What explains output volatility? Evidence from G3

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Discussion Paper No. 09/2010
What Explains Output Volatility? Evidence from the G3†

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Abstract

This paper investigates the short-run and long-run impact of the determinants of output volatility for the G3 during the period 1974-2009. We estimate a multivariate GARCH model and include the covariances of those determinants, which have been ignored in the prior relevant literature. Our findings indicate that nominal variability, namely variability in the interest rate and inflation, explains output volatility. Fiscal policy variations, captured by the volatility of government spending, are found to be important as well. Fluctuations in the international markets seem to affect significantly the volatility of output in almost all countries under examination. Finally, any real shock originated from the world’s most advanced country, the U.S., transcends to the other two with high significance.

Key Words: output volatility, multivariate GARCH, BEKK

JEL codes: E0, C32, C51, C52

† We would like to thank Claire Economidou, Emmanuel Mamatzakis and Theodore Panagiotidis for their valuable comments. The usual disclaimer applies.
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1. Introduction

A central issue in the theoretical and empirical macro literature concerns the relationship between macroeconomic uncertainty, which results from unanticipated changes of important macro variables, and macroeconomic performance measured by indicators, such as the output growth rate. Lately, there has been an increasing interest in the analysis of volatility of macroeconomic variables, in particular volatility of output growth. This interest has been spurred by the observed reduction in output volatility in industrial countries, the so-called “Great Moderation”.

Not surprisingly, there is a growing literature seeking to disentangle the varied causes of this general decline in macroeconomic volatility and to determine their explanatory role. The possible causes pointed out by the literature for the output volatility decline include the level of development (Acemoglu and Zilibotti, 1997; Pritchett, 2000), the size of the economy (Canning et al., 1998), any lack of strong institutions (Acemoglu et al., 2003) and the development of the financial sector (Easterly et al., 2000). In addition, improvements in inventory management (McConnell and Perez-Quiros, 2000; Kahn et al., 2002), improvements in monetary policy (Clarida et al., 2000), innovations in financial markets and changes in the dynamics of inflation (Blanchard and Simon, 2001), and good luck in the form of less intense exogenous shocks (Ahmed et al., 2002), may be responsible for the output volatility decline. Still, according to Stock and Watson’s (2002) calculations, about half of the decline in volatility is unaccounted for.

Methodologically, the unconditional volatility of macroeconomic aggregates has been computed using the standard deviation or variance of the aggregate (Fatas and Mihov, 2006; Imbs, 2007). The conditional volatility has been captured by Autoregressive Conditional Heteroskedasticity (ARCH) and Generalized ARCH (GARCH) models (Grier and Perry, 2000; Bredin and Fountas, 2005). However, none of these studies focuses on the determinants of output volatility. Rather, they focus on the effects of inflation and output volatility on output growth and/or inflation. However, there is evidence that output growth affects output volatility either positively (Fountas et al., 2002) or negatively (Fountas and Karanasos, 2006).\(^1\)

\(^1\) The negative effect is also confirmed by Fang and Miller (2008), who consider structural changes in the volatility process.
Additionally, it is found that inflation volatility impacts output volatility either positively (Logue and Sweeney, 1981) or negatively (Lee, 1999).²

The studies mentioned above either do not focus on the determinants of output volatility or provide only one variable in terms of volatility (inflation volatility) as a determinant of output volatility. Furthermore, none of the aforementioned studies does incorporate the covariances of the potential determinants of output volatility in their investigation.³ However, it is possible that the combination of changes in two macroeconomic variables could impact on the volatility of output. This combination or co-movement of the variables is captured by the conditional covariance terms, which we also take into consideration in our model.

Therefore, the contribution of the present paper is twofold: First, we examine the impact of various volatility determinants on output volatility. Second, we incorporate in the group of output volatility determinants the covariances of shocks to variables that we consider important driving forces of output volatility. More specifically, in this paper we purport to provide empirical evidence of the determinants of output variability for the G3 countries, namely, Germany, Japan and the U.S. Among the determinants, we include important domestic macroeconomic variables and international influences captured by the exchange rate, net trade and the U.S. volatility.⁴ The last three are considered here since the countries in our sample are major trading partners with each other and interact significantly with the U.S., the world’s largest economy.

We introduce the role of the U.S. because we are interested in focusing on how U.S. fiscal policy affects output volatility of the rest countries.⁵ Two of the international aspects of our model (the volatility of exchange rate and the U.S. government spending) have not been yet considered in the relevant past literature (with exception of Morana (2009) who addresses the correlation between exchange rate volatility and output volatility). With respect to the role of trade, terms of trade or trade openness are often used in the literature (e.g. Turnovsky and Chattopadhyay, 2003; Karras, 2006)).

² Fountas et al. (2002) point out no causality from inflation volatility to output volatility.
³ An exception of the above is Morana (2009), who considers the volatility of basic macroeconomic variables as determinants of output volatility and computes their correlation.
⁴ Net trade does not include interest payments on national debt. The advantage of net trade over current account is that the former is independent of assumptions regarding the structure of international financial markets.
⁵ Changes in government spending impacts on exchange rate, terms of trade and trade balance. The affected variables imply an association of a domestic with a foreign economy.
Lastly, the inclusion of the covariances is considered of great importance because it can capture the joint effect of shocks to specific macroeconomic variables on output volatility. For example, the covariance of output and inflation arises from output or inflation shocks that impact output volatility. Moreover, the selected covariance of the domestic government spending and interest rate may explain the effect of increasing government expenditure due to increasing borrowing on output volatility. Furthermore, the covariance of interest rate and inflation may explain the use of monetary policy under inflationary pressure. Finally, the covariance of output and net trade may explain the role of trade in increasing or decreasing output due to trade deficit or surplus.

To compute the vectors of conditional variances (measure of volatility) and contemporaneous covariances, we estimate a Diagonal BEKK model, a type of a multivariate GARCH model.\(^6\) We stress the BEKK specification in order to guarantee that the variance-covariance matrix is positive definite. The next step involves the estimation of a reduced-form model. To address short-run causality issues we resort to Granger causality tests, while the computation of the long-run effects of the determinants of output volatility is addressed following a variant of the approach of Grier and Smallwood (2007).

The remainder of the paper proceeds as follows: Section 2 discusses the macroeconomic theory that predicts the effects of these relationships. Section 3 describes the econometric model and methodology proposed. Section 4 discusses the data. Section 5 presents the empirical results. Section 6 reports the findings and reports some policy implications.

2. Theory

2.1. The effect of domestic fiscal policy volatility on output volatility

The effect of government spending volatility on output volatility depends on the source of government spending fluctuations (Turnovsky and Chattopadhyay, 2003). Specifically, an increase in the government’s absorption of risk (implying that the government directs its expenditure policy toward stabilization objectives) will increase government spending volatility and the latter will be associated with a reduction in output volatility. On the other hand, if the

\(^6\) This acronym comes from the synthesized work on multivariate ARCH models by Yoshi Baba, Rob Engle, Dennis Kraft and Ken Kroner.
fluctuations of government spending are attributed to exogenous government expenditure risk, the impact on output volatility will be positive. The negative correlation may reflect the possibility that countries with high and volatile government expenditure tend to engage more in successful countercyclical fiscal policies. The positive effect of government spending volatility on output volatility is supported by Gali (1994), providing evidence for the sample of OECD countries. Overall, the above analysis indicates that the direction of the impact of government spending volatility on output volatility is ambiguous.

2.2. The effect of monetary policy volatility on output volatility

According to Grinols and Turnovsky (1993), higher monetary volatility, captured by high nominal interest rate volatility, reduces (increases) the output growth rate and its volatility via provided savings fall (rise). The main argument of this contradictory result is the effect of savings. If consumers do not intend to substitute their consumption over time, then higher savings lead to higher output volatility. When consumers tend to substitute their consumption, a decrease in savings leads to higher output variability (Turnovsky and Chattopadhyay, 2003).

With respect to inflation volatility, its role in dampening or exacerbating output volatility has been of major importance. Countries with greater central bank independence and adoption of monetary policy regimes that are stricter on inflation, as is the case in the U.S., appear to exhibit a reduction in output volatility (Romer, 1999). In contrast, it is possible to observe a trade-off between inflation variability and output variability (Taylor, 1979). Moreover, evidence suggests that inflation fluctuations affect market prices and reduce economic activity (Hayek, 1944; Friedman, 1977). Since output is positively correlated with its volatility (Kormendi and Meguire, 1985; Grier and Tullock, 1989), the negative relationship between inflation and output volatility is confirmed. On the other hand, Blanchard and Simon (2001) suggest that inflation volatility is positively related with output volatility. The above analysis points to the conclusion that the sign of the effect of monetary policy (interest rate and inflation) variability on output variability is ambiguous from a theoretical point of view.

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7 This effect is also supported by the empirical evidence of Aizenman and Marion (1993).
8 Levi and Makin (1980) and Mullineaux (1980) find that inflation variability is negatively correlated with output growth.
2.3. The effect of international volatility on output volatility

In a global and rather integrated world, an interesting question that arises is whether any fluctuations in the exchange rate would cause fluctuations of output. Exchange rate fluctuations imply high risk in investing abroad and increasing exports. Thus, output dampens if not staying unaltered, and so does its volatility. Therefore, the impact of exchange rate volatility on output volatility is expected to be negative. This effect is in line with Friedman’s (1953) view that higher macroeconomic volatility can be dealt with in an attempt of exchange rate stabilization. A positive relationship between exchange rate volatility and output volatility is also possible according to Friedman’s perspective that exchange rate instability may be a symptom of macroeconomic instability concluding that there is a positive association between exchange rate volatility and macroeconomic volatility. Hence, in summary, the effect of exchange rate volatility on output volatility may be either positive or negative.

With respect to the effect of net trade volatility on output volatility, simulation evidence reveals that the direction of the effect is not uniform, but rather depends on the size of terms-of-trade volatility (Turnovsky and Chattopadhyay, 2003). If there is an increase in terms-of-trade volatility, then output volatility drops. Any further increase in the volatility in terms of trade leads to an increase in output volatility. In addition, an increase in terms-of-trade volatility results in faster or slower growth, leading to an increase or decrease of output volatility (Mendoza, 1997). Given the likely relationship between terms-of-trade volatility and trade balance volatility, the above arguments may be extended to argue that volatility in the trade balance may affect output volatility in an ambiguous way.

Furthermore, the impact of the U.S. government spending volatility on trade partners’ output volatility is defined indirectly through the channel of trade. In a two-country, Mundell-Fleming model, a large country as the U.S. drives up interest rates everywhere in the world simultaneously. The fiscal expansion succeeds in raising the domestic interest rate to the extent that it also raises the foreign one. In addition, the relative size of intertemporal and intratemporal substitution, combined with the home bias in private spending, determines the sign of response of net trade to an exogenous increase in government spending (Muller, 2008). Assuming a positive relationship between government spending and its volatility and net trade and its

\[ \text{If the elasticity of intertemporal substitution is high relative to the elasticity of intratemporal substitution, an increase in government spending will increase net trade.} \]
volatility, the impact of government spending volatility on net trade volatility is expected to be positive. Therefore, the U.S. government spending volatility affects positively the domestic net trade volatility and the latter, in turn, impacts on foreign output volatility with the same sign. However, the effect can also be negative on the grounds that slow response in the absorption of the shocks of the U.S. government spending dampens domestic output, and in turn, output volatility (Turnovsky and Chattopadhyay, 2003) transcending this effect to trade partner countries. Hence, the effect of the U.S. government spending volatility on foreign output volatility is a priori ambiguous and can be either positive or negative.

3. Model Specification

3.1. Modeling Volatility

In this section we present our econometric model and approach. To model conditional variances and covariances we estimate a multivariate GARCH model which is an extension of a univariate GARCH model.

Before embarking on the estimation of the multivariate GARCH model, we need first to test for ARCH effects. We have chosen to estimate a BEKK model (Engle and Kroner, 1995) because it ensures that the conditional variance-covariance matrix is always positive definite. However, there are several specifications for multivariate GARCH models.\(^{10}\) We estimate the Diagonal BEKK in order to avoid computational difficulties of jointly estimating all model parameters in the first stage.\(^ {11}\) Further, we include Autoregressive (AR) terms in order to account for autocorrelation. The introduction of asymmetric terms is of great importance in order to take into account “bad” or “good” news that affect the conditional variance of the variables under investigation.

\(^{10}\) A common specification of multivariate GARCH models is the VEC H model introduced by Bollerslev et al. (1988). As the number of variables employed in the model increases, the estimation of this model seems infeasible since a large number of parameters are needed to be estimated. For this reason, Bollerslev et al. (1988) restricted the conditional variance-covariance matrix by assuming that matrices A and B are diagonal. Other specifications of multivariate GARCH models include the Constant Conditional Correlation (CCC) specification (Bollerslev, 1990) and the Dynamic Conditional Correlation (DCC) model (Engle, 2002; Tse and Tsui, 2002). An analytical survey of multivariate GARCH models can be found in Bauwens, Laurent and Rombouts (2006).

\(^{11}\) EVIEWS 6 has been used for the estimation of BEKK models and there is the restriction of estimating the Diagonal form of multivariate GARCH models.
We present the Autoregressive-Asymmetric-Diagonal BEKK (AR-AS-DiagBEKK) model as it is used for the computation of the conditional variance (or/and covariance) of the variables under investigation. To illustrate the aforementioned model we include seven variables of interest: (i) real effective exchange rate (RXR), (ii) output (GDP), (iii) government spending (GS), (iv) interest rate (IR), (v) inflation (INF), (vi) net trade (NT) and (vii) U.S. government spending (GS USA) (i.e., seven conditional mean equations) and the simple GARCH(1,1) model for the conditional variance. We choose the GARCH(1,1) model because it is more parsimonious than ARCH and avoids over-fitting. In addition, it has been accepted that a GARCH(1,1) process is sufficient to capture the volatility clustering in the data and rarely any higher order model is estimated in the academic finance literature.

The selection of the aforementioned variables is based on economic theory and justified in the theoretical work of Obstfeld and Rogoff (1996), who suggest that domestic output is affected by the exchange rate, monetary and fiscal policy of the domestic and foreign economy, under different assumptions. In addition, Grydaki and Fountas (2009), who extend the work of Driskill and McCafferty (1980, 1987), support the validity of exchange rate, trade and monetary policy variables as determinants of domestic output. Moreover, they introduce the role of selected covariances, apart from monetary and real shocks, as determinants of output volatility.

The conditional mean equation is specified as:

\[
Y_t = \mu + \sum^p_{i=1} \Gamma_i Y_{t-i} + \varepsilon_t, \quad \varepsilon_t | \psi_{t-1} \sim (0,H_t)
\]

where, \(Y\), \(\mu\) and \(\varepsilon\) are 7x1 vectors of dependent variables, intercepts and the innovation vector, respectively; \(i\) denotes the autoregressive term of each dependent variable.

The conditional variance equation is given by:

\[
H_t = C^*_0 + A^*_1 \varepsilon_{t-1} \varepsilon'_{t-1}, A^*_1 + B^*_1 H_{t-1} B^*_1 + D^*_1 \xi_{t-1} \xi'_{t-1}, D^*_1
\]

where \(C^*_0\), \(A^*_1\), \(B^*_1\), \(D^*_1\) are 7x7 matrices of parameters, \(H_t\) is a 7x7 conditional variance-covariance matrix and \(\xi\) is a 7x1 vector which accounts for asymmetries in the conditional variance-covariance matrix.\(^{12}\) More specifically, \(\xi\) represents the effect of bad news on the conditional variance of the variables. We assume that bad news in terms of real effective exchange rate, interest rates and inflation are considered higher than expected magnitudes and,

\(^{12}\) Matrices \(C^*_0\), \(A^*_1\), \(B^*_1\), \(D^*_1\) and \(H_t\) are 6x6 and vectors \(Y, \mu, \varepsilon\) and \(\xi\) are 6x1 in the case of the U.S., where the domestic government spending coincides with the foreign one.
hence, correspond to a positive residual. On the other hand, we assume that bad news in terms of output, government spending and net trade correspond to lower than expected levels and, hence, lead to a negative residual. The positive definiteness of the variance-covariance matrix is ensured because of the quadratic nature of the terms on the right-hand side of equation (2). Matrices $A_{11}^*$, $B_{11}^*$, $D_{11}^*$ are diagonal by definition and $C_0^*$ is an upper triangular matrix.\(^\text{13}\)

### 3.2. Reduced-Form Model

Having derived the conditional variance vectors from Diagonal BEKK models and computed the moving covariance of the selected variables, our final step consists of estimating the impact of the volatilities, as well as, of (selected) covariances of domestic macroeconomic variables on output volatility for every country in our sample.\(^\text{14}\) To assess the impact of every regressor on output volatility, we apply Granger causality tests. In general, a dependent variable $y$ is said to be Granger-caused by an independent variable $x$, if $x$ helps in the prediction of $y$ when lags of $y$ are also used to predict $y$, or equivalently if the coefficients on the lagged $x$'s are statistically significant.

Equation (3) below regresses the volatility of output on the lagged values of the volatilities ($\sigma^2$) of output, exchange rate, government spending, interest rate, inflation, net trade and the U.S. government spending and the lags of the following four covariances (cov): interest rate and inflation, government spending and interest rate, output and inflation, and, output and net trade:\(^\text{15}\)

$$
\sigma^2_{\text{GDP},t} = c + \sum_{p=1}^{p} \{ \phi_{1p} \sigma^2_{\text{GDP},t-p} + \phi_{2p} \sigma^2_{\text{RXR},t-p} + \phi_{3p} \sigma^2_{\text{GS},t-p} + \phi_{4p} \sigma^2_{\text{IR},t-p} + \phi_{5p} \tau^2_{\text{INF},t-p} \\
+ \phi_{6p} \tau^2_{\text{NT},t-p} + \phi_{7p} \sigma^2_{\text{USA},t-p} + \phi_{8p} \text{cov}(\text{IR,INF})_{t-p} + \phi_{9p} \text{cov}(\text{GS,IR})_{t-p} \\
+ \phi_{10p} \text{cov}(\text{GDP,INF})_{t-p} + \phi_{11p} \text{cov}(\text{GDP,NT})_{t-p} \} + \epsilon_t
$$

\(^\text{13}\) Under the assumption that the error terms follow the Multivariate Student’s $t$ conditional distribution, the parameters of the multivariate GARCH model can be estimated by maximizing the log likelihood function:

$$
L_{\text{GARCH}} = T \log \left( (\Gamma(v+m)/2)^{\frac{v}{2}} \left( (\Gamma(v/2))^{\frac{v}{2}} \Gamma(v/2)(v-2)^{\frac{v}{2}} \right) - 1/2 \sum_{m} \{ \log \left( |H_m| \right) + (v+m) \log \left[ 1 + \epsilon_m^2/H_m \right] - \frac{v}{2} \} \right).
$$

Laurent and Peters (2002) provide details on the log likelihood functions of multivariate GARCH models.

\(^\text{14}\) For the theoretical justification of the selection of the covariances included in equation (3), see Obstfeld and Rogoff (1996) and Grydaki and Fountas (2009).

\(^\text{15}\) We select the specific covariances because they are considered more informative about the evolution of output volatility.
where $\phi_p$ is the coefficient of the $i$th variable for $p$ lags and $\epsilon_i$ is the error term. A regressor in equation (3) does not Granger cause output volatility when $\phi_i = \ldots = \phi_p = 0$ where $i = 2, \ldots, 11$. To test these hypotheses we conduct a Wald test and use the heteroskedasticity and correlation consistent standard errors suggested by Newey and West (1987). It is mentioned that this model is not subject to the generated regressors critique advanced by Pagan (1984) as in equation (3) we include the lagged variance and covariance terms, and not the contemporaneous ones.

We estimate a system of seven (six in the case of the U.S.) equations equal to the number of variables based on equations (1) and (2). Prior to our estimation, we undertake the following steps: (i) check for stationarity of the data and discussion of the descriptive statistics, (ii) test for heteroskedasticity, and (iii) specification tests on estimated BEKK models. These steps, together with the description of our variables and their sources, are presented in the next section.

4. Data and Estimation of Volatilities

To model output volatility we control for the volatilities of the following seasonally adjusted variables: (i) Real Exchange Rate (RXR): We use the real effective exchange rate; (ii) Output: We use the real Gross Domestic Product (GDP) created through deflation with the corresponding GDP deflator; (iii) Domestic Government Spending (GS): The real government spending has been used and has been deflated with the corresponding GDP deflators; (iv) Interest Rate (IR): The call money rate has been used as a proxy for short-term interest rate in Germany and Japan, while the treasury bill rate is used for the U.S.; (v) Inflation (INF): It is measured by the quarterly difference of log of the consumer price index (CPI); (vi) Net Trade (NT): It is defined as the difference of exports (f.o.b.) and imports (c.i.f.).

The main source of our data is the International Monetary Fund (IMF). Only the real exchange rate and net trade are obtained from the Organization for Economic Co-Operation and Development (OECD). Our sample consists of the three largest OECD countries, Germany, Japan, and the U.S. and the evidence is based on quarterly data of the period 1974Q1-2009Q2.

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16 We also account for structural breaks in each economy. In equation (3), and for the case of Germany, we include dummies in order to take into consideration the implementation of the European Monetary System (EMS), as well as, the unification of West and East Germany. For Japan, we consider the burst of the bubble in 1990, as well as, some spikes that occur in the conditional variance of output. Lastly, for the U.S., we take into account the change in monetary policy. Almost all the dummies are statistically insignificant and thus excluded from equation (3).
The starting point of the sample corresponds to the end of the Bretton Woods exchange rate
regime and the start of floating regime. The use of quarterly data is justified by the fact that some
series are not available at higher frequency (e.g. GDP, GS).

4.2. Preliminary Tests

Our first step of our analysis involves the examination of the stationarity property in our
data. The findings reveal that all variables in all countries are I(1) with the exception of INF, which is I(0) in all three cases. According to the four unit root tests and taking into account the
consensus of the literature on the stationarity of macroeconomic variables, we use the first
difference of the logs (except for NT) of all variables apart from INF, for which we use its level.
Moreover, all the stationary series are non-normally distributed according to the descriptive
statistics, in all countries. Thus, the estimation of BEKK models assuming multivariate t-
distributed errors is suggested.

Having removed the unit root from the variables, our next step involves the examination of
clustering volatility (the presence of ARCH effects) or any form of heteroskedasticity. To do so,
we first apply the ARCH Lagrange Multiplier (ARCH-LM) test. However, the complexity of
many economic time series generates non-linear dynamics that make classical econometric
techniques to fail (Kyrtsou, 2005, 2008). Therefore, in cases where ARCH-LM test is not
sufficient to detect heteroskedasticity, we also apply White’s (1980) heteroskedasticity test, as
well as, the Glejser (1969) and Harvey (1976) tests. The results are shown in Table 1.

A variable exhibits ARCH effects or heteroskedasticity in general, if the value of LM-
statistic is statistically significant at the conventional significance levels, 1%, 5% and 10%. In

17 We apply the following stationarity tests to the logs of our variables (apart from NT which can take negative
values as well): (i) Generalized Least Squares (GLS)-detrended Dickey-Fuller (DF-GLS) (Elliot, Rothenberg and
Stock, 1996), (ii) Ng-Perron (NP) (Ng and Perron, 2001), (iii) Augmented Dickey-Fuller (ADF) (Dickey and Fuller,
1979), and (iv) Phillips and Perron (PP) (Phillips and Perron, 1988). The non-stationarity null hypothesis is tested at
5% significance level. The unit root test results are not reported for space considerations but can be provided upon
request.

18 The considered descriptive statistics include the mean, the coefficient of variation, skewness, kurtosis and Jarque-
Bera statistics. Their values are not reported for space considerations and can be provided upon request.
Germany, IR and NT appear to support the presence of clustering volatility at 10% and 1% significance levels, respectively. With respect to the other variables, they exhibit heteroskedasticity according to White (GS and INF at 10% and 5%, respectively), Glejser (RXR at 10%) and Harvey (GDP at 1%) tests. In Japan, GDP, IR, NT are characterized by ARCH effects at 1% significance level and INF at 10% while GS exhibits heteroskedasticity at 1% according to Harvey test. Lastly, all variables in the U.S. are volatility clustered (GDP, IR and NT at 1% and RXR, GS at 10% significance level) with the exception of INF which is heteroskedastic at 1% according to Glejser test. Therefore, the estimation of BEKK models is appropriate in order to capture the conditional variance of the variables under investigation.

4.3. Specification Tests and Residual Diagnostics of Diagonal BEKK Models

Our third step proceeds with the estimation of the Diagonal BEKK model as it is described in equations (1) and (2). To account for possible autocorrelation, we use AR terms in all variables in the Diagonal BEKK conditional mean equation, considering 1 to 12 lags. The selection of the best model is based on the residual properties, i.e. no remaining autocorrelation and remaining ARCH effects. Taking into account the residual properties of all 36 estimated models, we end up estimating an AR($p$)-AS-DiagBEKK model, where $p = 2$ for Germany (coincides with the result suggested by the values of Log-Likelihood and SIC), $p = 4$ for Japan and an $p = 5$ for the U.S. Next, we provide some specification tests for AR-AS-DiagBEKK models in order to ensure that models fit the data well. Table 2 reports the specification tests for the three models.

[Table 2 HERE]

The results of Table 2 indicate that in all models the matrices of ARCH, GARCH and asymmetric terms are jointly significant at 1% significance level. The joint statistical significance of the diagonal elements of the same matrices indicates that lagged conditional variances, lagged squared innovations and lagged asymmetries in the determinants of output tend to affect the conditional variance of the determinants of output and output conditional variance itself. More specifically, the joint significance of the diagonal elements of $A_{11}^*$, $B_{11}^*$ and $D_{11}^*$ implies that shocks to monetary and fiscal variables, as well as, to the exchange rate, net trade
and the U.S. government spending, combined with their volatilities, tend to influence with a lag output volatility.

In addition, the joint statistical significance of the asymmetric terms, indicated by the joint significance of the diagonal elements of $D_{11}$, implies that the conditional variance of output and its determinants is affected by “bad” or “good” news. This is the case for Japan and the U.S. and not for Germany. Thus, we proceed with the estimation of an AR(2)-Symmetric Diagonal BEKK model for Germany since the conditional variances are not affected significantly by unexpected “news”. Even in this model the statistical significance of ARCH and GARCH terms is very strong. In addition, we test for the joint significance of the covariances of the determinants of output in the three models. We find that in none of the three cases the covariances are statistically significant. The latter implies that another computation of selected covariances is required and this is the four-period moving covariance as we have quarterly data.

The next step is to provide residual diagnostics for the three Diagonal BEKK models in order to test for remaining autocorrelation and ARCH effects. The tests are conducted at 1% significance level and Table 3 reports the results.

5. Results

5.1. Short-Run Effects

In this section we provide the short-run effects on output volatility for Germany, Japan and the U.S. Table 4 reports the short-run effects for 8 and 10 lags implying a volatility effect in two
to two-and-a-half years. We have chosen a longer time horizon because volatility effects probably take longer than level effects to materialize.

[Table 4 HERE]

Our results show that for Germany and Japan (along both lag lengths), as well as for the U.S. in the case of 8 lags, there is a negative effect of exchange rate volatility on output volatility. The impact is significant only for Germany (8 lags) at 1% significance level and the U.S. (10 lags) at 10% level. The insignificance of this effect is in line with Morana (2009). The positive and significant impact of exchange rate volatility on the U.S. output volatility (10 lags) is confirmed by Friedman (1953), where exchange rate volatility exacerbates output volatility.

Regarding the effect of domestic government spending volatility, findings reveal that there is a positive conjunction for Germany and Japan, while a negative one for the U.S. The negative U.S. result seems puzzling, a priori. However, this is consistent with the argument of Turnovsky and Chattopadhyay (2003). The impact of domestic government spending is significant in all countries and in both lag lengths with the exception of Germany and the U.S., where the significance is mentioned only for 10 lags at 10% significance level.

Continuing with the effect of interest rate volatility, we detect a negative association with output volatility in Germany and the U.S. whereas an ambiguous one in Japan. These results are in line with Aizenman and Marion (1993) and Turnovsky and Chattopadhyay (2003). However, the effect is significant only in the U.S. along both lag lengths at 10% and 1% level, respectively. Moreover, inflation volatility is found to affect output volatility positively in Germany and Japan and negatively in the U.S. at 10% along 10 lags. The positive effect follows the conclusion that Blanchard and Simon (2001) have drawn for the G7 countries, while the negative one is supported by Taylor (1979) referring to the trade-off between inflation volatility and output volatility. The effect of inflation volatility is significant in all cases apart from the U.S. along 8 lags. The extremely large in magnitude effect of inflation volatility on Japanese output volatility is not surprising. The Japanese economy of the second half of the 1980s is characterized as the “bubble economy”. The burst of the bubble came in the first half of the 1990s. Since then the effectiveness of fiscal and monetary policy in having an impact on output (taking the economy out of recession) has been heavily criticized (Cargill, Hutchison and Ito, 1997).
Commenting on the effect of net trade volatility, we detect a positive conjunction with output variability along all countries and both lag lengths. The statistical significance of this effect applies only to Germany and Japan at 5% and 1% significance level along 8 and 10 lags, respectively. This result is in broad agreement with Turnovsky and Chattopadhyay (2003). However, the magnitude of the effect is extremely small. Probably, the effect of net trade volatility is associated with the role of the U.S. government spending volatility, which also affects net trade volatility between trade partners. Indeed, the U.S. government spending volatility impinges a negative (ambiguous) statistically significant impact on German (Japanese) output volatility.\(^\text{19}\)

Comparing the relative importance of fiscal versus monetary policy volatility in explaining output volatility, we find the latter to be slightly more important, both quantitatively and statistically, for the countries in our sample.\(^\text{20}\) Interest rate volatility is proved to be statistically significant in two out of six cases, while inflation volatility is significant in five out of six cases. In a time horizon of two to two-and-a-half years inflation may be assumed to be determined by monetary policy and, thus, we can argue that monetary policy explains output variability in all cases. This is in line with the findings of Blanchard and Simon (2001), who argue that monetary policy rather than fiscal policy stabilizes the economy better because of transparent policy goals. In addition, fiscal policy explains output volatility in four out of six cases. Hence, volatility in both monetary and fiscal policy is proved to be significant in the determination of output volatility in the three largest OECD countries.

Finally, among the included covariances, the covariances of interest rate and inflation, domestic government spending and interest rate, and output and inflation are found to be statistically significant for all countries in at least one lag. The effect of the covariance of interest rate and inflation is expected to be either positive or negative. Higher inflation is associated with less output and thus with less output volatility. An increase in interest rates induces more or less saving (according to the elasticity of intertemporal substitution) and, thus, an increase or decrease of output. The sign of the covariance depends on which effect dominates. The negative effect holds in Germany and Japan, while the positive in the U.S. The same dominant play holds

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\(^\text{19}\) The negative effect is consistent with Muller (2008), allowing for the positive relationship between government spending and net trade. The ambiguous effect is in line with Turnovsky and Chattopadhyay (2003), who introduce the nature of the shock that causes the volatility in government spending.

\(^\text{20}\) The volatility of the two monetary variables, interest rate and inflation, is statistically significant. However, inflation volatility rather than interest rate volatility explains output volatility in most of the cases.
for the determination of the sign of the covariance of domestic government spending and interest rate. Government spending may increase (productive) or decrease (non productive) output (Barro, 1991) and, in turn, increases or decreases output volatility. Our findings support the positive effect of the covariance on output volatility in all countries. However, the effect may be also negative if the change in interest rate is greater than the change in government spending.

Regarding the effect of the covariance of output and inflation, we find ambiguous results for Germany and the U.S., while for Japan we provide a negative impact of the covariance on output volatility. The reasoning is the same as before: an increase in inflation is associated with less output and less output is linked either positively or negatively with output volatility. In addition, an exogenous increase in output, i.e. due to an increase in consumption, leads to higher or lower output volatility. Finally, the impact of the covariance of output and net trade is found positive for Germany and the U.S. and negative for Japan. The positive (negative) effect may be obtained by the fact that an increase in exports, and thus, net trade leads to increased output and the latter results in an increase (decrease) of output volatility, given the related literature of the conjunction between output and its volatility. Hence, according to the previous analysis, the overall effect of the selected covariances may be either positive or negative, depending on the magnitude of the change that occurs in the variables of each covariance pair.

5.2. Long-Run Effects

As we find ambiguous short-run effects for at least one determinant of output volatility (e.g. U.S. government spending volatility) for at least one country of the sample (Japan), we next examine the long-run causal relationships. We follow a variant of the approach of Grier and Smallwood (2007) in order to compute the long-run effects of the volatility of the determinants of output volatility. These long-run effects are calculated as:

\[
\text{Long Run Effect} = \frac{\sum_{i=1}^{p} \phi_{1,p}}{1 - \sum_{p=1}^{p} \phi_{1,p}} \sigma_{u,j}^2
\]
where $\sigma_{u,i}^2$ denotes the unconditional variance of the $i$th regressor.\textsuperscript{21} When we compute the long-run effect of the covariances we substitute $\sigma_{u,i}^2$ with $\text{cov}_i$ in equation (4).

In principle, the long-run effect could be mixed. That means that at least one significant lag length is positive and one negative. According to Grier and Smallwood (2007), the long-run effect turns out to be positive or negative according to the sign of the significant coefficient that corresponds to the longest lag. Table 5 reports the long-run effects of the determinants of output volatility.

[Table 5 HERE]

With the inclusion of covariances, the volatility of exchange rate impacts negatively on the volatility of output in the long run for the cases of Germany and the U.S. Regarding the fiscal variable, the volatility of the domestic government spending has a positive long-run impact on output volatility for all G3 countries. When it comes to monetary variables, interest rate volatility impacts positively on output volatility only in the case of the U.S., while inflation volatility impacts positively on output volatility in all cases. The volatility of net trade is found to affect output volatility in two of the three cases; negatively for Germany and positively for Japan. Lastly, the U.S. government spending volatility affects negatively the volatility of output in the long run for the case of Germany and Japan.\textsuperscript{22}

With respect to the long-run effect of the selected covariances we provide evidence in favor of a negative long-run impact of the covariance of interest rate and inflation on output volatility in all cases. The covariance of domestic government spending and interest rate is found to impinge a positive effect on output volatility in Germany and Japan, while for the U.S. the aforementioned covariance impacts negatively output volatility. Moreover, the covariance of output and inflation affects negatively the volatility of output in Germany and Japan, while this effect is positive in the U.S.\textsuperscript{23} Finally, the covariance of output and net trade impacts positively output volatility in Japan and the U.S.

\textsuperscript{21} Grier and Smallwood (2007) include the unconditional standard deviation in formula (4).

\textsuperscript{22} The negative effect is justified from the sign of the coefficient with the largest lagged value (Grier and Smallwood, 2007).

\textsuperscript{23} For Germany and the U.S. the result is, in principle, mixed.
A comparison of the results of short-run and long-run effects indicates the following: First, output volatility is explained not only by nominal variability (i.e., interest rate and inflation variability), but also by real (fiscal) variability. Second, exchange rate variability seems to be a significant contributor to output volatility because there is evidence for a significant effect in two of the three countries of our sample. Third, volatility in the U.S. government spending that is likely reflected in volatility in the U.S. current account and net trade, is a significant determinant of output volatility. Fourth, net trade volatility explains quite well output volatility in two of the three countries under investigation. Fifth, the role of the selected covariances is of obvious importance in explaining output variability since they are significant almost in all countries. Combining the above results we may claim that output volatility is due to, not only domestic factors (real and nominal), but also international aspects (exchange rates, net trade and U.S. government spending).

6. Conclusions

We examine the determinants of output volatility focusing on the volatility of several macroeconomic variables over the period 1974-2009 for the G3 countries, Germany, Japan and the U.S. Allowing for the potential impact of the volatilities of the determinants of output volatility, as well as, the impact of the covariances of these determinants, we estimate (i) an Autoregressive Asymmetric Diagonal BEKK model, in order to capture the volatility of the variables under investigation, and (ii) a reduced-form model, in order to perform Granger causality tests.

Our results are summarized as follows: In the short run, volatility in nominal variables reflected in changes in the interest rate and inflation explains output volatility. Fiscal policy variations, captured by the volatility of government spending, are found to be important as well. Fluctuations in the international markets seem to affect significantly the volatility of output in almost all countries under examination. Combining the effect of exchange rate volatility with that of net trade volatility we reach an overall conclusion of international aspects’ statistical significance in five out of six cases. Finally, any real shock originated from the world’s most advanced country, the U.S., transcends to Germany and Japan with high significance. In the long run, the picture remains similar, as the nominal shocks play a dominant role.
Taking into account the sign of the short-run effects, some policy implications may be proposed targeting to the stabilization of output. The maintained hypothesis here is that output volatility is detrimental to output growth as the literature consensus suggests. With respect to monetary policy variations, inflation volatility increases output volatility in Germany and Japan, while in the U.S. an opposite effect is obtained. This effect implies that Germany and Japan should target to the stabilization of inflation in order to experience stabilization of output. Interest rate volatility is found to have a significant and negative effect on output volatility only in the case of the U.S. Regarding fiscal policy variations, domestic government spending volatility seems to increase output volatility only in Germany and Japan, and decrease output volatility in the U.S. Thus, a stabilization policy about government spending in Germany and Japan will lead to a decrease of domestic output volatility.

However, the impact of the U.S. government spending volatility on German and Japanese output volatility is negative. This effect stems from the negative relationship between the U.S. government spending and output volatilities, which transcends abroad with the same sign. Therefore, the adoption of a more volatile fiscal policy in the U.S. will benefit not only itself but also its trade partners (Germany and Japan) by reducing output volatility. With respect to international fluctuations, exchange rate volatility seems to decrease (increase) German (U.S.) output volatility, while net trade volatility exacerbates output volatility in all countries. Given to the aforementioned effects, it is implied that a stabilization of trade policy may lead to stabilization of output in the countries under investigation. Finally, the impact of the covariances is of high significance in the short and long run and should be taken into account in policy-making decisions.
### Appendix

#### Table 1: Heteroskedasticity tests (LM-statistic)

<table>
<thead>
<tr>
<th></th>
<th>RXR</th>
<th>GDP</th>
<th>GS</th>
<th>IR</th>
<th>INF</th>
<th>NT</th>
</tr>
</thead>
<tbody>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td><strong>ARCH LM</strong></td>
<td>6.4384 (12)</td>
<td>0.5087 (12)</td>
<td>4.2260 (12)</td>
<td>13.4724 (8)</td>
<td>11.5655 (12)</td>
<td>43.5928 (4)</td>
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<td></td>
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<td>[0.9790]</td>
<td>[0.0966]</td>
<td>[0.4812]</td>
<td>[0.0000]</td>
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<tr>
<td><strong>GLEJSER</strong></td>
<td>7.9300 (4)</td>
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<td>----</td>
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<td>[0.0942]</td>
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<td><strong>HARVEY</strong></td>
<td>----</td>
<td>14.2012 (3)</td>
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<td>----</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td></td>
<td></td>
<td>[0.0026]</td>
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<td>31.4645</td>
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<td>[0.0631]</td>
<td></td>
<td>[0.0493]</td>
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</tr>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ARCH LM</strong></td>
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<td>47.5633 (12)</td>
<td>4.7181 (12)</td>
<td>28.7504 (12)</td>
<td>6.4974 (3)</td>
<td>36.3100 (12)</td>
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<td>[0.9667]</td>
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<td>[0.0898]</td>
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<td><strong>GLEJSER</strong></td>
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<td>----</td>
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<td>[0.0674]</td>
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<tr>
<td><strong>HARVEY</strong></td>
<td>----</td>
<td>----</td>
<td>16.5237 (3)</td>
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<td>----</td>
<td>----</td>
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<td></td>
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<td></td>
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<tr>
<td><strong>U.S.A.</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>ARCH LM</strong></td>
<td>5.4829 (2)</td>
<td>86.2937 (12)</td>
<td>7.8587 (4)</td>
<td>35.0632 (12)</td>
<td>9.4231 (12)</td>
<td>87.4646 (12)</td>
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<td>[0.0969]</td>
<td>[0.0005]</td>
<td>[0.6664]</td>
<td>[0.0000]</td>
</tr>
<tr>
<td><strong>GLEJSER</strong></td>
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<td>13.6567 (3)</td>
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<td></td>
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</table>

Notes: Figures represent the value of LM-statistic (Obs*R^2). The numbers in parentheses and brackets are the lags for ARCH test and the number of independent variables used for Glejser and Harvey tests, and probability values, respectively; ---- denote that ARCH-LM test is sufficient to justify the existence of heteroskedasticity.
<table>
<thead>
<tr>
<th>Country</th>
<th>GARCH Type</th>
<th>Specification</th>
<th>Hypothesis</th>
<th>Chi-square Statistic</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
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<td>No GARCH</td>
<td>AR(2)-Asymmetric</td>
<td>$H_0 : \alpha^<em>_{11} = \ldots = \alpha^</em><em>{77} = \beta^*</em>{11} = \ldots = \beta^<em>_{77} = \delta^</em><em>1 = \ldots = \delta^*</em>{77} = 0$</td>
<td>102230.1</td>
<td>0.0000</td>
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<tr>
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<td>No Asymmetry</td>
<td>No Covariance significance</td>
<td>$H_0 : c^<em>_1 = \ldots = c^</em>_7 = c^<em>_3 = \ldots = c^</em>_7 = c^<em>_4 = \ldots = c^</em>_7 = c^*_3 = 0$</td>
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<td>0.1013</td>
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<td>AR(2)-Symmetric</td>
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</tr>
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<td>$H_0 : \alpha^<em>_{11} = \ldots = \alpha^</em><em>{66} = \beta^*</em>{11} = \ldots = \beta^<em>_{66} = \delta^</em><em>1 = \ldots = \delta^*</em>{66} = 0$</td>
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<td>23.6997</td>
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</table>

Notes: For Germany and Japan we include seven variables in BEKK models because we also take into account the U.S. government spending. Consequently, the BEKK model in the case of the U.S. appears to have one variable less (six instead of seven). Figures and numbers in brackets reflect the value of Chi-square statistic and the corresponding probability value, respectively.
### Table 3: Residual diagnostics

<table>
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<tr>
<th></th>
<th>$e_{RXR,t}$</th>
<th>$e_{GDP,t}$</th>
<th>$e_{GS,t}$</th>
<th>$e_{IR,t}$</th>
<th>$e_{INF,t}$</th>
<th>$e_{NT,t}$</th>
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<tr>
<td>$Q(12)$</td>
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<td>[0.053]</td>
<td>[0.917]</td>
<td>[0.481]</td>
<td>[0.858]</td>
<td>[0.883]</td>
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<tr>
<td>$Q^2(12)$</td>
<td>3.820</td>
<td>11.824</td>
<td>2.042</td>
<td>0.460</td>
<td>0.827</td>
<td>2.599</td>
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<tr>
<td></td>
<td>[0.986]</td>
<td>[0.460]</td>
<td>[0.999]</td>
<td>[1.000]</td>
<td>[1.000]</td>
<td>[0.998]</td>
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</table>

Notes: Probability values are in brackets. $Q(p)$ and $Q^2(p)$ are the Ljung-Box test statistic for $p$th order serial correlation for standardized residuals and squared standardized residuals, respectively. --- denote absence of results since the domestic and foreign government spending coincide for the case of the U.S.
Table 4: Short-run effects (Granger causality tests)

<table>
<thead>
<tr>
<th></th>
<th>$\sigma^2_{RXR}$</th>
<th>$\sigma^2_{GS}$</th>
<th>$\sigma^2_{IR}$</th>
<th>$\sigma^2_{INF}$</th>
<th>$\sigma^2_{NT}$</th>
<th>$\sigma^2_{GS,USA}$</th>
<th>$cov(IR,INF)$</th>
<th>$cov(GS,IR)$</th>
<th>$cov(GDP,INF)$</th>
<th>$cov(GDP,NT)$</th>
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</thead>
<tbody>
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<td><strong>Germany</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8 lags</td>
<td>-0.0150</td>
<td>0.0064</td>
<td>-0.0001</td>
<td>1.1276</td>
<td>0.0000</td>
<td>-0.0193</td>
<td>-0.0100</td>
<td>0.0010</td>
<td>-0.0269</td>
<td>0.0003</td>
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<tr>
<td></td>
<td>[0.0000]</td>
<td>[0.1136]</td>
<td>[0.7206]</td>
<td>[0.0096]</td>
<td>[0.0352]</td>
<td>[0.0038]</td>
<td>[0.0006]</td>
<td>[0.0200]</td>
<td>[0.0055]</td>
<td>[0.3551]</td>
</tr>
<tr>
<td>10 lags</td>
<td>-0.0229</td>
<td>0.0158</td>
<td>-0.0006</td>
<td>1.8313</td>
<td>0.0000</td>
<td>-0.0111</td>
<td>-0.0269</td>
<td>0.0015</td>
<td>0.0038</td>
<td>0.0002</td>
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<td>[0.1407]</td>
<td>[0.0832]</td>
<td>[0.2819]</td>
<td>[0.0256]</td>
<td>[0.0447]</td>
<td>[0.0093]</td>
<td>[0.0000]</td>
<td>[0.0000]</td>
<td>[0.0000]</td>
<td>[0.6911]</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>8 lags</td>
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<td>0.1059</td>
<td>0.0001</td>
<td>233.8844</td>
<td>0.0000</td>
<td>1.1596</td>
<td>-0.3934</td>
<td>0.0559</td>
<td>-5.4998</td>
<td>-0.0004</td>
</tr>
<tr>
<td></td>
<td>[0.7915]</td>
<td>[0.0000]</td>
<td>[0.2205]</td>
<td>[0.0013]</td>
<td>[0.0001]</td>
<td>[0.0357]</td>
<td>[0.3820]</td>
<td>[0.0060]</td>
<td>[0.0000]</td>
<td>[0.0000]</td>
</tr>
<tr>
<td>10 lags</td>
<td>-0.4137</td>
<td>0.0216</td>
<td>-0.0001</td>
<td>241.0051</td>
<td>0.0000</td>
<td>-3.2761</td>
<td>-0.2491</td>
<td>0.0575</td>
<td>-1.9772</td>
<td>-0.0002</td>
</tr>
<tr>
<td></td>
<td>[0.9870]</td>
<td>[0.0362]</td>
<td>[0.5527]</td>
<td>[0.0341]</td>
<td>[0.0035]</td>
<td>[0.0751]</td>
<td>[0.0599]</td>
<td>[0.6551]</td>
<td>[0.0024]</td>
<td>[0.0674]</td>
</tr>
<tr>
<td><strong>U.S.A.</strong></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>8 lags</td>
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<td>-0.7171</td>
<td>-0.0007</td>
<td>-6.3281</td>
<td>0.0000</td>
<td>0.2843</td>
<td>0.0399</td>
<td>0.1727</td>
<td>0.0059</td>
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<tr>
<td></td>
<td>[0.5086]</td>
<td>[0.1630]</td>
<td>[0.0990]</td>
<td>[0.2626]</td>
<td>[0.2270]</td>
<td>[---]</td>
<td>[0.4951]</td>
<td>[0.1639]</td>
<td>[0.0191]</td>
<td>[0.2911]</td>
</tr>
<tr>
<td>10 lags</td>
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<td>-0.4630</td>
<td>-0.0020</td>
<td>-3.0669</td>
<td>0.0000</td>
<td>0.3707</td>
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<tr>
<td></td>
<td>(16.0330)</td>
<td>(18.2096)</td>
<td>(23.5382)</td>
<td>(17.8760)</td>
<td>(11.8164)</td>
<td>(---)</td>
<td>(22.3234)</td>
<td>(49.9080)</td>
<td>(60.6099)</td>
<td>(24.3228)</td>
</tr>
<tr>
<td></td>
<td>[0.0987]</td>
<td>[0.0515]</td>
<td>[0.0089]</td>
<td>[0.0571]</td>
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<td>[---]</td>
<td>[0.0135]</td>
<td>[0.0000]</td>
<td>[0.0000]</td>
<td>[0.0068]</td>
</tr>
</tbody>
</table>

Notes: Figures are the sum of the lagged coefficients of the causing variable. Figures in parentheses and brackets represent the value of Chi-square statistic and the corresponding probability value, respectively. --- denote absence of results since the domestic and foreign government spending coincide for the case of the U.S.
Table 5: Long-run effects

<table>
<thead>
<tr>
<th></th>
<th>Germany</th>
<th>Japan</th>
<th>U.S.A.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_{RXR}^2$</td>
<td>negative</td>
<td>insignificant</td>
<td>negative</td>
</tr>
<tr>
<td>$\sigma_{GS}^2$</td>
<td>positive</td>
<td>positive</td>
<td>positive</td>
</tr>
<tr>
<td>$\sigma_{IR}^2$</td>
<td>insignificant</td>
<td>insignificant</td>
<td>positive</td>
</tr>
<tr>
<td>$\sigma_{INF}^2$</td>
<td>positive</td>
<td>positive</td>
<td>positive</td>
</tr>
<tr>
<td>$\sigma_{NT}^2$</td>
<td>negative</td>
<td>positive</td>
<td>insignificant</td>
</tr>
<tr>
<td>$\sigma_{GS,USA}$</td>
<td>negative</td>
<td>negative *</td>
<td>---</td>
</tr>
<tr>
<td>$cov( IR, INF )$</td>
<td>negative</td>
<td>negative</td>
<td>negative</td>
</tr>
<tr>
<td>$cov( GS, IR )$</td>
<td>positive</td>
<td>positive</td>
<td>negative</td>
</tr>
<tr>
<td>$cov( GDP, INF )$</td>
<td>negative</td>
<td>negative</td>
<td>positive *</td>
</tr>
<tr>
<td>$cov( GDP, NT )$</td>
<td>insignificant</td>
<td>positive</td>
<td>positive</td>
</tr>
</tbody>
</table>

Notes: --- denote absence of results since the domestic and foreign government spending coincide for the case of the U.S. * indicates that the result is, in principle, mixed.
References


Hayek, Friedrich, *The Road to Serfdom*, University of Chicago Press, Chicago, IL, 1944.


