 0.123 | 0.059 |
| $\Delta^2 CGE3_G$ | -6.057 ^a (4) | -5.987 ^a (4) | -25.834 ^a | -30.450 ^a | 0.206 | 0.184 ^b |
| $CGE4_G$ | -2.581(1) | -2.566(1) | -2.283 | -2.165 | 0.338 | 0.118 |
| $\Delta CGE4_G$ | -4.986 ^a (0) | -4.915 ^a (0) | -4.783 ^a | -4.736 ^a | 0.102 | 0.078 |
| $\Delta^2 CGE4_G$ | -7.064 ^a (1) | -7.085 ^a (1) | -10.902 ^a | -11.019 ^a | 0.205 | 0.122 ^c |
| $CGE5_G$ | 0.399(10) | -2.286(10) | 0.854 | -1.300 | 0.908 ^a | 0.084 |
| $\Delta CGE5_G$ | -1.114(10) | -1.053(10) | -3.406 ^b | -3.543 ^b | 0.252 | 0.117 |
| $\Delta^2 CGE5_G$ | -2.149(9) | -3.188(8) | -9.433 ^a | -9.503 ^a | 0.214 | 0.116 |

1. The lag lengths for ADF(C) and ADF(T) were chosen by AIC and denoted in parentheses.
2. ^a, ^b, ^c indicate significance at the 1%, 5%, 10% level respectively.
3. (C), (T) indicate that the constant term and the constant and trend terms are included in the model concerned respectively.

Table 5: Unit root tests with a break

| Variables | ZA(A) | break date | lag | ZA(B) | break date | lag | ZA(C) | break date | lag |
|-------------------|---------------------|------------|-----|----------------------|------------|-----|----------------------|------------|-----|
| $CGR1_G$ | -3.783 | 1978 | 1 | -3.356 | 1989 | 1 | -3.855 | 1983 | 1 |
| $\Delta CGR1_G$ | -6.690 ^a | 1989 | 0 | -6.148 ^a | 1973 | 0 | -6.621 ^a | 1989 | 0 |
| $\Delta^2 CGR1_G$ | -5.547 ^a | 1984 | 5 | -5.312 ^a | 1971 | 5 | -6.316 ^a | 1974 | 5 |
| $CGR2_G$ | -3.651 | 1986 | 1 | -2.474 | 1995 | 1 | -3.425 | 1986 | 1 |
| $\Delta CGR2_G$ | -4.144 | 1980 | 0 | -3.828 | 1988 | 0 | -4.134 | 1980 | 0 |
| $\Delta^2 CGR2_G$ | -6.585 ^a | 1978 | 1 | -6.765 ^a | 2001 | 1 | -7.393 ^a | 2000 | 1 |
| $CGR3_G$ | -3.087 | 1994 | 1 | -4.275 ^c | 1990 | 1 | -4.782 | 1986 | 1 |
| $\Delta CGR3_G$ | -6.432 ^a | 1991 | 0 | -5.966 ^a | 1981 | 0 | -6.372 ^a | 1991 | 0 |
| $\Delta^2 CGR3_G$ | -7.071 ^a | 1995 | 2 | -6.906 ^a | 1965 | 2 | -7.165 ^a | 1995 | 2 |
| $CGR4_G$ | -4.925 ^b | 1964 | 0 | -4.244 ^c | 1968 | 0 | -4.848 ^c | 1964 | 0 |
| $\Delta CGR4_G$ | -7.878 ^a | 1982 | 0 | -7.844 ^a | 2000 | 0 | -7.950 ^a | 2000 | 0 |
| $\Delta^2 CGR4_G$ | -5.573 ^a | 1975 | 5 | -5.316 ^a | 2000 | 5 | -6.232 ^a | 1975 | 5 |
| $CGE1_G$ | -3.183 | 1988 | 1 | -2.149 | 1964 | 1 | -2.552 | 1984 | 1 |
| $\Delta CGE1_G$ | -3.600 | 1981 | 0 | -3.050 | 1992 | 0 | -3.392 | 1981 | 0 |
| $\Delta^2 CGE1_G$ | -7.612 ^a | 1979 | 0 | -8.032 ^a | 1999 | 0 | -8.504 ^a | 1999 | 0 |
| $CGE2_G$ | -3.380 | 1984 | 1 | -2.091 | 1964 | 1 | -2.826 | 1984 | 1 |
| $\Delta CGE2_G$ | -3.953 | 1980 | 0 | -3.395 | 1991 | 0 | -3.791 | 1984 | 0 |
| $\Delta^2 CGE2_G$ | -1.832 | 1980 | 0 | -1.607 | 1985 | 5 | -1.823 | 1980 | 5 |
| $CGE3_G$ | -3.830 | 1971 | 1 | -3.749 | 1978 | 1 | -4.007 | 1983 | 1 |
| $\Delta CGE3_G$ | -6.086 ^a | 1991 | 1 | -5.532 ^a | 1985 | 1 | -6.088 ^a | 1992 | 1 |
| $\Delta^2 CGE3_G$ | -6.332 ^a | 1994 | 4 | -5.979 ^a | 2000 | 4 | -6.531 ^a | 1996 | 4 |
| $CGE4_G$ | -4.044 | 1984 | 1 | -2.733 | 1975 | 1 | -3.923 | 1984 | 1 |
| $\Delta CGE4_G$ | -5.347 ^a | 1980 | 0 | -5.021 ^a | 1987 | 0 | -5.509 ^b | 2000 | 0 |
| $\Delta^2 CGE4_G$ | -5.428 ^a | 1973 | 2 | -5.564 ^a | 1999 | 2 | -5.971 ^a | 1996 | 2 |
| $CGE5_G$ | -2.040 | 1985 | 0 | -0.962 | 2000 | 0 | -1.718 | 1990 | 0 |
| $\Delta CGE5_G$ | -4.363 | 1980 | 0 | -3.948 | 1992 | 0 | -4.238 | 1982 | 0 |
| $\Delta^2 CGE5_G$ | -9.824 ^a | 1976 | 0 | -10.070 ^a | 1999 | 0 | -10.232 ^a | 1999 | 0 |

1. The lag lengths were chosen by AIC.
2. ^a, ^b, ^c indicate significance at the 1%, 5%, 10% level respectively.
3. Critical values are provided by Zivot and Andrews (1992) in Tables 2 to 4 respectively.
 - For Model A: 1% : -5.34, 5% : -4.80, 10% : -4.58.
 - For Model B: 1% : -4.93, 5% : -4.42, 10% : -4.11.
 - For Model C: 1% : -5.57, 5% : -5.08, 10% : -4.82.

Table 6: Cointegration tests

| Dependent | Group 1 | | Group 2 | | Group 3 | | Group 4 | |
|------------------|----------|----------------------|----------|----------------------|----------|----------------------|----------|----------|
| | $CGR1_G$ | $CGE3_G$ | $CGR1_G$ | $CGE4_G$ | $CGR3_G$ | $CGE3_G$ | $CGR3_G$ | $CGE4_G$ |
| τ statistic | -2.230 | -3.251 ^c | -2.287 | -2.637 | -1.712 | -3.132 ^c | -1.771 | -2.310 |
| p -value | 0.417 | 0.078 | 0.389 | 0.238 | 0.674 | 0.099 | 0.646 | 0.378 |
| z statistic | -9.203 | -21.523 ^b | -9.254 | -16.789 ^c | -7.637 | -19.545 ^b | -7.512 | -10.431 |
| p -value | 0.380 | 0.022 | 0.377 | 0.075 | 0.496 | 0.038 | 0.506 | 0.303 |
| lag order | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 |

1. The lag lengths were chosen by AIC.

2. ^a, ^b, ^c indicate significance at the 1%, 5%, 10% level respectively.

Table 7: Cointegration tests with a break

| Model C | Group 1 | | Group 2 | | Group 3 | | Group 4 | |
|----------------------|----------|---------------------|----------|----------|----------|----------|----------|----------|
| Dependent | $CGR1_G$ | $CGE3_G$ | $CGR1_G$ | $CGE4_G$ | $CGR3_G$ | $CGE3_G$ | $CGR3_G$ | $CGE4_G$ |
| ADF statistic | -3.269 | -4.269 | -3.083 | -3.288 | -2.188 | -3.871 | -2.303 | -3.297 |
| break date | 1999 | 1998 | 1975 | 1985 | 1975 | 1998 | 1998 | 1985 |
| lag-order | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Z_α statistic | -16.420 | -20.193 | -14.449 | -20.503 | -9.316 | -16.708 | -9.437 | -20.356 |
| break date | 1999 | 2000 | 1998 | 1986 | 1999 | 2000 | 1999 | 1986 |
| Z_t statistic | -2.988 | -3.463 | -2.791 | -3.084 | -2.281 | -3.242 | -2.282 | -3.085 |
| break date | 1999 | 2000 | 1974 | 1986 | 1999 | 2000 | 1999 | 1986 |
| Model C/T | Group 1 | | Group 2 | | Group 3 | | Group 4 | |
| Dependent | $CGR1_G$ | $CGE3_G$ | $CGR1_G$ | $CGE4_G$ | $CGR3_G$ | $CGE3_G$ | $CGR3_G$ | $CGE4_G$ |
| ADF statistic | -4.517 | -4.905 ^c | -4.349 | -4.239 | -3.946 | -4.298 | -3.998 | -4.122 |
| break date | 1975 | 1973 | 1976 | 1985 | 1998 | 1998 | 1995 | 1985 |
| lag-order | 1 | 1 | 2 | 1 | 1 | 1 | 1 | 1 |
| Z_α statistic | -23.949 | -25.179 | -22.661 | -31.576 | -22.695 | -21.122 | -21.110 | -29.307 |
| break date | 1999 | 2000 | 1978 | 1972 | 1996 | 1999 | 1996 | 1972 |
| Z_t statistic | -3.778 | -3.871 | -3.666 | -3.969 | -3.498 | -3.570 | -3.406 | -3.937 |
| break date | 1978 | 2000 | 1981 | 1984 | 1999 | 2000 | 1996 | 1972 |
| Model C/S | Group 1 | | Group 2 | | Group 3 | | Group 4 | |
| Dependent | $CGR1_G$ | $CGE3_G$ | $CGR1_G$ | $CGE4_G$ | $CGR3_G$ | $CGE3_G$ | $CGR3_G$ | $CGE4_G$ |
| ADF statistic | -3.314 | -4.103 | -2.990 | -3.475 | -2.540 | -3.942 | -2.312 | -3.949 |
| break date | 1992 | 1998 | 1998 | 1985 | 1992 | 1998 | 1998 | 1985 |
| lag-order | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| Z_α statistic | -16.346 | -20.061 | -14.772 | -21.464 | -9.477 | -18.528 | -9.416 | -27.203 |
| break date | 1992 | 2000 | 1998 | 1986 | 1993 | 1982 | 1999 | 1984 |
| Z_t statistic | -2.971 | -3.449 | -2.886 | -3.193 | -2.296 | -3.305 | -2.266 | -3.860 |
| break date | 1992 | 2000 | 1996 | 1986 | 1993 | 1982 | 1999 | 1984 |

1. The lag lengths were chosen by AIC.

2. Critical values are provided by Gregory and Hansen (1996) Table1.

• ADF and Z_t statistics:

–For Model C: 1% : -5.13, 5% : -4.61, 10% : -4.34.

–For Model C/T: 1% : -5.45, 5% : -4.99, 10% : -4.72.

–For Model C/S: 1% : -5.47, 5% : -4.95, 10% : -4.68.

• Z_α statistic:

–For Model C: 1% : -50.07, 5% : -40.48, 10% : -36.19.

–For Model C/T: 1% : -57.28, 5% : -47.96, 10% : -43.22.

–For Model C/S: 1% : -57.17, 5% : -47.04, 10% : -41.85.

Table 8: Threshold cointegration tests

| MTAR | Group 1 | | Group 2 | | Group 3 | | Group 4 | |
|--|---------------------------|---------------------------|----------------------------|----------------------------|-------------------------|---------------------------|---------------------------|----------------------------|
| | <i>CGR1_G</i> | <i>CGE3_G</i> | <i>CGR1_G</i> | <i>CGE4_G</i> | <i>CGR3_G</i> | <i>CGE3_G</i> | <i>CGR3_G</i> | <i>CGE4_G</i> |
| $\hat{\tau}$ | -0.632 | -0.107 | -0.752 | 0.426 | -0.424 | -0.122 | -0.384 | 0.354 |
| F statistic of $\rho_1 = \rho_2 = 0$ | 9.09 ^b (2, 49) | 8.91 ^b (2, 49) | 12.06 ^a (2, 49) | 8.78 ^b (2, 51) | 2.50(2, 49) | 8.98 ^b (2, 49) | 3.83(2, 49) | 8.14 ^b (2, 51) |
| t statistic of max $\rho_i = 0$ | -1.368 | -1.716 ^c | -1.555 | -0.640 | -0.751 | -2.036 ^b | -0.581 | -0.946 |
| F statistic of $\rho_1 = \rho_2$ | 9.94 ^a (1, 49) | 6.27 ^b (1, 49) | 15.24 ^a (1, 49) | 11.02 ^a (1, 51) | 2.12(1, 49) | 7.07 ^b (1, 49) | 4.41 ^b (1, 49) | 10.15 ^a (1, 51) |
| p -value | 0.003 | 0.016 | 0.000 | 0.002 | 0.152 | 0.011 | 0.041 | 0.003 |

1. For tests of symmetry, the standard F distribution is used, as in Ewing et al. (2006) and Payne et al. (2008). p -values are evaluated based on the standard F distribution.
2. Enders and Siklos (2001) gives critical values for Φ test and t -max test in Tables 5 and 6 respectively.

Table 9: Granger non-causality tests by Toda and Yamamoto

| | | Trend model | | | |
|----------|---|--------------|-----------------|-------------------------------|------------|
| | Null hypothesis | selected lag | estimated model | t (<i>Wald</i>) statistic | p -value |
| Group 5 | $CGR1_G \overset{G}{\nrightarrow} CGE1_G$ | 2 | 4 | 0.401 | 0.818 |
| | $CGE1_G \overset{G}{\nrightarrow} CGR1_G$ | 2 | 4 | 2.347 | 0.309 |
| Group 6 | $CGR1_G \overset{G}{\nrightarrow} CGE2_G$ | 1 | 3 | -0.629 | 0.533 |
| | $CGE2_G \overset{G}{\nrightarrow} CGR1_G$ | 1 | 3 | -0.423 | 0.674 |
| Group 7 | $CGR1_G \overset{G}{\nrightarrow} CGE5_G$ | 1 | 3 | 0.036 | 0.972 |
| | $CGE5_G \overset{G}{\nrightarrow} CGR1_G$ | 1 | 3 | -0.719 | 0.476 |
| Group 8 | $CGR2_G \overset{G}{\nrightarrow} CGE1_G$ | 1 | 3 | 1.181 | 0.246 |
| | $CGE1_G \overset{G}{\nrightarrow} CGR2_G$ | 1 | 3 | 1.894 ^c | 0.067 |
| Group 9 | $CGR2_G \overset{G}{\nrightarrow} CGE2_G$ | 1 | 3 | 1.161 | 0.254 |
| | $CGE2_G \overset{G}{\nrightarrow} CGR2_G$ | 1 | 3 | 1.572 | 0.125 |
| Group 10 | $CGR2_G \overset{G}{\nrightarrow} CGE3_G$ | 1 | 3 | 1.258 | 0.217 |
| | $CGE3_G \overset{G}{\nrightarrow} CGR2_G$ | 1 | 3 | -0.747 | 0.461 |
| Group 11 | $CGR2_G \overset{G}{\nrightarrow} CGE4_G$ | 1 | 3 | 1.258 | 0.217 |
| | $CGE4_G \overset{G}{\nrightarrow} CGR2_G$ | 1 | 3 | 0.381 | 0.705 |
| Group 12 | $CGR2_G \overset{G}{\nrightarrow} CGE5_G$ | 2 | 4 | 6.222 ^b | 0.045 |
| | $CGE5_G \overset{G}{\nrightarrow} CGR2_G$ | 2 | 4 | 7.033 ^b | 0.030 |
| Group 13 | $CGR3_G \overset{G}{\nrightarrow} CGE1_G$ | 4 | 6 | 1.160 | 0.885 |
| | $CGE1_G \overset{G}{\nrightarrow} CGR3_G$ | 4 | 6 | 9.951 ^b | 0.041 |
| Group 14 | $CGR3_G \overset{G}{\nrightarrow} CGE2_G$ | 4 | 6 | 3.807 | 0.433 |
| | $CGE2_G \overset{G}{\nrightarrow} CGR3_G$ | 4 | 6 | 5.398 | 0.249 |

1. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.
2. In each group, LR statistics select the lag-order of VAR model and two extra lags are added to test the causality.

Table 10: Granger non-causality tests by Toda and Yamamoto (cont.)

| | | Trend model | | | |
|----------|---|--------------|-----------------|-------------------------------|------------|
| | Null hypothesis | selected lag | estimated model | t (<i>Wald</i>) statistic | p -value |
| Group 15 | $CGR3_G \overset{G}{\nrightarrow} CGE5_G$ | 1 | 3 | -1.007 | 0.319 |
| | $CGE5_G \overset{G}{\nrightarrow} CGR3_G$ | 1 | 3 | -0.217 | 0.830 |
| Group 16 | $CGR4_G \overset{G}{\nrightarrow} CGE1_G$ | 1 | 3 | 0.208 | 0.836 |
| | $CGE1_G \overset{G}{\nrightarrow} CGR4_G$ | 1 | 3 | 0.569 | 0.572 |
| Group 17 | $CGR4_G \overset{G}{\nrightarrow} CGE2_G$ | 1 | 3 | 0.426 | 0.672 |
| | $CGE2_G \overset{G}{\nrightarrow} CGR4_G$ | 1 | 3 | 0.605 | 0.548 |
| Group 18 | $CGR4_G \overset{G}{\nrightarrow} CGE3_G$ | 1 | 3 | 6.482 ^a | 0.000 |
| | $CGE3_G \overset{G}{\nrightarrow} CGR4_G$ | 1 | 3 | 0.021 | 0.984 |
| Group 19 | $CGR4_G \overset{G}{\nrightarrow} CGE4_G$ | 1 | 3 | 0.455 | 0.651 |
| | $CGE4_G \overset{G}{\nrightarrow} CGR4_G$ | 1 | 3 | 0.522 | 0.605 |
| Group 20 | $CGR4_G \overset{G}{\nrightarrow} CGE5_G$ | 1 | 3 | 1.474 | 0.148 |
| | $CGE5_G \overset{G}{\nrightarrow} CGR4_G$ | 1 | 3 | 0.451 | 0.654 |
| Group 21 | $CGR2_G \overset{G}{\nrightarrow} CGR1_G$ | 1 | 3 | 1.128 | 0.267 |
| | $CGR1_G \overset{G}{\nrightarrow} CGR2_G$ | 1 | 3 | 0.103 | 0.919 |
| Group 22 | $CGR2_G \overset{G}{\nrightarrow} CGR3_G$ | 1 | 3 | 0.510 | 0.614 |
| | $CGR3_G \overset{G}{\nrightarrow} CGR2_G$ | 1 | 3 | -1.256 | 0.218 |
| Group 23 | $CGR4_G \overset{G}{\nrightarrow} CGR2_G$ | 2 | 4 | 8.117 ^b | 0.017 |
| | $CGR2_G \overset{G}{\nrightarrow} CGR4_G$ | 2 | 4 | 5.755 ^c | 0.056 |
| Group 24 | $CGR4_G \overset{G}{\nrightarrow} CGR3_G$ | 1 | 3 | -1.378 | 0.175 |
| | $CGR3_G \overset{G}{\nrightarrow} CGR4_G$ | 1 | 3 | 0.970 | 0.337 |

1. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.
2. In each group, LR statistics select the lag-order of VAR model and two extra lags are added to test the causality.

Table 11: Granger non-causality tests by differenced VAR model

| | | Constant model | | | | | | | | | |
|-----------------|---|--------------------|---------|-------|---------|--------------------|---------|--------------------|---------|---------------------|---------|
| lag-order | | 1 | | 2 | | 3 | | 4 | | 5 | |
| Null hypothesis | | Wald | p-value | Wald | p-value | Wald | p-value | Wald | p-value | Wald | p-value |
| Group 3 | $\Delta CGR3_G \not\rightarrow \Delta CGE3_G$ | 3.294 ^c | 0.070 | 2.750 | 0.253 | 2.495 | 0.476 | 4.369 | 0.358 | 6.329 | 0.275 |
| | $\Delta CGE3_G \not\rightarrow \Delta CGR3_G$ | 1.944 | 0.163 | 2.950 | 0.229 | 8.338 ^b | 0.040 | 7.879 ^c | 0.096 | 12.128 ^b | 0.033 |
| Group 4 | $\Delta CGR3_G \not\rightarrow \Delta CGE4_G$ | 1.188 | 0.276 | 1.656 | 0.437 | 2.303 | 0.512 | 2.633 | 0.621 | 4.185 | 0.523 |
| | $\Delta CGE4_G \not\rightarrow \Delta CGR3_G$ | 0.091 | 0.763 | 1.181 | 0.554 | 3.912 | 0.271 | 3.883 | 0.422 | 3.975 | 0.553 |

1. ^a, ^b, ^c indicate significance at the 1%, 5%, 10% level respectively.

Table 12: Granger non-causality tests by threshold (MTAR) error correction model

| lag-order | | Constant model | | | | | | | | | |
|-----------|---|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| | | 1 | | 2 | | 3 | | 4 | | 5 | |
| | | Wald/coef | p-value |
| Group 1 | $\Delta CGR1_G \overset{G}{\nrightarrow} \Delta CGE3_G$ | 1.337 | 0.248 | 1.287 | 0.525 | 2.121 | 0.548 | 2.327 | 0.676 | 2.346 | 0.799 |
| | $\hat{\rho}_1$ | -0.016 | 0.584 | -0.006 | 0.836 | 0.002 | 0.962 | -0.004 | 0.894 | -0.006 | 0.864 |
| | $\hat{\rho}_2$ | 0.009 | 0.888 | 0.006 | 0.926 | 0.030 | 0.660 | 0.022 | 0.757 | -0.003 | 0.973 |
| | $\Delta CGE3_G \overset{G}{\nrightarrow} \Delta CGR1_G$ | 5.527 ^b | 0.019 | 6.046 ^b | 0.049 | 9.502 ^b | 0.023 | 10.560 ^b | 0.032 | 12.557 ^b | 0.028 |
| | $\hat{\rho}_1$ | -0.070 | 0.386 | -0.069 | 0.428 | -0.060 | 0.501 | -0.067 | 0.475 | -0.073 | 0.461 |
| | $\hat{\rho}_2$ | -0.777 ^a | 0.000 | -0.751 ^a | 0.000 | -0.753 ^a | 0.000 | -0.776 ^a | 0.000 | -0.690 ^a | 0.002 |
| | $\hat{\tau} = -0.632$ | | | | | | | | | | |
| Group 2 | $\Delta CGR1_G \overset{G}{\nrightarrow} \Delta CGE4_G$ | 0.078 | 0.780 | 1.318 | 0.517 | 2.700 | 0.440 | 5.699 | 0.223 | 6.409 | 0.268 |
| | $\hat{\rho}_1$ | -0.045 | 0.483 | -0.070 | 0.306 | -0.046 | 0.536 | -0.073 | 0.334 | -0.088 | 0.293 |
| | $\hat{\rho}_2$ | -0.011 | 0.952 | -0.059 | 0.754 | -0.038 | 0.844 | -0.113 | 0.573 | -0.170 | 0.434 |
| | $\Delta CGE4_G \overset{G}{\nrightarrow} \Delta CGR1_G$ | 0.000 | 0.988 | 0.198 | 0.906 | 2.585 | 0.460 | 3.372 | 0.498 | 4.377 | 0.497 |
| | $\hat{\rho}_1$ | -0.107 | 0.151 | -0.100 | 0.215 | -0.093 | 0.277 | -0.108 | 0.229 | -0.154 | 0.118 |
| | $\hat{\rho}_2$ | -0.980 ^a | 0.000 | -0.968 ^a | 0.000 | -0.929 ^a | 0.000 | -0.957 ^a | 0.000 | -0.937 ^a | 0.001 |
| | $\hat{\tau} = -0.752$ | | | | | | | | | | |

1. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.

2. *Wald* statistics is for Granger non-causality test and coef indicates an estimate of ρ_i for $i = 1$ and 2.

Table 13: Basic Statistics 2

| Variables | Mean | Median | Max | Min | S.D. | Skew | Kurt | JB | p -value | Obs. |
|--------------------------|-------|--------|--------|-------|-------|--------|-------|---------------------|------------|------|
| <i>CGR1</i> | 9.825 | 10.450 | 11.101 | 7.027 | 1.344 | -0.793 | 2.139 | 7.465 ^b | 0.024 | 55 |
| <i>CGR2</i> | 9.018 | 9.456 | 10.858 | 5.284 | 1.456 | -1.068 | 3.118 | 8.576 ^b | 0.014 | 45 |
| <i>CGR3</i> | 9.664 | 10.326 | 11.004 | 6.680 | 1.381 | -0.845 | 2.263 | 7.793 ^b | 0.020 | 55 |
| <i>CGR4</i> | 7.845 | 8.145 | 9.707 | 5.643 | 1.214 | -0.449 | 1.711 | 5.657 ^c | 0.059 | 55 |
| <i>CGE1</i> | 9.869 | 10.605 | 11.321 | 6.881 | 1.421 | -0.858 | 2.248 | 8.048 ^b | 0.018 | 55 |
| <i>CGE2</i> | 9.632 | 10.398 | 11.104 | 6.704 | 1.399 | -0.861 | 2.243 | 8.110 ^b | 0.017 | 55 |
| <i>CGE3</i> | 7.973 | 8.667 | 9.380 | 4.884 | 1.336 | -0.991 | 2.671 | 9.253 ^a | 0.010 | 55 |
| <i>CGE4</i> | 9.187 | 9.901 | 10.462 | 6.372 | 1.297 | -0.927 | 2.385 | 8.738 ^b | 0.013 | 55 |
| <i>CGE5</i> | 8.369 | 9.247 | 10.316 | 4.918 | 1.713 | -0.788 | 2.146 | 7.366 ^b | 0.025 | 55 |
| <i>CGR1_{r1}</i> | 9.288 | 10.243 | 11.106 | 5.242 | 1.956 | -0.793 | 2.106 | 7.593 ^b | 0.022 | 55 |
| <i>CGR2_{r1}</i> | 8.709 | 9.258 | 10.688 | 4.006 | 1.835 | -1.163 | 3.160 | 10.200 ^a | 0.006 | 45 |
| <i>CGR3_{r1}</i> | 9.126 | 10.135 | 11.004 | 4.895 | 1.992 | -0.827 | 2.189 | 7.779 ^b | 0.020 | 55 |
| <i>CGR4_{r1}</i> | 7.308 | 8.021 | 9.536 | 3.907 | 1.811 | -0.585 | 1.773 | 6.580 ^b | 0.037 | 55 |
| <i>CGE1_{r1}</i> | 9.332 | 10.414 | 11.151 | 5.096 | 2.032 | -0.841 | 2.179 | 8.020 ^b | 0.018 | 55 |
| <i>CGE2_{r1}</i> | 9.095 | 10.208 | 10.951 | 4.919 | 2.010 | -0.843 | 2.175 | 8.080 ^b | 0.018 | 55 |
| <i>CGE3_{r1}</i> | 7.436 | 8.541 | 9.402 | 3.099 | 1.944 | -0.926 | 2.450 | 8.549 ^b | 0.014 | 55 |
| <i>CGE4_{r1}</i> | 8.650 | 9.717 | 10.426 | 4.587 | 1.908 | -0.883 | 2.265 | 8.384 ^b | 0.015 | 55 |
| <i>CGE5_{r1}</i> | 7.832 | 9.057 | 10.145 | 3.156 | 2.323 | -0.798 | 2.112 | 7.648 ^b | 0.022 | 55 |
| <i>CGR1_{r2}</i> | 9.251 | 10.245 | 11.067 | 5.268 | 1.994 | -0.764 | 2.028 | 7.511 ^b | 0.023 | 55 |
| <i>CGR2_{r2}</i> | 8.681 | 9.253 | 10.832 | 3.906 | 1.887 | -1.138 | 3.104 | 9.741 ^a | 0.008 | 45 |
| <i>CGR3_{r2}</i> | 9.089 | 10.138 | 10.964 | 4.920 | 2.030 | -0.798 | 2.107 | 7.673 ^b | 0.022 | 55 |
| <i>CGR4_{r2}</i> | 7.271 | 7.987 | 9.680 | 3.889 | 1.855 | -0.555 | 1.728 | 6.534 ^b | 0.038 | 55 |
| <i>CGE1_{r2}</i> | 9.295 | 10.417 | 11.294 | 5.122 | 2.071 | -0.807 | 2.101 | 7.823 ^b | 0.020 | 55 |
| <i>CGE2_{r2}</i> | 9.057 | 10.210 | 11.077 | 4.945 | 2.050 | -0.809 | 2.096 | 7.877 ^b | 0.019 | 55 |
| <i>CGE3_{r2}</i> | 7.398 | 8.515 | 9.372 | 3.125 | 1.980 | -0.891 | 2.345 | 8.255 ^b | 0.016 | 55 |
| <i>CGE4_{r2}</i> | 8.613 | 9.719 | 10.435 | 4.613 | 1.946 | -0.848 | 2.175 | 8.152 ^b | 0.017 | 55 |
| <i>CGE5_{r2}</i> | 7.794 | 9.060 | 10.289 | 3.165 | 2.364 | -0.767 | 2.047 | 7.471 ^b | 0.024 | 55 |
| <i>CGR1_{r3}</i> | 9.668 | 10.688 | 11.206 | 6.367 | 1.644 | -0.779 | 1.998 | 7.858 ^b | 0.020 | 55 |
| <i>CGR2_{r3}</i> | 8.967 | 9.613 | 10.860 | 4.674 | 1.668 | -1.211 | 3.241 | 11.116 ^a | 0.004 | 45 |
| <i>CGR3_{r3}</i> | 9.507 | 10.567 | 11.120 | 6.020 | 1.680 | -0.815 | 2.093 | 7.981 ^b | 0.018 | 55 |
| <i>CGR4_{r3}</i> | 7.688 | 8.352 | 9.709 | 5.043 | 1.507 | -0.553 | 1.664 | 6.899 ^b | 0.032 | 55 |
| <i>CGE1_{r3}</i> | 9.713 | 10.811 | 11.323 | 6.221 | 1.720 | -0.831 | 2.079 | 8.278 ^b | 0.016 | 55 |
| <i>CGE2_{r3}</i> | 9.475 | 10.566 | 11.106 | 6.044 | 1.699 | -0.833 | 2.072 | 8.328 ^b | 0.016 | 55 |
| <i>CGE3_{r3}</i> | 7.816 | 8.781 | 9.437 | 4.224 | 1.631 | -0.927 | 2.371 | 8.776 ^b | 0.012 | 55 |
| <i>CGE4_{r3}</i> | 9.031 | 10.046 | 10.464 | 5.712 | 1.597 | -0.876 | 2.163 | 8.633 ^b | 0.013 | 55 |
| <i>CGE5_{r3}</i> | 8.212 | 9.436 | 10.318 | 4.281 | 2.012 | -0.785 | 2.021 | 7.840 ^b | 0.020 | 55 |

1. The Skew, Kurt, JB and Obs. indicate skewness, kurtosis, Jarque-Bera statistic, and the number of observations respectively.
2. ^a, ^b, ^c indicate significance at the 1%, 5%, 10% level respectively.

Table 14: Granger non-causality tests by Toda and Yamamoto (nominal)

| Trend model | | | | | | |
|-------------|---------------------------------------|--------------|-----------------|-------------------------------|------------|--|
| | Null hypothesis | selected lag | estimated model | t (<i>Wald</i>) statistic | p -value | |
| Group 5 | $CGR1 \overset{G}{\nrightarrow} CGE1$ | 2 | 4 | 0.188 | 0.910 | |
| | $CGE1 \overset{G}{\nrightarrow} CGR1$ | 2 | 4 | 3.920 | 0.141 | |
| Group 6 | $CGR1 \overset{G}{\nrightarrow} CGE2$ | 4 | 6 | 13.232 ^a | 0.010 | |
| | $CGE2 \overset{G}{\nrightarrow} CGR1$ | 4 | 6 | 12.231 ^b | 0.016 | |
| Group 8 | $CGR2 \overset{G}{\nrightarrow} CGE1$ | 1 | 3 | 1.048 | 0.302 | |
| | $CGE1 \overset{G}{\nrightarrow} CGR2$ | 1 | 3 | 1.982 ^c | 0.055 | |
| Group 9 | $CGR2 \overset{G}{\nrightarrow} CGE2$ | 4 | 6 | 8.040 ^c | 0.090 | |
| | $CGE2 \overset{G}{\nrightarrow} CGR2$ | 4 | 6 | 6.098 | 0.192 | |
| Group 10 | $CGR2 \overset{G}{\nrightarrow} CGE3$ | 1 | 3 | 0.969 | 0.339 | |
| | $CGE3 \overset{G}{\nrightarrow} CGR2$ | 1 | 3 | 0.407 | 0.687 | |
| Group 11 | $CGR2 \overset{G}{\nrightarrow} CGE4$ | 1 | 3 | 0.744 | 0.462 | |
| | $CGE4 \overset{G}{\nrightarrow} CGR2$ | 1 | 3 | 1.191 | 0.242 | |
| Group 12 | $CGR2 \overset{G}{\nrightarrow} CGE5$ | 2 | 4 | 2.735 | 0.255 | |
| | $CGE5 \overset{G}{\nrightarrow} CGR2$ | 2 | 4 | 7.934 ^b | 0.019 | |
| Group 13 | $CGR3 \overset{G}{\nrightarrow} CGE1$ | 2 | 4 | 0.301 | 0.860 | |
| | $CGE1 \overset{G}{\nrightarrow} CGR3$ | 2 | 4 | 4.184 | 0.123 | |
| Group 14 | $CGR3 \overset{G}{\nrightarrow} CGE2$ | 2 | 4 | 3.821 | 0.148 | |
| | $CGE2 \overset{G}{\nrightarrow} CGR3$ | 2 | 4 | 4.017 | 0.134 | |

1. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.
2. In each group, LR statistics select the lag-order of VAR model and two extra lags are added to test the causality.

Table 15: Granger non-causality tests by Toda and Yamamoto (nominal) (cont.)

| Trend model | | | | | | |
|-------------|---------------------------------------|--------------|-----------------|-------------------------------|------------|--|
| | Null hypothesis | selected lag | estimated model | t (<i>Wald</i>) statistic | p -value | |
| Group 16 | $CGR4 \overset{G}{\nrightarrow} CGE1$ | 2 | 4 | 1.055 | 0.590 | |
| | $CGE1 \overset{G}{\nrightarrow} CGR4$ | 2 | 4 | 2.075 | 0.354 | |
| Group 17 | $CGR4 \overset{G}{\nrightarrow} CGE2$ | 2 | 4 | 0.132 | 0.936 | |
| | $CGE2 \overset{G}{\nrightarrow} CGR4$ | 2 | 4 | 4.045 | 0.132 | |
| Group 18 | $CGR4 \overset{G}{\nrightarrow} CGE3$ | 1 | 3 | 0.460 | 0.648 | |
| | $CGE3 \overset{G}{\nrightarrow} CGR4$ | 1 | 3 | 1.295 | 0.202 | |
| Group 19 | $CGR4 \overset{G}{\nrightarrow} CGE4$ | 1 | 3 | -0.394 | 0.696 | |
| | $CGE4 \overset{G}{\nrightarrow} CGR4$ | 1 | 3 | 1.878 ^c | 0.067 | |
| Group 20 | $CGR4 \overset{G}{\nrightarrow} CGE5$ | 1 | 3 | 0.765 | 0.448 | |
| | $CGE5 \overset{G}{\nrightarrow} CGR4$ | 1 | 3 | 0.746 | 0.460 | |
| Group 21 | $CGR2 \overset{G}{\nrightarrow} CGR1$ | 5 | 7 | 6.131 | 0.294 | |
| | $CGR1 \overset{G}{\nrightarrow} CGR2$ | 5 | 7 | 10.309 ^c | 0.067 | |
| Group 22 | $CGR2 \overset{G}{\nrightarrow} CGR3$ | 5 | 7 | 7.183 | 0.207 | |
| | $CGR3 \overset{G}{\nrightarrow} CGR2$ | 5 | 7 | 15.425 ^a | 0.009 | |
| Group 23 | $CGR4 \overset{G}{\nrightarrow} CGR2$ | 1 | 3 | 2.331 ^b | 0.026 | |
| | $CGR2 \overset{G}{\nrightarrow} CGR4$ | 1 | 3 | 1.209 | 0.235 | |
| Group 24 | $CGR4 \overset{G}{\nrightarrow} CGR3$ | 1 | 3 | -1.405 | 0.167 | |
| | $CGR3 \overset{G}{\nrightarrow} CGR4$ | 1 | 3 | 1.300 | 0.200 | |

1. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.

2. In each group, LR statistics select the lag-order of VAR model and two extra lags are added to test the causality.

Table 16: Granger non-causality tests by Toda and Yamamoto (real (GDP deflator))

| Trend model | | | | | | |
|-------------|---------------------------------------|--------------|-----------------|-------------------------------|------------|--|
| | Null hypothesis | selected lag | estimated model | t (<i>Wald</i>) statistic | p -value | |
| Group 6 | $CGR1_{r1} \xrightarrow{G} CGE2_{r1}$ | 2 | 4 | 2.467 | 0.291 | |
| | $CGE2_{r1} \xrightarrow{G} CGR1_{r1}$ | 2 | 4 | 4.863 ^c | 0.088 | |
| Group 8 | $CGR2_{r1} \xrightarrow{G} CGE1_{r1}$ | 2 | 4 | 2.114 | 0.348 | |
| | $CGE1_{r1} \xrightarrow{G} CGR2_{r1}$ | 2 | 4 | 6.741 ^b | 0.034 | |
| Group 9 | $CGR2_{r1} \xrightarrow{G} CGE2_{r1}$ | 4 | 6 | 9.560 ^b | 0.049 | |
| | $CGE2_{r1} \xrightarrow{G} CGR2_{r1}$ | 4 | 6 | 8.512 ^c | 0.075 | |
| Group 10 | $CGR2_{r1} \xrightarrow{G} CGE3_{r1}$ | 1 | 3 | 0.967 | 0.340 | |
| | $CGE3_{r1} \xrightarrow{G} CGR2_{r1}$ | 1 | 3 | 0.999 | 0.325 | |
| Group 11 | $CGR2_{r1} \xrightarrow{G} CGE4_{r1}$ | 1 | 3 | 0.413 | 0.682 | |
| | $CGE4_{r1} \xrightarrow{G} CGR2_{r1}$ | 1 | 3 | 2.109 ^b | 0.042 | |
| Group 12 | $CGR2_{r1} \xrightarrow{G} CGE5_{r1}$ | 2 | 4 | 2.629 | 0.269 | |
| | $CGE5_{r1} \xrightarrow{G} CGR2_{r1}$ | 2 | 4 | 10.968 ^a | 0.004 | |
| Group 14 | $CGR3_{r1} \xrightarrow{G} CGE2_{r1}$ | 2 | 4 | 2.656 | 0.265 | |
| | $CGE2_{r1} \xrightarrow{G} CGR3_{r1}$ | 2 | 4 | 4.694 ^c | 0.096 | |
| Group 17 | $CGR4_{r1} \xrightarrow{G} CGE2_{r1}$ | 2 | 4 | 0.396 | 0.820 | |
| | $CGE2_{r1} \xrightarrow{G} CGR4_{r1}$ | 2 | 4 | 6.895 ^b | 0.032 | |
| Group 21 | $CGR2_{r1} \xrightarrow{G} CGR1_{r1}$ | 5 | 7 | 2.958 | 0.707 | |
| | $CGR1_{r1} \xrightarrow{G} CGR2_{r1}$ | 5 | 7 | 9.533 ^c | 0.090 | |
| Group 22 | $CGR2_{r1} \xrightarrow{G} CGR3_{r1}$ | 5 | 7 | 3.805 | 0.578 | |
| | $CGR3_{r1} \xrightarrow{G} CGR2_{r1}$ | 5 | 7 | 13.013 ^b | 0.023 | |
| Group 23 | $CGR4_{r1} \xrightarrow{G} CGR2_{r1}$ | 1 | 3 | 2.618 ^b | 0.013 | |
| | $CGR2_{r1} \xrightarrow{G} CGR4_{r1}$ | 1 | 3 | 1.210 | 0.235 | |

1. ^a, ^b, ^c indicate significance at the 1%, 5%, 10% level respectively.
2. In each group, LR statistics select the lag-order of VAR model and two extra lags are added to test the causality.

Table 17: Granger non-causality tests by Toda and Yamamoto (real (CPI))

| | | Trend model | | | | |
|----------|---|--------------|-----------------|-------------------------------|------------|--|
| | Null hypothesis | selected lag | estimated model | t (<i>Wald</i>) statistic | p -value | |
| Group 5 | $CGR1_{r2} \overset{G}{\nrightarrow} CGE1_{r2}$ | 2 | 4 | 1.280 | 0.527 | |
| | $CGE1_{r2} \overset{G}{\nrightarrow} CGR1_{r2}$ | 2 | 4 | 45.062 ^a | 0.000 | |
| Group 6 | $CGR1_{r2} \overset{G}{\nrightarrow} CGE2_{r2}$ | 2 | 4 | 4.554 | 0.103 | |
| | $CGE2_{r2} \overset{G}{\nrightarrow} CGR1_{r2}$ | 2 | 4 | 4.149 | 0.126 | |
| Group 8 | $CGR2_{r2} \overset{G}{\nrightarrow} CGE1_{r2}$ | 2 | 4 | 1.459 | 0.482 | |
| | $CGE1_{r2} \overset{G}{\nrightarrow} CGR2_{r2}$ | 2 | 4 | 8.543 ^b | 0.014 | |
| Group 9 | $CGR2_{r2} \overset{G}{\nrightarrow} CGE2_{r2}$ | 2 | 4 | 0.228 | 0.892 | |
| | $CGE2_{r2} \overset{G}{\nrightarrow} CGR2_{r2}$ | 2 | 4 | 8.548 ^b | 0.014 | |
| Group 10 | $CGR2_{r2} \overset{G}{\nrightarrow} CGE3_{r2}$ | 1 | 3 | 0.817 | 0.420 | |
| | $CGE3_{r2} \overset{G}{\nrightarrow} CGR2_{r2}$ | 1 | 3 | 1.224 | 0.229 | |
| Group 11 | $CGR2_{r2} \overset{G}{\nrightarrow} CGE4_{r2}$ | 1 | 3 | 0.413 | 0.682 | |
| | $CGE4_{r2} \overset{G}{\nrightarrow} CGR2_{r2}$ | 1 | 3 | 2.109 ^b | 0.042 | |
| Group 12 | $CGR2_{r2} \overset{G}{\nrightarrow} CGE5_{r2}$ | 2 | 4 | 2.044 | 0.360 | |
| | $CGE5_{r2} \overset{G}{\nrightarrow} CGR2_{r2}$ | 2 | 4 | 12.630 ^a | 0.002 | |
| Group 13 | $CGR3_{r2} \overset{G}{\nrightarrow} CGE1_{r2}$ | 2 | 4 | 1.795 | 0.408 | |
| | $CGE1_{r2} \overset{G}{\nrightarrow} CGR3_{r2}$ | 2 | 4 | 4.136 | 0.127 | |
| Group 14 | $CGR3_{r2} \overset{G}{\nrightarrow} CGE2_{r2}$ | 2 | 4 | 5.364 ^c | 0.068 | |
| | $CGE2_{r2} \overset{G}{\nrightarrow} CGR3_{r2}$ | 2 | 4 | 4.531 | 0.104 | |
| Group 16 | $CGR4_{r2} \overset{G}{\nrightarrow} CGE1_{r2}$ | 2 | 4 | 1.237 | 0.539 | |
| | $CGE1_{r2} \overset{G}{\nrightarrow} CGR4_{r2}$ | 2 | 4 | 4.537 | 0.104 | |
| Group 17 | $CGR4_{r2} \overset{G}{\nrightarrow} CGE2_{r2}$ | 2 | 4 | 0.281 | 0.869 | |
| | $CGE2_{r2} \overset{G}{\nrightarrow} CGR4_{r2}$ | 2 | 4 | 7.329 ^b | 0.026 | |
| Group 21 | $CGR2_{r2} \overset{G}{\nrightarrow} CGR1_{r2}$ | 1 | 3 | 1.323 | 0.195 | |
| | $CGR1_{r2} \overset{G}{\nrightarrow} CGR2_{r2}$ | 1 | 3 | 1.449 | 0.157 | |
| Group 22 | $CGR2_{r2} \overset{G}{\nrightarrow} CGR3_{r2}$ | 3 | 5 | 6.386 ^c | 0.094 | |
| | $CGR3_{r2} \overset{G}{\nrightarrow} CGR2_{r2}$ | 3 | 5 | 5.354 | 0.148 | |
| Group 23 | $CGR4_{r2} \overset{G}{\nrightarrow} CGR2_{r2}$ | 1 | 3 | 2.735 ^a | 0.010 | |
| | $CGR2_{r2} \overset{G}{\nrightarrow} CGR4_{r2}$ | 1 | 3 | 1.297 | 0.204 | |

1. ^a, ^b, ^c indicate significance at the 1%, 5%, 10% level respectively.

2. In each group, LR statistics select the lag-order of VAR model and two extra lags are added to test the causality.

Table 18: Granger non-causality tests by Toda and Yamamoto (real (CGPI))

| | | Trend model | | | |
|----------|---|--------------|-----------------|-------------------------------|------------|
| | Null hypothesis | selected lag | estimated model | t (<i>Wald</i>) statistic | p -value |
| Group 8 | $CGR2_{r3} \xrightarrow{G} \not\rightarrow CGE1_{r3}$ | 2 | 4 | 5.111 ^c | 0.078 |
| | $CGE1_{r3} \xrightarrow{G} \not\rightarrow CGR2_{r3}$ | 2 | 4 | 7.569 ^b | 0.023 |
| Group 9 | $CGR2_{r3} \xrightarrow{G} \not\rightarrow CGE2_{r3}$ | 2 | 4 | 0.776 | 0.412 |
| | $CGE2_{r3} \xrightarrow{G} \not\rightarrow CGR2_{r3}$ | 2 | 4 | 7.829 ^b | 0.020 |
| Group 10 | $CGR2_{r3} \xrightarrow{G} \not\rightarrow CGE3_{r3}$ | 1 | 3 | 0.820 | 0.418 |
| | $CGE3_{r3} \xrightarrow{G} \not\rightarrow CGR2_{r3}$ | 1 | 3 | 1.340 | 0.189 |
| Group 11 | $CGR2_{r3} \xrightarrow{G} \not\rightarrow CGE4_{r3}$ | 1 | 3 | 0.820 | 0.418 |
| | $CGE4_{r3} \xrightarrow{G} \not\rightarrow CGR2_{r3}$ | 1 | 3 | 2.046 ^b | 0.049 |
| Group 12 | $CGR2_{r3} \xrightarrow{G} \not\rightarrow CGE5_{r3}$ | 2 | 4 | 6.299 ^b | 0.043 |
| | $CGE5_{r3} \xrightarrow{G} \not\rightarrow CGR2_{r3}$ | 2 | 4 | 11.067 ^a | 0.004 |
| Group 16 | $CGR4_{r3} \xrightarrow{G} \not\rightarrow CGE1_{r3}$ | 2 | 4 | 2.265 | 0.322 |
| | $CGE1_{r3} \xrightarrow{G} \not\rightarrow CGR4_{r3}$ | 2 | 4 | 5.734 ^c | 0.057 |
| Group 17 | $CGR4_{r3} \xrightarrow{G} \not\rightarrow CGE2_{r3}$ | 2 | 4 | 1.337 | 0.513 |
| | $CGE2_{r3} \xrightarrow{G} \not\rightarrow CGR4_{r3}$ | 2 | 4 | 8.349 ^b | 0.015 |
| Group 18 | $CGR4_{r3} \xrightarrow{G} \not\rightarrow CGE3_{r3}$ | 1 | 3 | 0.134 | 0.894 |
| | $CGE3_{r3} \xrightarrow{G} \not\rightarrow CGR4_{r3}$ | 1 | 3 | 1.932 ^c | 0.060 |
| Group 19 | $CGR4_{r3} \xrightarrow{G} \not\rightarrow CGE4_{r3}$ | 2 | 4 | 0.756 | 0.685 |
| | $CGE4_{r3} \xrightarrow{G} \not\rightarrow CGR4_{r3}$ | 2 | 4 | 10.906 ^a | 0.004 |
| Group 20 | $CGR4_{r3} \xrightarrow{G} \not\rightarrow CGE5_{r3}$ | 2 | 4 | 2.073 | 0.355 |
| | $CGE5_{r3} \xrightarrow{G} \not\rightarrow CGR4_{r3}$ | 2 | 4 | 4.318 | 0.116 |
| Group 21 | $CGR2_{r3} \xrightarrow{G} \not\rightarrow CGR1_{r3}$ | 1 | 3 | 1.955 ^c | 0.059 |
| | $CGR1_{r3} \xrightarrow{G} \not\rightarrow CGR2_{r3}$ | 1 | 3 | 1.237 | 0.225 |
| Group 22 | $CGR2_{r3} \xrightarrow{G} \not\rightarrow CGR3_{r3}$ | 3 | 5 | 9.813 ^b | 0.020 |
| | $CGR3_{r3} \xrightarrow{G} \not\rightarrow CGR2_{r3}$ | 3 | 5 | 6.338 ^c | 0.096 |
| Group 23 | $CGR4_{r3} \xrightarrow{G} \not\rightarrow CGR2_{r3}$ | 1 | 3 | 2.702 ^b | 0.011 |
| | $CGR2_{r3} \xrightarrow{G} \not\rightarrow CGR4_{r3}$ | 1 | 3 | 1.580 | 0.123 |
| Group 24 | $CGR4_{r3} \xrightarrow{G} \not\rightarrow CGR3_{r3}$ | 1 | 3 | -0.927 | 0.359 |
| | $CGR3_{r3} \xrightarrow{G} \not\rightarrow CGR4_{r3}$ | 1 | 3 | 2.592 ^b | 0.013 |

1. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.
2. In each group, LR statistics select the lag-order of VAR model and two extra lags are added to test the causality.

Table 19: Granger non-causality tests by differenced VAR model (nominal)

| | | Trend model | | | | | | | | | |
|-----------------|---|-------------|-----------------|-------------|-----------------|-------------|-----------------|--------------------|-----------------|-------------|-----------------|
| lag-order | | 1 | | 2 | | 3 | | 4 | | 5 | |
| Null hypothesis | | <i>Wald</i> | <i>p</i> -value | <i>Wald</i> | <i>p</i> -value | <i>Wald</i> | <i>p</i> -value | <i>Wald</i> | <i>p</i> -value | <i>Wald</i> | <i>p</i> -value |
| Group 7 | $\Delta CGR1 \overset{G}{\nrightarrow} \Delta CGE5$ | 2.537 | 0.111 | 3.076 | 0.215 | 3.872 | 0.276 | 6.130 | 0.190 | 6.059 | 0.301 |
| | $\Delta CGE5 \overset{G}{\nrightarrow} \Delta CGR1$ | 0.001 | 0.972 | 0.607 | 0.738 | 0.192 | 0.979 | 0.651 | 0.957 | 0.623 | 0.987 |
| Group 15 | $\Delta CGR3 \overset{G}{\nrightarrow} \Delta CGE5$ | 2.693 | 0.101 | 3.572 | 0.168 | 4.695 | 0.196 | 8.575 ^c | 0.073 | 7.591 | 0.180 |
| | $\Delta CGE5 \overset{G}{\nrightarrow} \Delta CGR3$ | 0.266 | 0.606 | 0.875 | 0.646 | 0.788 | 0.852 | 1.462 | 0.833 | 1.637 | 0.897 |

1. ^a, ^b, ^c indicate significance at the 1%, 5%, 10% level respectively.

Table 20: Granger non-causality tests by differenced VAR model (real (GDP deflator))

| | | Trend model | | | | | | | | | |
|-----------------|---|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| lag-order | | 1 | | 2 | | 3 | | 4 | | 5 | |
| Null hypothesis | | Wald | p-value |
| Group 5 | $\Delta CGR1_{r1} \overset{G}{\nrightarrow} \Delta CGE1_{r1}$ | 0.198 | 0.656 | 1.390 | 0.499 | 1.228 | 0.746 | 2.465 | 0.651 | 3.265 | 0.659 |
| | $\Delta CGE1_{r1} \overset{G}{\nrightarrow} \Delta CGR1_{r1}$ | 0.155 | 0.694 | 3.076 | 0.215 | 1.918 | 0.590 | 2.700 | 0.609 | 6.788 | 0.237 |
| Group 7 | $\Delta CGR1_{r1} \overset{G}{\nrightarrow} \Delta CGE5_{r1}$ | 3.139 ^c | 0.076 | 4.243 | 0.120 | 4.248 | 0.236 | 7.820 ^c | 0.098 | 7.427 | 0.191 |
| | $\Delta CGE5_{r1} \overset{G}{\nrightarrow} \Delta CGR1_{r1}$ | 0.046 | 0.831 | 1.733 | 0.420 | 0.337 | 0.953 | 0.412 | 0.981 | 0.342 | 0.997 |
| Group 13 | $\Delta CGR3_{r1} \overset{G}{\nrightarrow} \Delta CGE1_{r1}$ | 1.137 | 0.286 | 3.377 | 0.185 | 2.288 | 0.515 | 2.955 | 0.565 | 4.702 | 0.453 |
| | $\Delta CGE1_{r1} \overset{G}{\nrightarrow} \Delta CGR3_{r1}$ | 0.164 | 0.686 | 5.276 ^c | 0.071 | 3.099 | 0.377 | 4.799 | 0.309 | 7.928 | 0.160 |
| Group 15 | $\Delta CGR3_{r1} \overset{G}{\nrightarrow} \Delta CGE5_{r1}$ | 3.970 ^b | 0.046 | 4.826 ^c | 0.090 | 4.913 | 0.178 | 10.650 ^b | 0.031 | 11.077 ^b | 0.050 |
| | $\Delta CGE5_{r1} \overset{G}{\nrightarrow} \Delta CGR3_{r1}$ | 0.340 | 0.560 | 2.862 | 0.239 | 0.573 | 0.903 | 1.164 | 0.884 | 1.336 | 0.931 |
| Group 24 | $\Delta CGR4_{r1} \overset{G}{\nrightarrow} \Delta CGR3_{r1}$ | 0.622 | 0.430 | 0.700 | 0.705 | 0.462 | 0.927 | 1.914 | 0.752 | 1.913 | 0.861 |
| | $\Delta CGR3_{r1} \overset{G}{\nrightarrow} \Delta CGR4_{r1}$ | 10.607 ^a | 0.001 | 11.029 ^a | 0.004 | 15.802 ^a | 0.001 | 15.062 ^a | 0.005 | 13.831 ^b | 0.017 |

1. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.

Table 21: Granger non-causality tests by differenced VAR model (real (CPI))

| | | Trend model | | | | | | | | | |
|-----------------|--|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|---------------------|---------|
| lag-order | | 1 | | 2 | | 3 | | 4 | | 5 | |
| Null hypothesis | | Wald | p-value |
| Group 7 | $\overset{G}{\Delta CGR}_{1,r,2} \nrightarrow \overset{G}{\Delta CGE}_{5,r,2}$ | 5.536 ^b | 0.019 | 6.274 ^b | 0.043 | 6.406 ^c | 0.093 | 8.579 ^c | 0.073 | 8.432 | 0.134 |
| | $\overset{G}{\Delta CGE}_{5,r,2} \nrightarrow \overset{G}{\Delta CGR}_{1,r,2}$ | 0.235 | 0.628 | 2.072 | 0.355 | 0.234 | 0.972 | 0.190 | 0.996 | 0.292 | 0.998 |
| Group 15 | $\overset{G}{\Delta CGR}_{3,r,2} \nrightarrow \overset{G}{\Delta CGE}_{5,r,2}$ | 7.076 ^a | 0.008 | 7.226 ^b | 0.027 | 7.910 ^b | 0.048 | 11.937 ^b | 0.018 | 13.855 ^b | 0.017 |
| | $\overset{G}{\Delta CGE}_{5,r,2} \nrightarrow \overset{G}{\Delta CGR}_{3,r,2}$ | 1.040 | 0.308 | 3.693 | 0.158 | 0.463 | 0.927 | 1.210 | 0.876 | 1.669 | 0.893 |
| Group 24 | $\overset{G}{\Delta CGR}_{4,r,2} \nrightarrow \overset{G}{\Delta CGR}_{3,r,2}$ | 0.334 | 0.563 | 0.672 | 0.714 | 0.376 | 0.945 | 1.551 | 0.818 | 1.780 | 0.879 |
| | $\overset{G}{\Delta CGR}_{3,r,2} \nrightarrow \overset{G}{\Delta CGR}_{4,r,2}$ | 11.562 ^a | 0.001 | 12.291 ^a | 0.002 | 17.383 ^a | 0.001 | 15.964 ^a | 0.003 | 14.735 ^b | 0.012 |

1. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.

Table 22: Granger non-causality tests by differenced VAR model (real (CGPI))

| lag-order | Trend model | | | | | | | | | | |
|-----------------|--|--------------------|-------|---------|-------|---------|-------|---------|-------|---------|-------|
| | 1 | | 2 | | 3 | | 4 | | 5 | | |
| Null hypothesis | Wald | p-value | Wald | p-value | Wald | p-value | Wald | p-value | Wald | p-value | |
| Group 5 | $\Delta CGR1_{r3}$ | 0.453 | 0.501 | 2.500 | 0.287 | 2.093 | 0.553 | 2.186 | 0.702 | 2.383 | 0.794 |
| | $\overset{G}{\nrightarrow} \Delta CGE1_{r3}$ | | | | | | | | | | |
| | $\Delta CGE1_{r3}$ | 0.174 | 0.676 | 2.244 | 0.326 | 1.450 | 0.694 | 2.625 | 0.622 | 3.678 | 0.597 |
| | $\overset{G}{\nrightarrow} \Delta CGR1_{r3}$ | | | | | | | | | | |
| Group 6 | $\Delta CGR1_{r3}$ | 0.903 | 0.342 | 1.181 | 0.554 | 1.328 | 0.723 | 1.477 | 0.831 | 1.353 | 0.929 |
| | $\overset{G}{\nrightarrow} \Delta CGE2_{r3}$ | | | | | | | | | | |
| | $\Delta CGE2_{r3}$ | 0.543 | 0.461 | 2.670 | 0.263 | 2.684 | 0.443 | 3.929 | 0.416 | 4.318 | 0.505 |
| | $\overset{G}{\nrightarrow} \Delta CGR1_{r3}$ | | | | | | | | | | |
| Group 7 | $\Delta CGR1_{r3}$ | 3.024 ^c | 0.082 | 4.138 | 0.126 | 3.814 | 0.282 | 4.790 | 0.310 | 4.521 | 0.477 |
| | $\overset{G}{\nrightarrow} \Delta CGE5_{r3}$ | | | | | | | | | | |
| | $\Delta CGE5_{r3}$ | 0.197 | 0.657 | 1.268 | 0.530 | 0.248 | 0.969 | 0.526 | 0.971 | 1.185 | 0.946 |
| | $\overset{G}{\nrightarrow} \Delta CGR1_{r3}$ | | | | | | | | | | |
| Group 13 | $\Delta CGR3_{r3}$ | 0.801 | 0.371 | 3.470 | 0.176 | 2.559 | 0.465 | 3.352 | 0.501 | 3.919 | 0.561 |
| | $\overset{G}{\nrightarrow} \Delta CGE1_{r3}$ | | | | | | | | | | |
| | $\Delta CGE1_{r3}$ | 0.284 | 0.594 | 3.474 | 0.176 | 2.301 | 0.512 | 3.724 | 0.445 | 4.245 | 0.515 |
| | $\overset{G}{\nrightarrow} \Delta CGR3_{r3}$ | | | | | | | | | | |
| Group 14 | $\Delta CGR3_{r3}$ | 1.498 | 0.221 | 2.243 | 0.326 | 1.849 | 0.604 | 2.191 | 0.701 | 2.182 | 0.823 |
| | $\overset{G}{\nrightarrow} \Delta CGE2_{r3}$ | | | | | | | | | | |
| | $\Delta CGE2_{r3}$ | 0.507 | 0.477 | 3.455 | 0.178 | 3.205 | 0.361 | 4.667 | 0.323 | 4.815 | 0.439 |
| | $\overset{G}{\nrightarrow} \Delta CGR3_{r3}$ | | | | | | | | | | |
| Group 15 | $\Delta CGR3_{r3}$ | 3.054 ^c | 0.081 | 4.104 | 0.128 | 3.366 | 0.339 | 5.512 | 0.239 | 6.432 | 0.266 |
| | $\overset{G}{\nrightarrow} \Delta CGE5_{r3}$ | | | | | | | | | | |
| | $\Delta CGE5_{r3}$ | 0.683 | 0.409 | 2.170 | 0.338 | 0.609 | 0.894 | 1.449 | 0.836 | 2.381 | 0.794 |
| | $\overset{G}{\nrightarrow} \Delta CGR3_{r3}$ | | | | | | | | | | |

1. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.

Table 23: Granger non-causality tests by threshold (MTAR) error correction model (nominal)

| lag-order | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | |
|-----------|---|---------------------|-------------|---------------------|-------------|---------------------|-------------|---------------------|-------------|---------------------|-------------|------------|-------------|------------|--|
| | $Wald/coef$ | p -value | $Wald/coef$ | p -value | $Wald/coef$ | p -value | $Wald/coef$ | p -value | $Wald/coef$ | p -value | $Wald/coef$ | p -value | $Wald/coef$ | p -value | |
| Group 1 | $\overset{G}{\Delta CGR1} \nrightarrow \Delta CGE3$ | 0.200 | 0.654 | 0.171 | 0.918 | 0.154 | 0.985 | 1.851 | 0.763 | 1.583 | 0.903 | | | | |
| | $\hat{\rho}_1$ | 0.044 | 0.459 | 0.038 | 0.582 | 0.049 | 0.523 | 0.038 | 0.644 | 0.093 | 0.315 | | | | |
| | $\hat{\rho}_2$ | 0.649 ^a | 0.000 | 0.646 ^a | 0.000 | 0.644 ^a | 0.000 | 0.610 ^a | 0.000 | 0.591 ^a | 0.001 | | | | |
| Group 2 | $\overset{G}{\Delta CGE3} \nrightarrow \Delta CGR1$ | 0.764 | 0.382 | 1.425 | 0.491 | 9.616 ^b | 0.022 | 9.619 ^b | 0.047 | 20.808 ^a | 0.001 | | | | |
| | $\hat{\rho}_1$ | -0.073 | 0.155 | -0.053 | 0.354 | -0.071 | 0.220 | -0.072 | 0.253 | -0.161 ^b | 0.016 | | | | |
| | $\hat{\rho}_2$ | -0.171 | 0.144 | -0.163 | 0.172 | -0.204 ^c | 0.070 | -0.203 ^c | 0.095 | -0.155 | 0.179 | | | | |
| | $\hat{\tau} = -0.126$ | | | | | | | | | | | | | | |
| Group 3 | $\overset{G}{\Delta CGR1} \nrightarrow \Delta CGE4$ | 0.004 | 0.952 | 1.881 | 0.390 | 2.159 | 0.540 | 4.162 | 0.385 | 5.852 | 0.321 | | | | |
| | $\hat{\rho}_1$ | 0.001 | 0.989 | 0.000 | 0.999 | 0.021 | 0.810 | 0.017 | 0.864 | 0.061 | 0.591 | | | | |
| | $\hat{\rho}_2$ | 0.415 ^a | 0.001 | 0.406 ^a | 0.007 | 0.413 ^a | 0.008 | 0.397 ^b | 0.013 | 0.398 ^b | 0.014 | | | | |
| Group 4 | $\overset{G}{\Delta CGE4} \nrightarrow \Delta CGR1$ | 0.000 | 0.991 | 0.199 | 0.905 | 4.750 | 0.191 | 6.431 | 0.169 | 14.346 ^b | 0.014 | | | | |
| | $\hat{\rho}_1$ | -0.123 ^c | 0.097 | -0.100 | 0.216 | -0.140 ^c | 0.094 | -0.169 ^c | 0.068 | -0.306 ^a | 0.003 | | | | |
| | $\hat{\rho}_2$ | -0.206 | 0.145 | -0.189 | 0.192 | -0.187 | 0.176 | -0.220 | 0.127 | -0.250 ^c | 0.069 | | | | |
| | $\hat{\tau} = -0.060$ | | | | | | | | | | | | | | |
| Group 5 | $\overset{G}{\Delta CGR3} \nrightarrow \Delta CGE3$ | 0.595 | 0.441 | 0.706 | 0.703 | 0.673 | 0.880 | 0.983 | 0.912 | 2.341 | 0.800 | | | | |
| | $\hat{\rho}_1$ | 0.065 | 0.311 | 0.067 | 0.358 | 0.061 | 0.419 | 0.038 | 0.644 | 0.096 | 0.292 | | | | |
| | $\hat{\rho}_2$ | 0.563 ^a | 0.000 | 0.557 ^a | 0.001 | 0.659 ^a | 0.000 | 0.618 ^a | 0.001 | 0.552 ^a | 0.003 | | | | |
| Group 6 | $\overset{G}{\Delta CGE3} \nrightarrow \Delta CGR3$ | 0.770 | 0.380 | 1.485 | 0.476 | 8.950 ^b | 0.030 | 8.935 ^c | 0.063 | 19.327 ^a | 0.002 | | | | |
| | $\hat{\rho}_1$ | -0.056 | 0.286 | -0.012 | 0.827 | -0.055 | 0.327 | -0.059 | 0.338 | -0.136 ^b | 0.032 | | | | |
| | $\hat{\rho}_2$ | -0.327 ^a | 0.008 | -0.299 ^b | 0.015 | -0.243 ^b | 0.036 | -0.278 ^b | 0.030 | -0.210 ^c | 0.079 | | | | |
| | $\hat{\tau} = -0.137$ | | | | | | | | | | | | | | |
| Group 7 | $\overset{G}{\Delta CGR3} \nrightarrow \Delta CGE4$ | 0.057 | 0.812 | 1.236 | 0.539 | 1.483 | 0.686 | 2.280 | 0.684 | 5.111 | 0.402 | | | | |
| | $\hat{\rho}_1$ | 0.0289 | 0.706 | 0.029 | 0.729 | 0.042 | 0.645 | 0.025 | 0.800 | 0.049 | 0.669 | | | | |
| | $\hat{\rho}_2$ | 0.359 ^b | 0.017 | 0.351 ^b | 0.022 | 0.365 ^b | 0.022 | 0.357 ^b | 0.031 | 0.329 ^b | 0.046 | | | | |
| Group 8 | $\overset{G}{\Delta CGE4} \nrightarrow \Delta CGR3$ | 0.284 | 0.594 | 1.030 | 0.597 | 3.978 | 0.264 | 5.196 | 0.268 | 6.947 | 0.225 | | | | |
| | $\hat{\rho}_1$ | -0.085 | 0.254 | -0.028 | 0.719 | -0.071 | 0.360 | -0.103 | 0.233 | -0.176 ^c | 0.078 | | | | |
| | $\hat{\rho}_2$ | -0.379 ^a | 0.010 | -0.349 ^b | 0.016 | -0.315 ^b | 0.021 | -0.338 ^b | 0.017 | -0.336 ^b | 0.019 | | | | |
| | $\hat{\tau} = -0.096$ | | | | | | | | | | | | | | |

1. Trend model
2. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.
3. *Wald* statistics is for Granger non-causality test and coef indicates an estimate of ρ_i for $i = 1$ and 2 .

Table 24: Granger non-causality tests by threshold (MTAR) error correction model (real (GDP deflater))

| lag-order | 1 | | 2 | | 3 | | 4 | | 5 | |
|-----------------------|---|---------------------|-----------|---------------------|-----------|---------------------|---------------------|---------------------|-----------|---------|
| | Wald/coef | p-value | Wald/coef | p-value | Wald/coef | p-value | Wald/coef | p-value | Wald/coef | p-value |
| Group 1 | $\Delta CGR1_{r1} \xrightarrow{G} \Delta CGE3_{r1}$ | 0.602 | 0.438 | 0.790 | 0.674 | 1.192 | 4.250 | 3.108 | 0.373 | 0.683 |
| | $\hat{\rho}_1$ | 0.026 | 0.675 | 0.036 | 0.619 | 0.046 | 0.040 | 0.087 | 0.627 | 0.355 |
| | $\hat{\rho}_2$ | 0.640 ^a | 0.000 | 0.630 ^a | 0.000 | 0.631 ^a | 0.595 ^a | 0.001 | 0.001 | 0.001 |
| Group 2 | $\Delta CGE3_{r1} \xrightarrow{G} \Delta CGR1_{r1}$ | 0.102 | 0.749 | 1.848 | 0.397 | 7.291 ^c | 7.132 | 16.355 ^a | 0.129 | 0.006 |
| | $\hat{\rho}_1$ | -0.102 ^c | 0.098 | -0.066 | 0.343 | -0.090 | -0.092 | -0.195 ^b | 0.232 | 0.018 |
| | $\hat{\rho}_2$ | -0.186 | 0.189 | -0.180 | 0.209 | -0.210 | -0.219 | -0.197 | 0.140 | 0.159 |
| $\hat{\tau} = -0.128$ | | | | | | | | | | |
| Group 2 | $\Delta CGR1_{r1} \xrightarrow{G} \Delta CGE4_{r1}$ | 0.301 | 0.583 | 0.793 | 0.673 | 0.570 | 2.270 | 2.635 | 0.686 | 0.756 |
| | $\hat{\rho}_1$ | -0.007 | 0.928 | 0.010 | 0.912 | 0.052 | 0.045 | 0.050 | 0.689 | 0.708 |
| | $\hat{\rho}_2$ | 0.395 ^b | 0.018 | 0.394 ^b | 0.019 | 0.402 ^b | 0.387 ^b | 0.384 ^b | 0.029 | 0.037 |
| Group 3 | $\Delta CGE4_{r1} \xrightarrow{G} \Delta CGR1_{r1}$ | 0.031 | 0.861 | 0.593 | 0.744 | 2.252 | 2.754 | 9.375 ^c | 0.600 | 0.095 |
| | $\hat{\rho}_1$ | -0.152 ^c | 0.088 | -0.116 | 0.235 | -0.150 | -0.165 | -0.336 ^b | 0.163 | 0.012 |
| | $\hat{\rho}_2$ | -0.250 | 0.153 | -0.231 | 0.196 | -0.227 | -0.245 | -0.305 ^c | 0.179 | 0.084 |
| $\hat{\tau} = -0.068$ | | | | | | | | | | |
| Group 3 | $\Delta CGR3_{r1} \xrightarrow{G} \Delta CGE3_{r1}$ | 0.134 | 0.715 | 0.366 | 0.833 | 0.749 | 2.732 | 2.145 | 0.604 | 0.829 |
| | $\hat{\rho}_1$ | 0.059 | 0.388 | 0.082 | 0.286 | 0.063 | 0.040 | 0.093 | 0.632 | 0.328 |
| | $\hat{\rho}_2$ | 0.515 ^a | 0.002 | 0.519 ^a | 0.002 | 0.655 ^a | 0.643 ^a | 0.609 ^a | 0.000 | 0.626 |
| Group 4 | $\Delta CGE3_{r1} \xrightarrow{G} \Delta CGR3_{r1}$ | 0.240 | 0.624 | 3.152 | 0.207 | 7.305 ^c | 6.968 | 15.485 ^a | 0.138 | 0.008 |
| | $\hat{\rho}_1$ | -0.068 | 0.276 | -0.005 | 0.936 | -0.065 | -0.068 | -0.160 ^b | 0.354 | 0.039 |
| | $\hat{\rho}_2$ | -0.392 ^a | 0.008 | -0.354 ^b | 0.015 | -0.262 ^c | -0.281 ^c | -0.230 | 0.062 | 0.105 |
| $\hat{\tau} = -0.138$ | | | | | | | | | | |
| Group 4 | $\Delta CGR3_{r1} \xrightarrow{G} \Delta CGE4_{r1}$ | 0.252 | 0.615 | 0.238 | 0.888 | 0.157 | 1.086 | 1.947 | 0.896 | 0.856 |
| | $\hat{\rho}_1$ | 0.021 | 0.800 | 0.051 | 0.577 | 0.070 | 0.062 | 0.056 | 0.577 | 0.672 |
| | $\hat{\rho}_2$ | 0.343 ^b | 0.037 | 0.350 ^b | 0.037 | 0.364 ^b | 0.366 ^b | 0.355 ^c | 0.039 | 0.051 |
| Group 5 | $\Delta CGE4_{r1} \xrightarrow{G} \Delta CGR3_{r1}$ | 0.278 | 0.598 | 2.708 | 0.258 | 2.235 | 2.827 | 4.914 | 0.587 | 0.426 |
| | $\hat{\rho}_1$ | -0.099 | 0.270 | -0.022 | 0.819 | -0.063 | -0.072 | -0.153 | 0.507 | 0.222 |
| | $\hat{\rho}_2$ | -0.413 ^b | 0.019 | -0.374 ^b | 0.031 | -0.339 ^b | -0.337 ^b | -0.346 ^b | 0.048 | 0.044 |
| $\hat{\tau} = -0.096$ | | | | | | | | | | |

1. Trend model

2. ^{a b c}, indicate significance at the 1%, 5%, 10% level respectively.

3. *Wald* statistics is for Granger non-causality test and coef indicates an estimate of ρ_i for $i = 1$ and 2.

Table 25: Granger non-causality tests by threshold (MTAR) error correction model (real (GDP deflator)) (cont.)

| lag-order | 1 | | 2 | | 3 | | 4 | | 5 | |
|-----------|--|---------------------|-------------------|---------------------|-------------------|-----------------|---------------------|---------------------|---------------------|-----------------|
| | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value |
| Group 16 | $\Delta CGR_{4r1} \overset{G}{\hat{\rho}_1}$ | 0.004 | 0.949 | 0.222 | 0.895 | 0.704 | 1.406 | 1.813 | 2.853 | 0.770 |
| | ΔCGE_{1r1} | -0.081 | 0.303 | -0.084 | 0.301 | 0.456 | -0.061 | -0.058 | -0.060 | 0.490 |
| | $\hat{\rho}_2$ | -0.026 | 0.500 | -0.033 | 0.464 | 0.987 | -0.001 | -0.020 | -0.066 | 0.304 |
| | $\Delta CGE_{1r1} \overset{G}{\hat{\rho}_1}$ | 0.538 | 0.463 | 2.538 | 0.281 | 0.295 | 3.705 | 4.590 | 7.527 | 0.184 |
| | ΔCGR_{4r1} | -1.239 ^a | 0.000 | -1.240 ^a | 0.000 | 0.000 | -1.210 ^a | -1.244 ^a | -1.199 ^a | 0.000 |
| | $\hat{\rho}_2$ | -0.176 | 0.191 | -0.161 | 0.282 | 0.386 | -0.144 | -0.144 | -0.229 | 0.281 |
| | $\hat{\tau} = 0.239$ | | | | | | | | | |
| Group 18 | $\Delta CGR_{4r1} \overset{G}{\hat{\rho}_1}$ | 0.111 | 0.739 | 0.128 | 0.938 | 0.932 | 0.437 | 5.921 | 4.455 | 0.205 |
| | ΔCGE_{3r1} | -0.002 | 0.974 | -0.005 | 0.931 | 0.707 | 0.024 | -0.002 | 0.021 | 0.971 |
| | $\hat{\rho}_2$ | 0.175 | 0.254 | 0.214 | 0.212 | 0.387 | 0.154 | 0.278 | 0.369 | 0.339 |
| | $\Delta CGE_{3r1} \overset{G}{\hat{\rho}_1}$ | 1.290 | 0.256 | 1.669 | 0.434 | 0.532 | 2.199 | 3.804 | 4.955 | 0.433 |
| | ΔCGR_{4r1} | -0.109 | 0.349 | -0.132 | 0.311 | 0.284 | -0.161 | -0.157 | -0.214 | 0.294 |
| | $\hat{\rho}_2$ | -1.012 ^a | 0.007 | -0.874 ^b | 0.032 | 0.049 | -0.847 ^b | -2.084 ^a | -2.342 ^a | 0.004 |
| | $\hat{\tau} = -0.256$ | | | | | | | | | |
| Group 19 | $\Delta CGR_{4r1} \overset{G}{\hat{\rho}_1}$ | 0.041 | 0.840 | 1.197 | 0.550 | 0.545 | 2.135 | 2.346 | 2.823 | 0.672 |
| | ΔCGE_{4r1} | -0.048 | 0.595 | -0.046 | 0.614 | 0.761 | -0.028 | -0.025 | -0.023 | 0.792 |
| | $\hat{\rho}_2$ | -0.003 | 0.946 | -0.014 | 0.780 | 0.609 | 0.030 | 0.022 | 0.015 | 0.738 |
| | $\Delta CGE_{4r1} \overset{G}{\hat{\rho}_1}$ | 2.031 | 0.154 | 3.648 | 0.161 | 0.087 | 6.560 ^c | 8.135 ^c | 11.368 ^b | 0.087 |
| | ΔCGR_{4r1} | -0.958 ^a | 0.000 | -0.966 ^a | 0.000 | 0.000 | -0.915 ^a | -0.972 ^a | -0.973 ^a | 0.000 |
| | $\hat{\rho}_2$ | -0.101 | 0.402 | -0.075 | 0.566 | 0.611 | -0.074 | -0.093 | -0.181 | 0.567 |
| | $\hat{\tau} = 0.242$ | | | | | | | | | |
| Group 20 | $\Delta CGR_{4r1} \overset{G}{\hat{\rho}_1}$ | 0.637 | 0.425 | 1.323 | 0.516 | 0.675 | 1.530 | 1.373 | 5.076 | 0.849 |
| | ΔCGE_{5r1} | -0.130 | 0.274 | -0.134 | 0.261 | 0.236 | -0.146 | -0.148 | -0.229 ^c | 0.256 |
| | $\hat{\rho}_2$ | -0.021 | 0.669 | -0.008 | 0.892 | 0.951 | 0.004 | -0.011 | -0.103 | 0.882 |
| | $\Delta CGE_{5r1} \overset{G}{\hat{\rho}_1}$ | 0.105 | 0.745 | 1.649 | 0.439 | 0.305 | 3.627 | 6.832 | 11.086 ^b | 0.145 |
| | ΔCGR_{4r1} | -1.376 ^a | 0.000 | -1.413 ^a | 0.000 | 0.000 | -1.483 ^a | -1.507 ^a | -1.621 ^a | 0.000 |
| | $\hat{\rho}_2$ | -0.267 ^c | 0.059 | -0.236 | 0.138 | 0.159 | -0.248 | -0.320 | -0.472 ^b | 0.125 |
| | $\hat{\tau} = 0.235$ | | | | | | | | | |

1. Trend model

2. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.

3. *Wald* statistics is for Granger non-causality test and coef indicates an estimate of ρ_i for $i = 1$ and 2.

Table 26: Granger non-causality tests by threshold (MTAR) error correction model (real (CPI))

| lag-order | 1 | | 2 | | 3 | | 4 | | 5 | | |
|-----------------------|---|---------------------|-------------------|---------------------|-------------------|---------------------|-------------------|---------------------|-------------------|---------------------|-------|
| | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | |
| Group 1 | $\Delta CGR1_{r2} \overset{G}{\nrightarrow} \Delta CGE3_{r2}$ | 2.311 | 0.128 | 2.572 | 0.276 | 2.515 | 0.473 | 4.220 | 0.377 | 2.545 | 0.770 |
| | $\hat{\rho}_1$ | 0.033 | 0.598 | 0.041 | 0.576 | 0.054 | 0.507 | 0.052 | 0.552 | 0.102 | 0.310 |
| | $\hat{\rho}_2$ | 0.637 ^a | 0.000 | 0.623 ^a | 0.000 | 0.634 ^a | 0.000 | 0.608 ^a | 0.001 | 0.614 ^a | 0.001 |
| Group 2 | $\Delta CGE3_{r2} \overset{G}{\nrightarrow} \Delta CGR1_{r2}$ | 0.134 | 0.714 | 1.581 | 0.454 | 5.181 | 0.159 | 5.421 | 0.247 | 13.209 ^b | 0.022 |
| | $\hat{\rho}_1$ | -0.102 ^c | 0.092 | -0.069 | 0.315 | -0.095 | 0.189 | -0.094 | 0.235 | -0.201 ^b | 0.021 |
| | $\hat{\rho}_2$ | -0.191 | 0.167 | -0.186 | 0.185 | -0.213 | 0.117 | -0.211 | 0.156 | -0.187 | 0.189 |
| $\hat{\tau} = -0.128$ | | | | | | | | | | | |
| Group 3 | $\Delta CGR1_{r2} \overset{G}{\nrightarrow} \Delta CGE4_{r2}$ | 1.393 | 0.238 | 1.840 | 0.399 | 1.241 | 0.743 | 2.193 | 0.700 | 2.464 | 0.782 |
| | $\hat{\rho}_1$ | -0.004 | 0.963 | 0.019 | 0.834 | 0.060 | 0.555 | 0.056 | 0.628 | 0.077 | 0.586 |
| | $\hat{\rho}_2$ | 0.435 ^a | 0.009 | 0.434 ^b | 0.010 | 0.443 ^a | 0.010 | 0.435 ^b | 0.016 | 0.441 ^b | 0.020 |
| Group 4 | $\Delta CGE4_{r2} \overset{G}{\nrightarrow} \Delta CGR1_{r2}$ | 0.029 | 0.866 | 0.630 | 0.730 | 1.807 | 0.613 | 2.466 | 0.651 | 7.110 | 0.213 |
| | $\hat{\rho}_1$ | -0.159 ^c | 0.069 | -0.125 | 0.200 | -0.161 | 0.126 | -0.175 | 0.148 | -0.336 ^b | 0.018 |
| | $\hat{\rho}_2$ | -0.215 | 0.208 | -0.198 | 0.259 | -0.200 | 0.242 | -0.215 | 0.234 | -0.264 | 0.140 |
| $\hat{\tau} = -0.068$ | | | | | | | | | | | |
| Group 5 | $\Delta CGR3_{r2} \overset{G}{\nrightarrow} \Delta CGE3_{r2}$ | 1.294 | 0.255 | 1.968 | 0.374 | 2.031 | 0.566 | 3.280 | 0.512 | 1.813 | 0.874 |
| | $\hat{\rho}_1$ | 0.061 | 0.379 | 0.083 | 0.281 | 0.065 | 0.420 | 0.047 | 0.588 | 0.105 | 0.294 |
| | $\hat{\rho}_2$ | 0.536 ^a | 0.001 | 0.532 ^a | 0.002 | 0.661 ^a | 0.000 | 0.659 ^a | 0.000 | 0.632 ^a | 0.001 |
| Group 6 | $\Delta CGE3_{r2} \overset{G}{\nrightarrow} \Delta CGR3_{r2}$ | 0.395 | 0.530 | 3.284 | 0.194 | 5.660 | 0.129 | 5.609 | 0.230 | 12.997 ^b | 0.023 |
| | $\hat{\rho}_1$ | -0.071 | 0.233 | -0.014 | 0.833 | -0.073 | 0.276 | -0.072 | 0.322 | -0.164 ^b | 0.037 |
| | $\hat{\rho}_2$ | -0.376 ^a | 0.007 | -0.346 ^b | 0.013 | -0.257 ^c | 0.059 | -0.274 ^c | 0.064 | -0.219 | 0.120 |
| $\hat{\tau} = -0.138$ | | | | | | | | | | | |
| Group 7 | $\Delta CGR3_{r2} \overset{G}{\nrightarrow} \Delta CGE4_{r2}$ | 1.337 | 0.248 | 1.311 | 0.519 | 0.769 | 0.857 | 1.085 | 0.897 | 1.729 | 0.885 |
| | $\hat{\rho}_1$ | 0.021 | 0.806 | 0.052 | 0.565 | 0.069 | 0.492 | 0.062 | 0.592 | 0.067 | 0.625 |
| | $\hat{\rho}_2$ | 0.385 ^b | 0.019 | 0.391 ^c | 0.019 | 0.401 ^b | 0.019 | 0.402 ^b | 0.025 | 0.400 ^b | 0.032 |
| Group 8 | $\Delta CGE4_{r2} \overset{G}{\nrightarrow} \Delta CGR3_{r2}$ | 0.105 | 0.746 | 3.129 | 0.209 | 1.969 | 0.579 | 2.539 | 0.638 | 3.888 | 0.566 |
| | $\hat{\rho}_1$ | -0.105 | 0.224 | -0.031 | 0.737 | -0.073 | 0.440 | -0.080 | 0.455 | -0.140 | 0.264 |
| | $\hat{\rho}_2$ | -0.370 ^b | 0.028 | -0.336 ^b | 0.043 | -0.313 ^b | 0.048 | -0.310 ^c | 0.059 | -0.311 ^c | 0.063 |
| $\hat{\tau} = -0.095$ | | | | | | | | | | | |

1. Trend model

2. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.

3. *Wald* statistics is for Granger non-causality test and coef indicates an estimate of ρ_i for $i = 1$ and 2.

Table 27: Granger non-causality tests by threshold (MTAR) error correction model (real (CPI)) (cont.)

| lag-order | 1 | | | 2 | | | 3 | | | 4 | | | 5 | | |
|-----------------------|--|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|-----------|---------|-----------|---------|--|
| | Wald/coef | p-value | Wald/coef | p-value | Wald/coef | p-value | Wald/coef | p-value | Wald/coef | p-value | Wald/coef | p-value | Wald/coef | p-value | |
| Group 18 | $\Delta CCGR_{4r2} \overset{G}{\nrightarrow} \Delta CGE_{3r2}$ | 0.396 | 0.529 | 0.341 | 0.843 | 0.573 | 0.903 | 5.932 | 0.204 | 4.122 | 0.532 | | | | |
| | $\hat{\rho}_1$ | 0.002 | 0.961 | -0.002 | 0.978 | 0.030 | 0.636 | 0.003 | 0.958 | 0.034 | 0.626 | | | | |
| | $\hat{\rho}_2$ | 0.127 | 0.404 | 0.154 | 0.362 | 0.096 | 0.588 | 0.190 | 0.518 | 0.303 | 0.376 | | | | |
| | $\Delta CCGE_{3r2} \overset{G}{\nrightarrow} \Delta CGR_{4r2}$ | 1.190 | 0.275 | 1.593 | 0.451 | 2.086 | 0.555 | 3.860 | 0.425 | 5.141 | 0.399 | | | | |
| | $\hat{\rho}_1$ | -0.108 | 0.354 | -0.135 | 0.304 | -0.161 | 0.288 | -0.155 | 0.308 | -0.219 | 0.187 | | | | |
| $\hat{\rho}_2$ | -1.009 ^a | 0.006 | -0.885 ^b | 0.028 | -0.873 ^b | 0.041 | -2.119 ^a | 0.004 | -2.420 ^a | 0.004 | | | | | |
| $\hat{\tau} = -0.258$ | | | | | | | | | | | | | | | |
| Group 19 | $\Delta CCGR_{4r2} \overset{G}{\nrightarrow} \Delta CGE_{4r2}$ | 0.111 | 0.739 | 0.978 | 0.613 | 2.388 | 0.496 | 2.545 | 0.637 | 3.304 | 0.653 | | | | |
| | $\hat{\rho}_1$ | -0.041 | 0.654 | -0.039 | 0.669 | -0.022 | 0.809 | -0.021 | 0.828 | -0.015 | 0.885 | | | | |
| | $\hat{\rho}_2$ | -0.002 | 0.974 | -0.012 | 0.820 | 0.036 | 0.540 | 0.030 | 0.660 | 0.032 | 0.686 | | | | |
| | $\Delta CCGE_{4r2} \overset{G}{\nrightarrow} \Delta CGR_{4r2}$ | 2.054 | 0.152 | 4.505 | 0.105 | 7.380 ^c | 0.061 | 8.800 ^c | 0.066 | 11.173 ^b | 0.048 | | | | |
| | $\hat{\rho}_1$ | -0.958 ^a | 0.000 | -0.971 ^a | 0.000 | -0.919 ^a | 0.000 | -0.983 ^a | 0.000 | -0.978 ^a | 0.000 | | | | |
| $\hat{\rho}_2$ | -0.101 | 0.407 | -0.084 | 0.525 | -0.081 | 0.586 | -0.107 | 0.520 | -0.192 | 0.318 | | | | | |
| $\hat{\tau} = 0.242$ | | | | | | | | | | | | | | | |
| Group 20 | $\Delta CCGR_{4r2} \overset{G}{\nrightarrow} \Delta CGE_{5r2}$ | 0.835 | 0.361 | 1.585 | 0.453 | 1.956 | 0.582 | 1.808 | 0.771 | 4.819 | 0.438 | | | | |
| | $\hat{\rho}_1$ | -0.125 | 0.287 | -0.124 | 0.296 | -0.139 | 0.259 | -0.137 | 0.289 | -0.215 | 0.104 | | | | |
| | $\hat{\rho}_2$ | -0.025 | 0.606 | -0.012 | 0.838 | -0.004 | 0.943 | -0.021 | 0.795 | -0.114 | 0.204 | | | | |
| | $\Delta CCGE_{5r2} \overset{G}{\nrightarrow} \Delta CGR_{4r2}$ | 0.144 | 0.705 | 2.860 | 0.239 | 4.596 | 0.204 | 7.143 | 0.129 | 11.170 ^b | 0.048 | | | | |
| | $\hat{\rho}_1$ | -1.357 ^a | 0.000 | -1.407 ^a | 0.000 | -1.473 ^a | 0.000 | -1.489 ^a | 0.000 | -1.602 ^a | 0.000 | | | | |
| $\hat{\rho}_2$ | -0.267 ^c | 0.060 | -0.246 | 0.120 | -0.268 | 0.128 | -0.349 | 0.101 | -0.505 ^b | 0.039 | | | | | |
| $\hat{\tau} = 0.235$ | | | | | | | | | | | | | | | |

1. Trend model
2. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.
3. *Wald* statistics is for Granger non-causality test and coef indicates an estimate of ρ_i for $i = 1$ and 2 .

Table 28: Granger non-causality tests by threshold (MTAR) error correction model (real (CGPI))

| lag-order | 1 | | 2 | | 3 | | 4 | | 5 | | |
|-----------------------|---|---------------------|-------------------|---------------------|-------------------|---------------------|-------------------|---------------------|-------------------|---------------------|-------|
| | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | <i>Wald</i> /coef | <i>p</i> -value | |
| Group 1 | $\Delta CGR_{1,r3} \overset{G}{\nrightarrow} \Delta CGE_{3,r3}$ | 2.173 | 0.140 | 1.322 | 0.516 | 2.103 | 0.551 | 2.939 | 0.568 | 1.587 | 0.903 |
| | $\hat{\rho}_1$ | -0.014 | 0.822 | 0.010 | 0.891 | 0.021 | 0.797 | -0.004 | 0.961 | 0.052 | 0.621 |
| | $\hat{\rho}_2$ | 0.590 ^a | 0.000 | 0.582 ^a | 0.000 | 0.580 ^a | 0.000 | 0.518 ^a | 0.003 | 0.526 ^a | 0.004 |
| Group 2 | $\Delta CGE_{3,r3} \overset{G}{\nrightarrow} \Delta CGR_{1,r3}$ | 0.093 | 0.761 | 1.471 | 0.479 | 7.832 ^b | 0.050 | 7.317 | 0.120 | 14.226 ^b | 0.014 |
| | $\hat{\rho}_1$ | -0.143 ^b | 0.042 | -0.099 | 0.206 | -0.141 ^c | 0.087 | -0.150 | 0.103 | -0.267 ^a | 0.010 |
| | $\hat{\rho}_2$ | -0.236 | 0.140 | -0.216 | 0.176 | -0.229 | 0.127 | -0.262 | 0.120 | -0.243 | 0.137 |
| $\hat{\tau} = -0.128$ | | | | | | | | | | | |
| Group 3 | $\Delta CGR_{1,r3} \overset{G}{\nrightarrow} \Delta CGE_{4,r3}$ | 1.471 | 0.225 | 1.265 | 0.531 | 1.000 | 0.801 | 1.191 | 0.880 | 0.970 | 0.965 |
| | $\hat{\rho}_1$ | -0.050 | 0.569 | -0.020 | 0.841 | 0.028 | 0.803 | 0.024 | 0.862 | 0.029 | 0.866 |
| | $\hat{\rho}_2$ | 0.325 ^c | 0.058 | 0.334 ^c | 0.059 | 0.329 ^c | 0.067 | 0.324 ^c | 0.089 | 0.325 | 0.106 |
| Group 4 | $\Delta CGE_{4,r3} \overset{G}{\nrightarrow} \Delta CGR_{1,r3}$ | 0.142 | 0.706 | 0.235 | 0.889 | 3.118 | 0.374 | 3.017 | 0.555 | 8.373 | 0.137 |
| | $\hat{\rho}_1$ | -0.198 ^c | 0.055 | -0.162 | 0.149 | -0.225 ^c | 0.069 | -0.246 | 0.100 | -0.468 ^a | 0.009 |
| | $\hat{\rho}_2$ | -0.313 | 0.108 | -0.278 | 0.155 | -0.266 | 0.161 | -0.281 | 0.166 | -0.351 ^c | 0.080 |
| $\hat{\tau} = -0.060$ | | | | | | | | | | | |
| Group 5 | $\Delta CGR_{3,r3} \overset{G}{\nrightarrow} \Delta CGE_{3,r3}$ | 1.083 | 0.298 | 0.548 | 0.760 | 1.973 | 0.578 | 3.029 | 0.553 | 1.189 | 0.946 |
| | $\hat{\rho}_1$ | 0.021 | 0.770 | 0.062 | 0.432 | 0.041 | 0.614 | 0.008 | 0.933 | 0.066 | 0.522 |
| | $\hat{\rho}_2$ | 0.473 ^a | 0.005 | 0.479 ^a | 0.005 | 0.602 ^a | 0.001 | 0.591 ^a | 0.001 | 0.575 ^a | 0.003 |
| Group 6 | $\Delta CGE_{3,r3} \overset{G}{\nrightarrow} \Delta CGR_{3,r3}$ | 0.108 | 0.742 | 2.454 | 0.293 | 7.805 ^c | 0.050 | 7.221 | 0.125 | 12.344 ^b | 0.030 |
| | $\hat{\rho}_1$ | -0.110 | 0.127 | -0.038 | 0.628 | -0.118 | 0.144 | -0.130 | 0.146 | -0.232 ^b | 0.022 |
| | $\hat{\rho}_2$ | -0.439 ^a | 0.009 | -0.387 ^b | 0.019 | -0.296 ^c | 0.063 | -0.303 ^c | 0.084 | -0.268 | 0.121 |
| $\hat{\tau} = -0.137$ | | | | | | | | | | | |
| Group 7 | $\Delta CGR_{3,r3} \overset{G}{\nrightarrow} \Delta CGE_{4,r3}$ | 1.147 | 0.284 | 1.445 | 0.485 | 1.094 | 0.778 | 1.269 | 0.867 | 1.101 | 0.954 |
| | $\hat{\rho}_1$ | -0.020 | 0.817 | 0.025 | 0.769 | 0.037 | 0.734 | 0.051 | 0.695 | 0.048 | 0.768 |
| | $\hat{\rho}_2$ | 0.331 ^c | 0.054 | 0.352 ^b | 0.047 | 0.345 ^c | 0.055 | 0.355 ^c | 0.060 | 0.346 ^c | 0.080 |
| Group 8 | $\Delta CGE_{4,r3} \overset{G}{\nrightarrow} \Delta CGR_{3,r3}$ | 0.485 | 0.486 | 1.261 | 0.532 | 2.879 | 0.411 | 2.672 | 0.614 | 3.727 | 0.589 |
| | $\hat{\rho}_1$ | -0.149 | 0.153 | -0.073 | 0.502 | -0.146 | 0.209 | -0.148 | 0.285 | -0.245 | 0.156 |
| | $\hat{\rho}_2$ | -0.432 ^b | 0.033 | -0.383 ^c | 0.052 | -0.359 ^c | 0.059 | -0.357 ^c | 0.073 | -0.369 ^c | 0.074 |
| $\hat{\tau} = -0.096$ | | | | | | | | | | | |

1. Trend model

2. ^{a, b, c} indicate significance at the 1%, 5%, 10% level respectively.

3. *Wald* statistics is for Granger non-causality test and coef indicates an estimate of ρ_i for $i = 1$ and 2.

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