# The Transmission of Shocks between Europe, Japan and the United States

**Shushanik Papanyan**

Department of Economics
University of Texas at Arlington
Arlington, TX 76019-0479

Tel: 817-272-3221
Fax: 817-272-3145
papanyan@uta.edu
http://www.uta.edu/faculty/papanyan

**Job Market Paper**
November 6, 2005

## Abstract

This paper identifies the types of shocks that affect the economies of Europe, the U.S. and Japan and the transmission path of those shocks between the countries. Identification of the origin and nature of the shocks and the transmission of those shocks between countries leads to a better understanding of international business cycle dynamics and international policy cooperation. The identification of shocks is based on the cointegrated VAR methodology. The categorization and interpretation of the shocks is based on theoretical studies on international business cycles and international policy coordination. I find that country-specific U.S permanent shocks transmit to Europe and Japan. Those shocks are approximately symmetric and, when positive, have a locomotive effect on the countries. The U.S. itself is not affected by the country-specific permanent shocks of Europe and Japan. Country-specific Europe permanent shocks transmit only to Japan and vice versa. The model identifies one symmetric transitory shock that affects all three countries and that is very persistent.

***JEL Classification:*** F42, F02, C32, E32,

***Keywords:*** transmission of shocks, international policy coordination, international business cycles, locomotive effect, cointegrated VAR, G3.

I thank William Crowder, Chris Murray, David Papell and the seminar participants at the University of Texas at Arlington for their helpful comments and suggestions.

## 1. INTRODUCTION

The fluctuations that occur within a country's economy today can not be completely attributed to the shocks arising within that country. The increasing degree of openness of modern economies makes nations dependent upon other countries' business cycle fluctuations as well. While the transmission of business cycles from one country to another is an established fact, the question remains as to which types of shocks contribute to the common economic fluctuations between the countries.

The objective of this paper is to identify the types of shocks that affect countries and the transmission path of those shocks from one country to another. Identification of the origin and nature of the shocks and the transmission of those shocks between countries enables us to better understand the dynamics of international business cycles as well as to coordinate international policy more effectively. In this paper the identification of shocks is based on both the statistical model and the data-generating process of the underlying time series. The categorization and interpretation of the shocks is based on two streams of economic literature: theoretical studies of international business cycles and of international policy coordination.

Doyle and Faust (2002) state that international transmission of G7 business cycles are attributed to two kinds of shocks: global shocks that are common to all the nations and country-specific shocks that transmit from one country to another. In this regard, the G7/G8 summits of today began as the "Library Group" in 1973 with the objectives of increasing international economic policy cooperation (abandonment of fixed exchange rates) and of guarding against negative global shocks. Economic cooperation later evolved into policy coordination,[1] with specific actions for countries' monetary and fiscal policies.

In order to learn more about the ability of summits to soothe the global shocks and stimulate economic growth, researchers have produced a stream of literature on international policy coordination that accomplishes two things. First, it addresses the effect of monetary and fiscal policy coordination on the countries' current account balances, exchange rate fluctuations, inflation, and growth rates. Second, it estimates the

---

[1] Economic policy cooperation refers to the exchange of information to minimize the adverse spillovers of economic policy actions, while economic coordination refers to cooperative economic policy action.

effectiveness of coordinated policy making. Particular interest is devoted to the G3 group, which is Europe,[2] the U.S. and Japan, since they are the most influential players in macroeconomic policy coordination (Christodoulakis et al. (1994), Christodoulakis et al. (1996), Clarida et al. (1998) and Clarida and Prendergast (1999), Caporale et al. (2003)).

The lesson learned from combining economic models on international policy coordination with real-world experience is that the effectiveness of coordinating and implementing macroeconomic policy depends on the type of exogenous shocks that economies experience (Meyer et al. (2004)). Theoretical analyses of policy coordination and stabilization conflicts differentiate between three types of shocks: symmetric shocks, asymmetric shocks and country-specific shocks. Symmetric shocks affect countries in exactly the same way, while asymmetric shocks have an opposite effect on countries. The country-specific shocks are defined as purely idiosyncratic shocks which affect only one country and do not transmit to the other countries. In the case of the transmission of a country-specific shock to the other countries, it is categorized as symmetric or asymmetric depending on the effect it has on the other countries.

The importance of both global shocks and country-specific shocks, as well as the transmission mechanism of country specific shocks, is also emphasized in international business cycle models (Ahmed et al. (1993), Backus et al. (1992) and Glick and Rogoff (1995)). An important fact accentuated by business cycle theory is that country-specific and common shocks should be differentiated according to their effect on the economy. Within the theoretical framework of business cycles which examines shocks that are important in disturbing the economy, two types of shocks are commonly accepted: monetary shocks and technology shocks. Monetary shocks, which are assumed to be neutral in neoclassical theory, can indeed have lasting effects on the economies. This point is proven by the slow speed of adjustment of real exchange rates to purchasing power parity. In this regard Basu and Taylor (1999) insist that a "good business cycle model should be able to deliver both short-run monetary non-neutrality and long-run reversion to neutrality." Technology/productivity shocks are studied within real business cycle models. In real business cycle models the long-run behavior of output is

---

[2] This study uses an aggregate of G7 euro area countries Germany, France, and Italy as a proxy for Europe. Other studies also include the United Kingdom (Elliott and Fatas (1996)). Pre-Euro studies refer to Germany, the U.S. and Japan as the G3.

determined by supply-side exogenous shocks to technology. Since technical progress is modeled as a random-walk process, the shock to technology has a permanent effect on the countries' growth path.

Consequently, this paper categorizes shocks affecting developed nations as either global or country-specific. Based on the synthesis of international business cycle and policy coordination models, each of those shocks can be categorized into the following two groups. Shocks can be a supply-side technology/productivity shock, which has a permanent effect on the economy, or a monetary shock, in accordance with Basu and Taylor (1999), that has a short-run effect on the countries but which dissipates in the long-run. In the spirit of Nelson and Plosser (1982), this study refers to those shocks as real and nominal shocks that have permanent and transitory effects on economic fluctuations, respectively. In addition, shocks can have symmetric or asymmetric effect on the countries, depending on how countries react to external shocks. In this regard, positive country-specific shocks that have an approximately symmetric effect on the other countries can have a "locomotive effect" on the rest of the system. The locomotive effect refers to the instance when a positive country-specific shock is transmitted to another country. Thus, increased economic activity in one country stimulates positive economic activity in another country.

Following the representative group of literature on international policy coordination, this study focuses on the G3 countries. Accordingly, the identification of the shocks described above is achieved via an empirical investigation of time series properties of the real output of Europe, the U.S. and Japan. The econometric methodology applied follows Juselius (1998) example, where the important information sources for the empirical identification of types of shocks are economic theory and the time series properties of the data.[3] Figure 1 summarizes the econometric methodology of the paper. It is an application of the cointegrated Vector Autoregressive (VAR) methodology. Under the assumption that the real outputs of the G3 countries are first order integrated, a cointegrated VAR model makes it possible to identify permanent and

---

[3] Juselius (1998) relies on three sources of information – (1) economic theory, (2) the institutions of the political economy, and (3) the time series properties of the data. This paper is not directly examining the institutions of the political economy. Nevertheless, it incorporates political interventions and extraordinary events in the data analysis section.

transitory shocks that affect countries, the origins of those shocks, and the transmission of the shock from one country to another. The permanent and transitory shocks identified in this paper are viewed as real and nominal shocks, respectively. In addition, the cointegrated VAR model identifies the empirically stationary long-run steady-state relation between the countries and the speed of adjustment towards that relation.

The first important result of this study is the finding that the permanent shocks originating in the U.S. have an approximately symmetric effect on the rest of the system, while the U.S. itself is not affected by permanent shocks in Europe or Japan. In the specific case when the U.S. is affected by a positive productivity shock, the U.S. has a locomotive effect on the rest of the system. This result is consistent with Elliot and Fatas (1996) who investigate the transmission of productivity shocks between Europe, Japan and the U.S. and the contribution of those shocks to the output fluctuations of the countries. They find that positive cross-country comovements are due to the transmission of productivity shocks originating in the U.S., while European and Japanese productivity shocks do not have a significant effect on other countries' economic fluctuations.

The finding that U.S. country-specific permanent shocks are the major driving force behind international business cycles of the economic system examined is also supported by Ahmed et al. (1993). Ahmed et al. (1993) estimate a two-country model of international real business cycles where the U.S. is one of the countries and the second is the aggregate of five G7 countries (excluding Italy). They find that the supply-shocks originating in the U.S. are important in generating international business cycles.

The second important result of this study is the finding that there exists only one long-run stationary relation between Europe, the U.S. and Japan. Thus, these countries share one common steady-state relation. This result translates into one transitory shock, which can be labeled as a nominal shock that simultaneously affects all three countries. Therefore this transitory shock is considered to be symmetric. The transitory shock to the system is very persistent and, as is shown in the paper, will take approximately 20 years to die out.

The existence of a symmetric nominal shock in the system with one long-run relation that pulls countries to the steady-state is a positive result in terms of the achievements of international economic policy cooperation between the G3. This result is supported by Meyer et al. (2004) who point out that even though the current monetary authorities are more reluctant to commit to concrete, pre-announced actions of monetary policy coordination, there is an informal consensus on the direction of policy and on the appropriate responses to shocks. They suggest that in the case of monetary policy, continuous information exchange between government officials can lead to an implicit form of policy coordination. On the other hand, the persistence of the transitory shock is evidence of money non-neutrality and existing rigidities in the economies.

The final result of the paper is that the permanent shocks that originate in Europe are transmitted only to Japan and vice versa. Also the productivity shocks to Europe or Japan do not have a significant effect on the opposite country's growth rate. This result highlights the importance of quantitative measures in understanding the transmission mechanism of permanent shocks. In the 1978 Bonn summit, for example, leaders of France, Germany and Japan committed to expansionary fiscal policy packages in order to stimulate their economies and to have a locomotive effect on the other G7 countries' growth rates, while the U.S. promised to deregulate domestic oil prices. These economic policy commitments contributed to a spurt of global inflation and thus the Bonn summit is viewed as an example of a failure in international policy coordination. Policies promoted by the Bonn summit contradict the results of this study as well as the conclusions reached by other empirical investigations on the propagation of shocks in G7 countries. According to the results of this paper, a change in the growth rate of Europe or Japan will not have a significant effect on the other countries and will not spread to the U.S. at all.

The rest of this paper is organized as follows. Section 2 presents general background on the cointegrated VAR model, identification of permanent and transitory shocks within the cointegrated VAR model, and a determination of the cointegration rank in the system. Section 3 presents the properties of the time series examined and finds the appropriate VAR model that best fits the examined data. Section 4 discusses the empirical results. Section 5 concludes.

## 2. MODEL SPECIFICATION AND DETERMINATION OF COINTEGRATION RANK[4]

The general form of the $k$ th order vector autoregressive model, VAR(k) is:

$$x_{it} = \Pi_1 x_{it-1} + ... + \Pi_k x_{it-k} + \Phi D_t + \varepsilon_{it}, \quad t = 1,...,T \qquad (1)$$

where $x_{it} = x_{1t}, x_{2t}, ..., x_{pt}$ are the variables of interest, $D_t$ is the deterministic term, which contains permanent impulse dummies and the constant of the model. $\Pi_1,...,\Pi_k,\Phi$ are parameters of the model, $\varepsilon_{it} \sim iidN(0,\Omega)$ and $k$ is the lag length. The corresponding vector error correction model (ECM) is:

$$\Delta x_{it} = \Gamma_1^{(m)} \Delta x_{pt-1} + \Gamma_2^{(m)} \Delta x_{pt-2} + ... + \Gamma_{k-1}^{(m)} \Delta x_{pt-k+1} + \Pi x_{t-m} + \Phi D_t + \varepsilon_{it} \qquad (2)$$

where $\Pi = -I + \sum_{j=1}^{k} \Pi_j$, $m$ is an integer between 1 and $k$. The $\Pi$ matrix summarizes the long-run effects in the system and stays unchanged regardless of the chosen lag $m$. $\Gamma_i^{(m)}$ for $i = 1,...,k-1$ contains the short-run effects of the model and depends on the chosen lag $m$ within the model.

$\Pi = \alpha\beta'$ decomposition allows us to identify the adjustment mechanism in the system examined. Assuming that $r$ is the cointegration rank and $p$ is the number of variables, $\beta'$ is described by an $r \times p$ matrix, where $\beta' x_{it}$ is the deviation of each variable $i$ from the steady state of the system, and $\alpha$ is a $p \times r$ matrix that shows the speed of adjustment to the steady state for each of the variables in the system. $\beta'$ represents the common long-run relations in the system with corresponding $\alpha$ factor loadings (Figure 3).

According to the Granger representation theorem stated in Engle and Granger (1987) and Johansen (1991) under the assumption that the variables are integrated of first order, $x_{it} \sim I(1)$, and $\Delta x_{it}$, $\beta' x_{it}$ have stationary and invertible vector autoregressive moving average representation. The ECM $\Delta x_{it} = \alpha\beta' x_{it-1} + \sum_j^{k-1} \Gamma_j \Delta x_{it-j} + \Phi D_t + \varepsilon_{it}$ can be presented in its moving average form as follows:

---

[4] This section relies on Juselius (2005) and Søren Johansen's lecture notes for summer school on cointegrated VAR models.

$$x_{it} = C\sum_{s=1}^{t}\varepsilon_{is} + C(L)\varepsilon_{it} + \tau(t) + A \qquad (3)$$

where $C = \beta_\perp(\alpha_\perp^{'}\Gamma\beta_\perp)^{-1}\alpha_\perp^{'}$, $\Gamma = I_p - \sum_{j=1}^{k-1}\Gamma_j$, $\tau(t) = C\Phi\sum_{s=1}^{t}D_s + C(L)\Phi D_t$, the coefficients of $C(L)$ are given by $\Delta C_i = \Pi C_{i-1} + \sum_{j=1}^{k-1}\Gamma_j\Delta C_{i-j}$ for $i = 1,2,...,$ and $A$ depends on the initial values of $x_{it}$. The Granger representation theorem presents a trend-cycle decomposition of cointegrated VAR. $\alpha_\perp^{'}\sum_{s=1}^{t}\varepsilon_{is}$ are common stochastic trends of the model corresponding to $\tilde{\beta}_\perp = \beta_\perp(\alpha_\perp^{'}\Gamma\beta_\perp)^{-1}$ factor loadings and $C(L)\varepsilon_{it}$ is the stationary process, or cycle. The number of common trends is equal to $p - r$.

$\alpha_\perp^{'}\sum_{s=1}^{t}\varepsilon_{is}$, the common trends, derived from the moving average representation of the model, are the driving forces of the system that push the process along the attractor set. At the same time, the process is pulled towards the attractor set by the adjustment coefficients of the autoregressive representation of the model. Figure 2 presents an illustration of pushing and pulling forces in a two dimensional system $x_{it} = (x_{1t}, x_{2t})$ along the steady-state position. Assuming that the steady-state corresponds to a $\beta^{'} = [1,-1]$ cointegration relation, the attractor set $\beta_\perp = [1,1]$ will correspond to a $45^\circ$ degree line along which $x_{1t} = x_{2t}$ and to a system in steady-state.

The reduced model of ECM is derived by application of the Frisch-Waugh theorem. To derive the reduced model, the equation (2) is written in the more compact form:

$$Z_{0t} = \alpha\beta^{'}Z_{1t} + \Psi Z_{2t} + \varepsilon_{it} \qquad (4)$$

where $Z_{0t}, Z_{1t}, Z_{2t}$ and $\Psi$ are defined as:

$$Z_{0t} = \Delta x_{it}$$
$$Z_{1t} = x_{it-1}$$
$$Z_{2t} = [\Delta x_{it-1}, \Delta x_{it-2}, ..., \Delta x_{it-k+1}, D_t]$$
$$\Psi = [\Gamma_1, \Gamma_2, ..., \Gamma_{k-1}, \Phi]$$

Then, applying Frisch-Waugh theorem to (4), the reduced form (5) is obtained:

$$R_{0t} = \alpha\beta^{'}R_{1t} + R_{\varepsilon t} \qquad (5)$$

where $R_{0t}$ and $R_{1t}$ are defined by the auxiliary regressions:

$$Z_{0t} = \hat{B}_1' Z_{2t} + R_{0t}$$

$$Z_{1t} = \hat{B}_2' Z_{2t} + R_{1t}$$

$\hat{B}_1' = M_{02}M_{22}^{-1}$, $\hat{B}_2' = M_{12}M_{22}^{-1}$ are OLS estimates, $M_{ij} = \Sigma_t (Z_{it}Z_{jt}')/T$, $p\lim_{T\to\infty} M_{jj} = \Sigma$, and $R_{\varepsilon t}$ is the error term. The reduced form (5) is referred to as the concentrated model of cointegrated VAR because it concentrates out the short-run transitory effects and results in a more apparent long-run adjustment model.

The existence of cointegration (Johansen LR trace test, Johansen (1988, 1991, 1994)) is based on the concentrated model (5). It tests the null of $p - r^*$ unit root processes in the model against the alternative of $r^* = p$, corresponding to no unit roots and stationary $x_t$ $((H_{r^*} / H_p))$. The trace test has a nested character:

$$H_0 \subset H_1 \subset \ldots \subset H_{r^*} \subset \ldots \subset H_p .$$

It starts with the most restrictive case of having no cointegration relations $(H_{r=0} / H_p)$, thereby having the maximum number of unit roots, and works its way down to having no unit roots $(H_{r=p} / H_p)$. The LR test is:

$$-2\ln LR(H_r / H_p) = -T\sum_{i=r+1}^{p} \ln(1 - \hat{\lambda}_i)$$

where $\lambda_i$s are the eigenvalues of the system defined as $\left|\lambda S_{11} - S_{10}S_{01}^{-1}S_{01}\right| = 0$ for $\hat{\lambda}_1 > \hat{\lambda}_2 > \ldots > \hat{\lambda}_p$. The likelihood values for $H_r$ and $H_p$ are given by:

$$L_{\max}^{-2/T}(H_r) = |S_{00}|\prod_{i=1}^{r}(1 - \hat{\lambda}_i)$$

$$L_{\max}^{-2/T}(H_p) = |S_{00}|\prod_{i=1}^{p}(1 - \hat{\lambda}_i)$$

and

$$S_{ij} = T^{-1}\sum_{t=1}^{T} R_{it}R_{jt}' .$$

$\hat{\lambda}_1 = 0$ corresponds to zero cointegration relations in the model. The unit root corresponds to zero eigenvalues $\hat{\lambda}_i$.

It is important to note that the trace test has size and power distortions, in particular for short time series and for near unit root processes. To correct for the size of the test, the small sample Barlett correction developed by Johansen (2002) can be applied. However, it does not solve the power problem. Juselius (2005) mentions that there are cases when, for hypotheses that are close to the unit circle, the size of the test and the power of the relevant alternative are almost of the same magnitude. Thus, Juselius (2005) suggests using additional information to determine the cointegration rank, such as recursive graphs of trace statistic, roots of the companion matrix, and t-values of the $\alpha$ coefficients. Recursive graphs of trace statistics are calculated by $-T_j \ln(1-\lambda_i)$, $j = T_1,...,T$. They will grow linearly for all $i = 1,...r$ where $\lambda_i \neq 0$ and will stay constant for $i = r+1,..., p$. The largest characteristic root of the companion matrix will be close to the unit circle if the $r^{th}+1$ cointegrating vector is nonstationary and is incorrectly included in the model. Similarly, we will not gain much information from including the $r^{th}+1$ cointegrating vector if the t-values corresponding to the vector $\alpha$ coefficients are not significant.

## 3. DATA ANALYSIS WITHIN THE VAR MODEL: MISSPECIFICATION TESTS

The data examined in this paper consist of quarterly real GDP for the U.S., Japan and Europe, which is the aggregate of G7 euro area countries France, Germany, and Italy. The period covered is from 1970:1 to 2004:3. The series are seasonally adjusted, and are in 2000 dollars.

Based on the standard deviations of the time series, there are several outliers in the time series, which correspond to extraordinary large shocks due to economic interventions or changes in the economy's regime, with delayed dynamic effect in the data. Those outliers are identified as standardized residuals larger than $(1-0.025)^{1/T}$, where T is the number of observations in each series. In this case T is equal to 139 and $(1-0.025)^{1/T} = 3.56$

Estimation of the VAR model is based on the assumption that the variables' residuals follow a white noise process. Extraordinarily large shocks that correspond to an economic reform or intervention cause a violation of the normality assumption. The deviation from the normality assumption leads to incorrect statistical inferences. Thus it is important to identify the dates of such shocks and to correct them with unrestricted permanent impulse dummies, where each of the impulse dummies is of the form $[0 \quad \ldots \quad 0 \quad 1 \quad 0 \quad \ldots \quad 0]$.

Prior to correcting for outliers, the VAR(2) model is estimated, and several specification tests are performed to check for residual autocorrelation and normality. The estimated VAR(2) model contains an unrestricted mean, which allows for a linear trend in the data but not for one in the cointegrated VAR system. The number of variables in the model is $p = 3$. $x_{it}^{'} = [x_{1t} \quad x_{2t} \quad x_{3t}]$ correspond to the natural logarithms of real GDP series of Europe, the U.S. and Japan. The GDP series are assumed to follow a random walk with drift.

The test results are presented in Table 1a. The LM$_1$ and LM$_4$ test of $\varepsilon_{it}$ autocorrelation, with $\varepsilon_{it-1}$ and $\varepsilon_{it-4}$ respectively, test the null of no autocorrelation. The LM-test is calculated using a Wilks' ratio test with a small sample correction (Anderson (1984)). It is asymptotically distributed $\chi^2$ with $p^2$ degrees of freedom.

$$LM(j) = -\left(T - p(k+1) - \frac{1}{2}\right)\ln\left(\frac{\left|\tilde{\Omega}(j)\right|}{\left|\hat{\Omega}\right|}\right)$$

Based on the result of the LM$_1$ and LM$_4$ tests, we reject autocorrelation in the first and fourth lags of residuals. The multivariate test for normality is based on Doornik and Hansen (1994). It is distributed $\chi^2$ with $2p$ degrees of freedom. The null of the test is normality and it is rejected with a zero p-value. The trace correlation is a joint measure of explained variation in the VAR model and is equal to $0.12$.

$$Trace\ correlation = 1 - trace(\hat{\Omega} Var(x_t)^{-1}) / p$$

The next section of Table 1a presents univariate properties of the time series. Residual heteroskedasticity (ARCH) test statistics are calculated as follows:

$$(T-k)\times R^2$$

where $R^2$ is from the auxiliary regression $\overset{\wedge}{\varepsilon}_{it}^{2} = \gamma_0 + \sum_{j=1}^{k} \gamma_j \overset{\wedge}{\varepsilon}_{it-j}^{2} + u_{it}$ and $k$ is the number of lags. The univariate Jarque-Bera test for normality is also calculated:

$$\frac{T(skewness)^2}{6} + \frac{T(kurtosis-3)^2}{24}$$

Both tests are asymptotically distributed $\chi^2$ with $2$ degrees of freedom. Under the null of the Jarque-Bera test, the errors are normally distributed:

$$\left( \overset{\wedge}{\varepsilon}_{it}^{2} / \overset{\wedge}{\sigma}_{i} \right)^{3} \overset{a}{\sim} N(0,6)\,,\ \left( \overset{\wedge}{\varepsilon}_{it}^{2} / \overset{\wedge}{\sigma}_{i} \right)^{4} \overset{a}{\sim} N(3,24)$$

Based on the univariate and multivariate residual analyses, there are significant deviations from the normal distribution in skewness and/or kurtosis for all 3 time series. The ARCH test failed to reject the null of no residual heteroskedasticity for all the series. The null of normality of each of the time series is rejected.

Thus several dummy variables have to be introduced to correct for innovative outliers existing in those series. Based on VAR(2) standard residuals output, the following outliers $\left( \left| \overset{\wedge}{\varepsilon}_{it} \right| > 3.56\, \overset{\wedge}{\sigma}_{\varepsilon} \right)$ were identified in the time series of G7 countries: Europe 1991:1(standardized residual = 7.18), corresponding to German reunification; the U.S. 1978:2 (standardized residual = 3.76) and Japan 1974:1 (standardized residual = -5.21), corresponding to the first and second oil shocks.

Failure to account for the extraordinary shocks in the system can also cause parameter non-constancy. Figure 3a illustrates the recursively calculated loglikelihood function of the model that does not account for any of the above identified outliers. The loglikelihood function sharply drops below the confidence bound at the first quarter of 1991. This is obviously caused by the by the 1991 reforms in Germany.

Figure 3b illustrates the recursively estimated loglikelihood function for the VAR(2) that incorporates following permanent impulse dummy variables identified in the data:

$$D_t^{'} = \left[ D_{p741} \quad D_{p782} \quad D_{p911} \right].$$

Table 1b presents a residual analysis of VAR(2) that incorporates the $D_t$ regressor. The loglikelihood function is within its 95% confidence band through out the estimated period. According to the LM$_1$ and LM$_4$ tests, the null of no autocorrelation is accepted. The LM test of normality of the VAR model is rejected. There is substantial skewness and/or kurtosis discrepancy from the normal distribution for both Europe and the U.S. The univariate normality test rejects the normal distribution in Europe and in the U.S. series. According to the ARCH test we are unable to reject heteroskedasticity in the residuals of Europe and the U.S. These problems can potentially arise when there are several standardized residuals with an absolute value close to *3.56*, which can create a heteroskedastic effect. The low p-value of multivariate LM normality test in the system can be attributed to the outcome of the heteroskedasticity test. Nonetheless, the cointegration results are robust to small ARCH and excess kurtosis (Gonzalo, 1994).

The next important step is to determine the correct lag length for the VAR model. For this purpose the Schwartz, Akaike and Hannan-Quinn information criteria were conducted. The tests are defined by:

$$SIC = \ln\left|\hat{\Omega}^k\right| + (p^2 k)\frac{\ln T}{T}$$

$$AIC = \ln\left|\hat{\Omega}^k\right| + (p^2 k)\frac{2}{T}$$

$$HQ = \ln\left|\hat{\Omega}^k\right| + (p^2 k)\frac{2\ln\ln T}{T}$$

Lag selection tests along with $\ln\left|\hat{\Omega}\right| = -2/T(\ln L_{\max})$ are reported in Table 2. In the calculation of SIC, AIC and HQ, the number of observations is kept constant for all lags. The Schwartz and Hannan-Quinn criteria suggest lag 1, while AIC suggests lag 2. However, based on the p-values of the LM$_1$ test, lag 2 is a better choice to model the time series of interest.

## 4. IDENTIFICATION OF LONG-RUN STRUCTURE: EMPIRICAL RESULTS

According to the residual analysis, misspecification tests and the lag determination performed in the previous section the model specification estimated is VAR(2) with three unrestricted dummies and an unrestricted constant:

$$x_{it} = \Pi_1 x_{it-1} + \Pi_2 x_{it-2} + \Phi D_t + \varepsilon_{it}\,, \quad t = 1,...,T$$

It corresponds to VECM:

$$\Delta x_{it} = \Gamma_1^m \Delta x_{pt-1} + \Pi x_{t-m} + \Phi D_t + \varepsilon_{it}\,,^{5} \ \varepsilon_{it} \sim iidN(0,\Omega)$$

The cointegration rank is determined according to the results of the LR trace test presented in Table 3. The trace test statistics fail to reject the hypotheses of $p - r = 2$ common trends and $r = 1$ cointegration relation with a very high p-value of 0.92. This result is also supported by inspection of the roots of the companion matrix (Table 4), which reveals that indeed the lowest root corresponds to $r = 1$ and equals to $0.94$, which indicates a stationary yet slow equilibrium adjusting processes. Figure 4 illustrates recursively estimated traces. Based on the trace of the concentrated model, there is 1 linearly growing trace. Additionally, Ho and Sørensen (1996) illustrate that the Johansen (1991) LR test should be used with considerable care for small sample size, high dimension systems with $p \geq 4$, while in this study the number of variables is 3. Thus, there is a clear indication of one cointegration relation and two common trends in the model. Therefore, this system of three countries contains one long-run steady state relation and two common trends. Accordingly, the countries are affected by one transitory shock and two permanent shocks.

Since information on the long-run steady-state relation of the model is contained in the $\beta$ cointegrating vector, the long-run identification problem translates into the identification of a $\beta$ vector. This is achieved by imposing testable restrictions on the $\beta$ vector and then comparing the significance of the tests. In order for the restrictions on $\beta$ to be testable, the restrictions should be over-identifying, which means that the

---

[5] Note that for VAR(2), the only choices for $m$ are 1 or 2. In this regard, $\Gamma_1^{(1)} = -\Pi_2$ or $\Gamma_1^{(2)} = (I - \Pi_1)$, while matrix $\Pi$ remains unchanged.

number of the restrictions on each vector $\beta_i$ should be greater than $r-1$. Long-run restrictions on $\beta$ are tested with the LR test. The technical derivation of the test procedures is shown in Johansen and Juselius (1992).

Table 5 presents the results from different restrictions posed on the $\beta$ vector. In the "0-1" notation of Table 5, "0" signifies a variable whose coefficient in the $\beta$ vector is restricted to zero and "1" signifies a variable in the vector that is cointegrated. For the purpose of simplicity, the coefficients of the restricted vectors are suppressed. A cointegration relation between any pair of countries within the system is rejected. Thus the cointegration relation is between the three countries: Europe, the U.S. and Japan. Figure 5 illustrates the cointegration relation between the three countries. It is seen that the cycle along the steady-state is of very long-run perspective.

Since the cointegration relation is between the entire system: Europe, the U.S. and Japan, the transitory/nominal shock affects all three countries and is identified as a symmetric shock. Figure 6a presents the responses of the outputs of Europe, the U.S. and Japan to the common transitory shock. The effect of the transitory shock is below 1% for all three countries. It has immediate effect on Europe and Japan, and up to a year lagged effect on the U.S. However the transitory shock is very persistent. It is apparent from the figures that it will take 17 to 20 years for the transitory shock to dissipate.

Equally important is the identification of a structure that best characterizes the $\alpha$ matrix, since the structure of common trends is defined by $\alpha_{\perp}^{'}\sum_{s=1}^{t}\varepsilon_{is}$ and therefore depends on $\alpha$. There is one important property of $\alpha$ that should be tested for: weak exogeneity. The weak exogeneity condition is tested for by the LR test described in Johansen and Juselius (1990). It is the hypothesis of a zero row restriction in $\alpha$ that tests whether the cumulative residuals of the variable corresponding to the zero row are a common driving trend in the system. If the hypothesis is accepted, that variable affects the long-run stochastic path of the other variables while at the same time is not affected by them.

Part two of Table 5 illustrates results from restrictions imposed on the $\alpha$ matrix. We fail to reject the hypotheses of the U.S. as a weakly exogenous variable with a p-value equal to 0.91. Consequently, the cumulative residuals of the U.S. are a common driving trend for the three countries. The shocks to the U.S. have a permanent influence on the other countries while the U.S. itself is not influenced by shocks to those countries. Since permanent shocks that originate in the U.S. affect the remaining countries in the model in approximately the same way, they are approximately symmetric. In case of a positive permanent shock, the U.S. has a locomotive effect. What is the implication of this result on the model?

Table 6 presents the $\Pi$ matrix and $\alpha, \beta$ vectors according to the restriction that the U.S. is a weakly exogenous variable in the system. The VECM representation of the system is:[6]

$$\begin{bmatrix} \Delta \text{Real GDP}_{\text{Europe}} \\ \Delta \text{Real GDP}_{\text{U.S.}} \\ \Delta \text{Real GDP}_{\text{Japan}} \end{bmatrix} = \begin{bmatrix} -0.8 \\ 0 \\ -0.14 \end{bmatrix} \left[ \text{Real GDP}_{\text{Europe}} + (-0.5)\text{Real GDP}_{\text{U.S.}} + (-0.2)\text{Real GDP}_{\text{Japan}} \right] + \mu + \varepsilon$$

Since the U.S. is identified as a weakly exogenous variable in the system, the equilibrium adjustment mechanism is purely between the remaining two countries, Europe and Japan, while for example the equilibrium level of Europe's output is:

$$\text{Real GDP}^{*}{}_{\text{Europe}} = 0.5\text{Real GDP}_{\text{U.S.}} + 0.2\text{Real GDP}_{\text{Japan}}$$

Figure 6b presents the responses of the outputs of Europe, the U.S. and Japan to the permanent shock in the U.S. A 1% positive permanent shock in U.S. will permanently increase the output of Japan by 1.2% and the output of Europe by 0.8%. The U.S. permanent shock will immediately affect Japan but it will take a year to have a permanent effect of the same size on Europe. According to the impulse response functions, the spread of the U.S. permanent shock will be faster in Japan than in Europe.

Table 7 illustrates the $\alpha_{\perp}, \tilde{\beta}_{\perp}, C$ matrices according to the restriction that the U.S. is weakly exogenous. According to $\alpha_{\perp}$ the second trend is driven by the cumulative residuals of Europe and Japan. Thus, Europe and Japan transmit permanent shocks between each other and are influenced by shocks from the U.S. Figure 6c presents the responses of the output of Europe, the U.S. and Japan to the 1% shock to the second

---

[6] For simplicity it is assumed that $\Gamma_1 = 0$ and the superscript *t* is suppressed.

common trend.  A 1% shock to the second trend will have a very insignificant (0.1%) negative transitory effect on the U.S. output.  However, in the long-run it will permanently increase the output of Japan by 1.6% and the output of Europe by only 0.4%.

Figure 7 illustrates 2 common trends of the system.  The U.S common trend plays the dominant role of the driving force in the system.  Over the examined 35 years it grew 106%.  In contrast the Europe-Japan trend is relatively flat and grew only 13%.

## 5. CONCLUSION

The objective of this paper is to identify the types of shocks that affect the G3 group as well as the transmission mechanism of those shocks from one country to another.  This objective is achieved through the application of cointegrated VAR methodology.  This methodology allows the identification of the origins and types of common shocks, their transmission mechanism and their impact on the other countries. The empirical identification of the types of shocks affecting the most influential group of the countries in the world and the understanding of their transmission mechanism is important for determining the effectiveness of international policy coordination as well as for understanding the dynamics of international business cycles.

Based on the statistical model estimated, the system of three countries – Europe, the U.S. and Japan – contains two common trends and one cointegration relation.  The U.S. is the driving force behind the first trend.  The second trend is a combination of cumulative residuals of Europe and Japan.  The cointegration relation is between all three countries.

Since the U.S. is the driving force behind one of the common trends, the permanent shocks to U.S. output transmit to Europe and Japan. Even though real shocks originating in the U.S. spread faster and have a slightly larger affect on Japan than on Europe, they can be considered to be approximately symmetric.  The U.S. itself is not affected by permanent shocks from Europe and/or Japan.  This result is important for policy coordination purposes.  The Meyer et al. (2004) summary on today’s international policy coordination issues points out that classification of productivity shocks is one of the uncertain areas for scholars. In the case when the shock is purely country-specific (with no transmission to the other countries), it can explain the divergence between the growth rates of G3 countries. However, if the productivity shock is symmetric then it will have positive externalities for the other countries. I find that the productivity shock is both symmetric and country-specific. The finding that the main driving force behind the G3 group is a country-specific productivity shock originating in the U.S., which also has a symmetric impact on the rest of the countries, implies that increased productivity in the U.S. due to borrowing abroad has a locomotive effect on the rest of the countries. Therefore, the U.S. current account imbalance, which leads to a productivity increase, is beneficial to the rest of the G3 group. Bruno (1997) finds that capital movements are a key parameter in international business cycle transmission. Thus the transmission of country-specific technological shocks to other countries – creating a locomotive effect – is possible when investment goods are imperfect substitutes. This suggests a possible imperfect substitution between the U.S. and Europe and between the U.S. and Japan.

Permanent shocks originating in Europe affect only Japan and vice versa. The Europe-Japan common trend is relatively flat. The existence of a second common trend between Europe and Japan that has a weak growth rate can be a possible explanation for why the business cycle of G3 is diverged and for why the growth rates of Europe and Japan are weaker than the growth rate of the U.S.

Since there is one stationary long-run relation that integrates all three countries, they have the same adjustment mechanism to the steady-state. Accordingly, there is one symmetric transitory shock that affects all three countries. The transitory shock is persistent and takes up to 20 years to die off. The persistence of the transitory shock is evidence of existing economic rigidities and money non-neutrality. The existence of a single steady-state relation in the system means that there is a consensus on the direction of policy and on the appropriate responses to shocks between G3 countries. This result is supported by Meyer et al. (2004) who point out that although the current monetary authorities are more reluctant to commit to concrete, pre-announced actions of monetary policy coordination, there is an informal consensus on the direction of policy and on the appropriate responses to shocks. They suggest that in the case of monetary policy, continuous information exchange between government officials can lead to an implicit form of policy coordination. The finding of a symmetric nominal shock supports the policy cooperation efforts of summits, since the models on policy coordination show that a common monetary response is optimal in the case of symmetric shocks.

## REFERENCES

Ahmed, Shaghil; Ickes, Barry W.; Wang, Ping and Yoo, Byung Sam. “International Business Cycles.” *American Economic Review*, June 1993, 83(3), pp. 335-59.

Anderson Theodore W. *An Introduction to Multivariate Statistical Analysis*. New York: John Wiley & Sons, 1984.

Backus, David A.; Kehoe, Patrick J. and Kydland, Finn E. “International Real Business Cycles.” *Journal of Political Economy*, August 1992, 100(4), pp. 745-75.

Basu, Susanto and Taylor, Alan M. “Business Cycles in International Historical Perspective.” *Journal of Economic Perspectives*, Spring 1999, 13(2), pp. 45-68.

Bruno, Catherine. “International Capital Movements and the Locomotive Effect,” *Economics Letters*, November 1997, 56(3), pp. 311-6.

Caporale, Guglielmo M.; Chui, Michael; Hall, Stephen G. and Henry, Brian. “Evaluating the Gains to Cooperation in the G-3.” *Empirica*, December 2003, 30(4), pp. 337-56

Christodoulakis, Nicos; Kemball-Cook, David and Levine, Paul. “Robust Rules for G3 Macroeconomic Policy Coordination.” *Economic Modeling*, January 1994, 11(1), pp. 87-104.

Christodoulakis, Nicos; Garratt, Anthony and Currie David. “Target Zones and Alternative Proposals for G3 Policy Coordination: An Empirical Evaluation Using GEM.” *Journal of Macroeconomics*, Winter 1996, 18(1), pp.49-68.

Clarida, Richard; Gali, Jordi and Gertler, Mark. “Monetary Policy Rules in Practice Some International Evidence.” *European Economic Review*, June 1998, 42(6), pp. 1033-67.

Clarida, Richard and Prendergast, Joe. “Recent G3 Current Account Imbalances: How Important are Structural Factors?” National Bureau of Economic Research (Cambridge, MA) Working Paper No. 6935, February 1999.

Doornik, Jurgen A. and Hansen, Henrik. “An Omnibus Test for Univariate and Multivariate Normality” Nuffield College, Oxford working papers W4&91, December 1994.

Doyle, Brian M. and Faust Jon. “An Investigation of Co-movements among the Growth Rates of the G-7 Countries.” *Federal Reserve Bulletin*, October 2002, pp. 427-37.

Elliott, Graham and Fatas, Antonio. “International Business Cycles and the Dynamics of the Current Account.” *European Economic Review*, February 1996, 40(2), pp. 361-87.

Engle, Robert F. and Granger, C. W. J. “Cointegration and Error Correction: Representation, Estimation, and Testing.” *Econometrica*, March 1987, 55(2), pp.251-76.

Glick, Reuven and Rogoff, Kenneth. “Global versus Country-specific Productivity Shocks and the Current Account.” *Journal of Monetary Economics*, February 1995, 35(1), pp. 159-92.

Gonzalo, Jesus. “Five Alternative Methods of Estimating Long-Run Equilibrium Relationships.” *Journal of Econometrics*, January-February 1994, 60(1-2), pp. 203-33

Ho, Mun S. and Sørensen, Bent E. “Finding Cointegration Rank in High Dimensional Systems Using the Johansen Test: An Illustration Using Data Based Monte Carlo Simulations.” *The Review of Economics and Statistics*, November 1996, 78(4), pp. 726-32.

Johansen, Soren. “Statistical Analysis of Cointegrated Vectors.” *Journal of Economic Dynamics and Control*, June-September 1988, 12(2-3), pp. 231-54.

Johansen, Soren. “Estimation and Hypothesis Testing of Cointegrated Vectors in Gaussian Vector Autoregressive Models.” *Econometrica*, November 1991, 59(6), pp. 1551-80.

Johansen, Soren. “The Role of the Constant and Linear Terms in Cointegration Analysis of Nonstationary Variables.” *Econometric Review*, 1994, 13(2), pp. 205-29

Johansen, Soren. "A Small Sample Correction of the Test for Cointegrating Rank in the Vector Autoregressive Model." *Econometrica*, September 2002, 70(5), pp. 1929-61.

Johansen, Soren and Juselius, Katarina. “Maximum Likelihood Estimation and Inference on Cointegration: With Application to the Demand for Money.” *Oxford Bulletin of Economics and Statistics*, May 1990, 52(2), pp.169-210.

Johansen S and Juselius, Katarina. “Testing Structural Hypotheses in a Multivariate Cointegration Analysis of the PPP and the UIP for UK.” *Journal of Econometrics*, July-September 1992, 53(1-3), pp. 211-44.

Juselius, Katarina. *The Cointegrated VAR Model: Econometric Methodology and Macroeconomic Applications*, forthcoming Oxford University press, 2005.

Juselius, Katarina. “A Structured VAR for Denmark under Changing Monetary Regimes,” *Journal of Business and Economic Statistics*, October 1998, 16(4), pp. 400-11.

Meyer, Laurence H.; Doyle, Brian M.; Gagnon, Joseph E. and Henderson, Dale W. “International Coordination of Macroeconomic Policies: Still Alive in the New Millennium?” in David Vines and Christopher Gilbert, eds., *The IMF and its Critics*: Cambridge University Press, Cambridge, UK, 2004. pp. 59-105.

Nelson, Charles R. and Plosser, Charles I. “Trends and Random Walks in Macroeconomic Time Series.” *Journal of Monetary Economics*, September 1982, 10(2), pp. 139-62.

**Table 1a: Specification Tests for the Unrestricted VAR(2) Model**

**Multivariate Tests:**

**Residual Autocorrelations:**

| | | |
|---|---|---|
| LM $_1$ | $\chi^2(9) = 5.9215$ | P-value = 0.748 |
| LM $_4$ | $\chi^2(9) = 9.8572$ | P-value = 0.362 |

**Normality:**

| | | |
|---|---|---|
| LM | $\chi^2(6) = 127.5966$ | P-value = 0.000 |

**Trace Correlation** = 0.1240

**Univariate Tests:**

| | Europe | U.S. | Japan |
|---|---|---|---|
| **Mean** | 0.0000 | 0.0000 | 0.0000 |
| **Std. Dev.** | 0.0068 | 0.0082 | 0.0089 |
| **Skewness** | 2.3486 | -0.0961 | -1.0568 |
| **Kurtosis** | 21.5311 | 4.9331 | 7.4018 |
| **ARCH (2)** | 0.1404 | 4.0412 | 0.1595 |
| **Normality** | 82.2006 | 20.0126 | 29.7855 |
| **R-Squared** | 0.2025 | 0.0793 | 0.1578 |

**Table 1b: Specification Tests for the Unrestricted VAR(2) Model after Correction for the Outliers**

**Multivariate Tests:**

**Residual Autocorrelations:**

| | | |
|---|---|---|
| LM $_1$ | $\chi^2(9) = 0.6041$ | P-value = 1.000 |
| LM $_4$ | $\chi^2(9) = 5.9307$ | P-value = 0.747 |

**Normality:**

| | | |
|---|---|---|
| LM | $\chi^2(6) = 25.3497$ | P-value = 0.000 |

**Trace Correlation** = 0.3372

**Univariate Tests:**

| | Europe | U.S. | Japan |
|---|---|---|---|
| **Mean** | 0.0000 | 0.0000 | 0.0000 |
| **Std. Dev.** | 0.0053 | 0.0075 | 0.0079 |
| **Skewness** | -0.5039 | -0.4701 | -0.1268 |
| **Kurtosis** | 4.7715 | 4.5040 | 3.0351 |
| **ARCH (2)** | 3.1744 | 8.8904 | 1.9276 |
| **Normality** | 13.8502 | 11.3829 | 0.6064 |
| **R-Squared** | 0.5271 | 0.2154 | 0.3360 |

**Table 2: SIC, HQ, AIC and Likelihood Ratio Tests for Lag Selection**

| **Lags** | **Log** | **Information Criteria** | | | **LM(1)** | **Trace** |
|---|---|---|---|---|---|---|
| ***k*** | **Likelihood** | **SIC** | **AIC** | **HQ** | **p-value** | **Correlation** |
| 1 | -29.9247 | **-29.1616** | -29.7914 | **-29.4299** | **0.008** | 0.3113 |
| 2 | -30.0731 | -28.9830 | **-29.8064** | -29.3663 | 0.683 | 0.3442 |
| 3 | -30.1416 | -28.7245 | -29.7416 | -29.2227 | 0.500 | 0.3575 |
| 4 | -30.2512 | 28.5071 | -29.7179 | -29.1203 | 0.633 | 0.3800 |

**Note:** Lag selection is performed after taking into account permanent dummies. SIC, HQ and AIC are Schwarz, Hannan-Quinn, and Akaike information criteria respectively. SIC, HQ and AIC are performed keeping effecting sample size constant.

**Table 3: Trace Test Statistics for Determination of the Cointegration Rank for the Unrestricted VAR(2) Model with Dummies**

| **r** | **p - r** | **Eigen. Value** | **Trace*** | **95% Critical Value** | **P-Value*** |
|---|---|---|---|---|---|
| 0 | 3 | 0.2381 | 40.4123 | 29.8044 | 0.0017 |
| **1** | **2** | **0.0330** | **3.6490** | **15.4082** | **0.9225** |
| 2 | 1 | 0.0000 | 0.0031 | 3.8415 | 0.9557 |

**Note:** r is number of cointegrating relations and p-r is number of common stochastic trends in the system.
* Barlett Correction

**Table 4: Roots of the Companion Matrix**

| **Modulus of Seven Largest Roots** | | |
|---|---|---|
| **Rank = 3** | **Rank = 2** | **Rank = 1** |
| 0.9993 | 1 | 1 |
| 0.9835 | 0.9829 | 1 |
| 0.9186 | 0.9190 | 0.9407 |

**Table 5: Restrictions on Known $\beta$ and Zero Row Restrictions on $\alpha$ Matrix**

| | **Europe** | **U.S.** | **Japan** | $\chi^2(\upsilon)$ | **p-value** |
|---|---|---|---|---|---|
| $H_1^{\beta}$ | 1 | 1 | 0 | 4.6422 (1) | 0.0312 |
| $H_2^{\beta}$ | 1 | 0 | 1 | 16.8382 (1) | 0.0000 |
| $H_3^{\beta}$ | 0 | 1 | 1 | 16.6855 (1) | 0.0000 |
| $H_1^{\alpha}$ | 1 | 0 | 0 | 16.0912 (1) | 0.0001 |
| $H_2^{\alpha}$ | **0** | **1** | **0** | **0.0114 (1)** | **0.9148** |
| $H_3^{\alpha}$ | 0 | 0 | 1 | 22.2808 (1) | 0.0000 |

**Table 6:** $\alpha, \beta', \Pi$ **Matrices: Model 3(1), Zero Row Restrictions on** $\alpha$

| $\Pi = \alpha\beta'$ **Matrix** | | | |
|---|---|---|---|
| | **Europe** | **U.S.** | **Japan** |
| **Europe** | -0.0809 | 0.0399 | 0.0184 |
| | (-4.3947) | (4.3947) | (4.3947) |
| **U.S.** | 0.0000 | 0.0000 | 0.0000 |
| | (0.0000) | (0.0000) | (0.0000) |
| **Japan** | -0.1426 | 0.0703 | 0.0324 |
| | (-5.1834) | (5.1834) | (5.1834) |
| $\beta'$ **Matrix** | | | |
| | **Europe** | **U.S.** | **Japan** |
| $\beta_1$ | 1.0000 | -0.4928 | -0.2269 |
| | (0.0000) | (-8.0283) | (-3.6847) |
| $\alpha'$ **Matrix** | | | |
| | **Europe** | **U.S.** | **Japan** |
| $\alpha_1$ | -0.0809 | 0.0000 | -0.1426 |
| | (-4.3947) | (0.0000) | (-5.1834) |

**Table 7:** $\alpha_\perp, \tilde{\beta}_\perp, C$ **Matrices: Model 3(1), Zero Row Restriction on** $\alpha$

| $C$ | | | |
|---|---|---|---|
| | $\sum \varepsilon_{1t}$ | $\sum \varepsilon_{2t}$ | $\sum \varepsilon_{3t}$ |
| **Europe** | -0.7200 | **0.9952** | **0.4085** |
| | (-1.4120) | **(4.2534)** | **(3.1898)** |
| **U.S.** | -0.2569 | **1.4818** | 0.1457 |
| | (-0.4008) | **(5.0395)** | (0.9055) |
| **Japan** | **-2.6148** | **1.1677** | **1.4836** |
| | **(-2.3652)** | **(2.3020)** | **(5.3432)** |
| $\tilde{\beta}_\perp'$ | | | |
| | **Europe** | **U.S.** | **Japan** |
| $\tilde{\beta}_{\perp 1}$ | -0.7200 | -0.2569 | -2.6148 |
| $\tilde{\beta}_{\perp 2}$ | 0.9952 | 1.4818 | 1.1677 |
| $\alpha_\perp'$ | | | |
| $\alpha_{\perp 1}$ | 1.0000 | 0.0000 | -0.5674 |
| $\alpha_{\perp 2}$ | 0.0000 | 1.0000 | 0.0000 |

* t-values are in the brackets

Figure 1: The Econometric Methodology

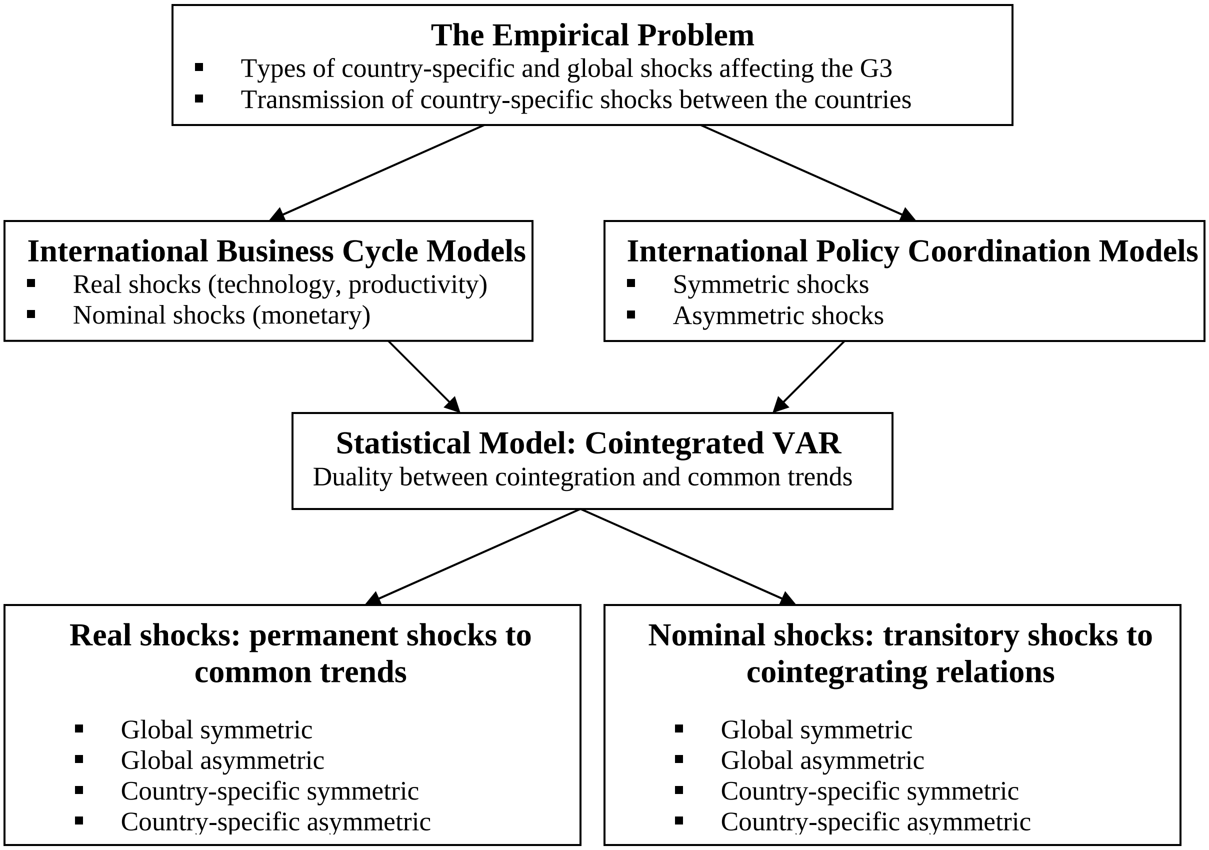


**Figure 2:** **Pushing and Pulling Forces within** a **Cointegrated VAR Model for** a **Two Dimensional** $x_{it} = (x_{1t}, x_{2t})$ **System**

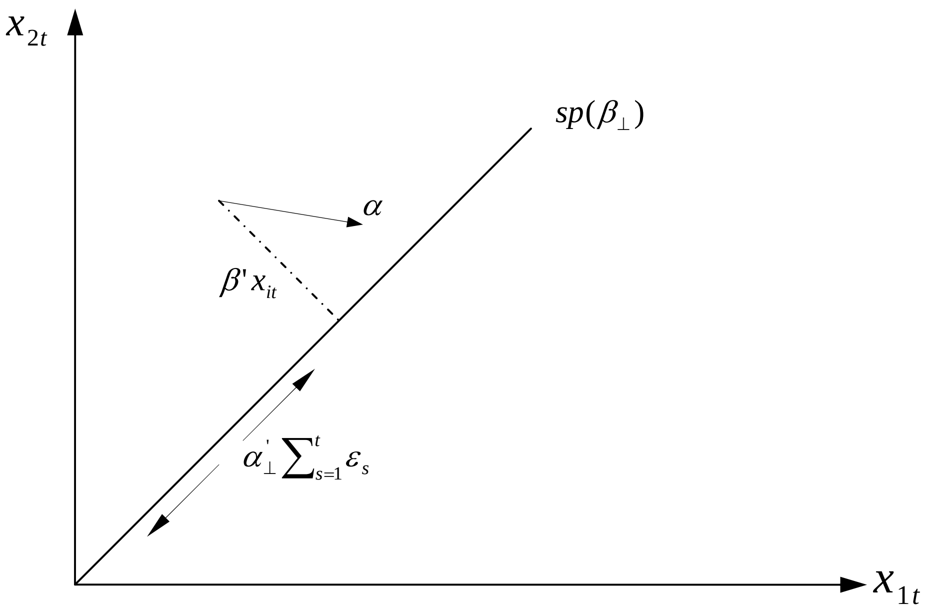


**Figure 3a:** **Recursively Calculated Loglikelihood Function Based on the Full and Concentrated Models without Dummy Variables: Baseline Sample 1970:1 – 1980:1**

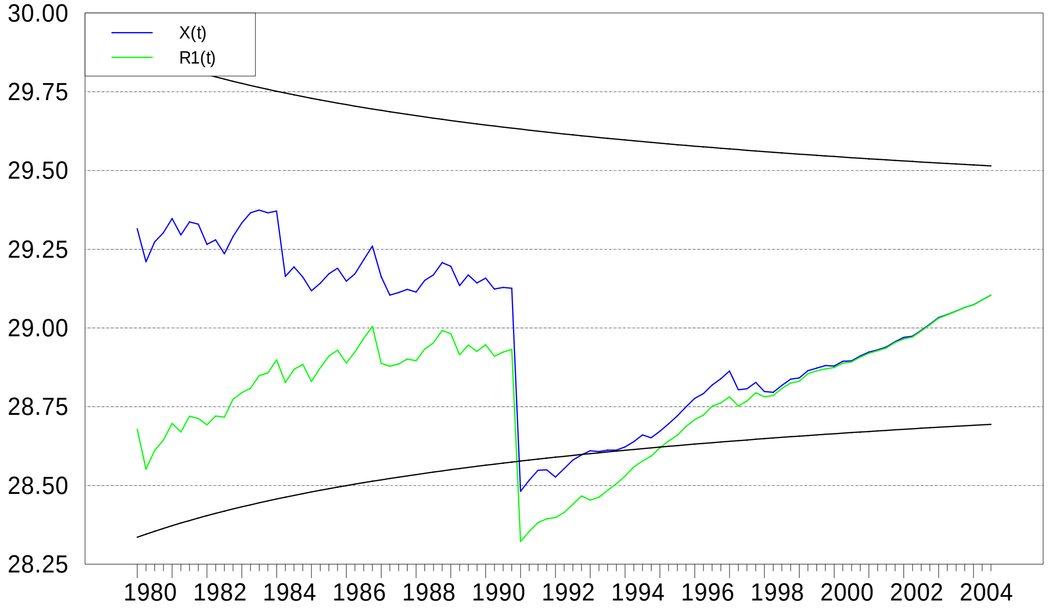
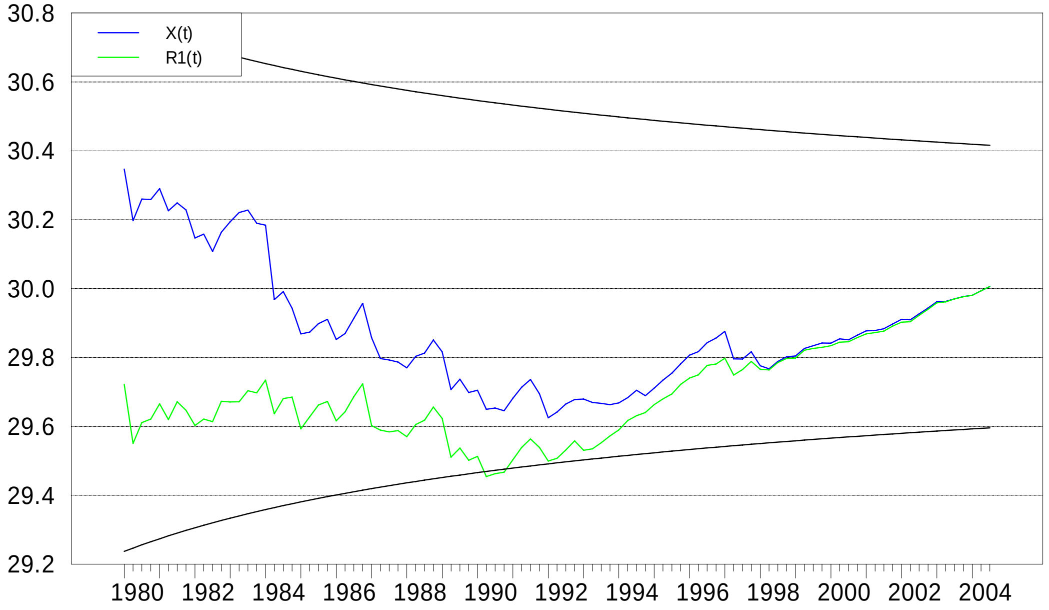
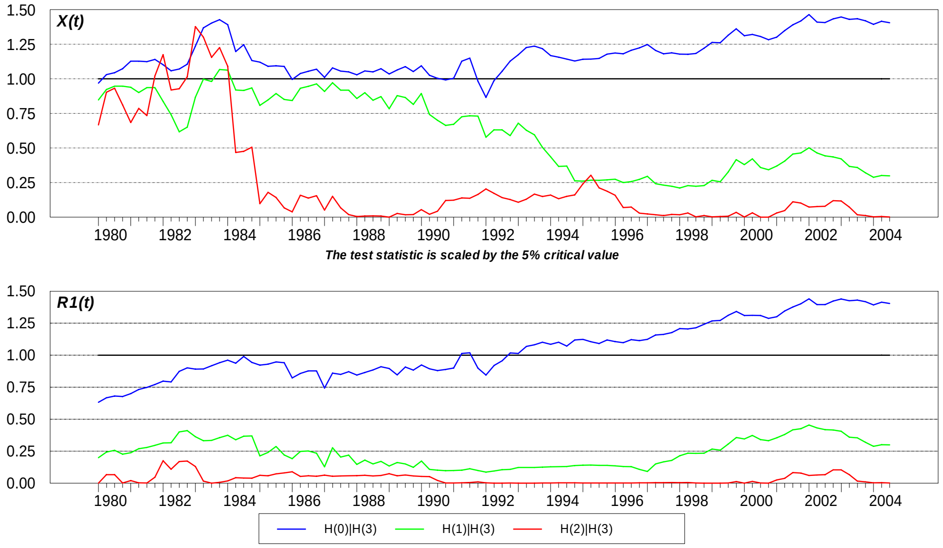


**Figure 3b:** **Recursively calculated Loglikelihood Function Based on the Full and Concentrated Models without Dummy variables: Baseline Sample 1970:1 – 1980:1**



## Figure 4: Recursively Calculated Trace Test Statistics Based on the Full and Concentrated Models: Baseline Sample 1970:1 – 1980:1



*The test statistic is scaled by the 5% critical value*

***WARNING: THE CRITICAL VALUES ARE INVALID!***

**Figure 5: Long-Run Steady-State Relation**

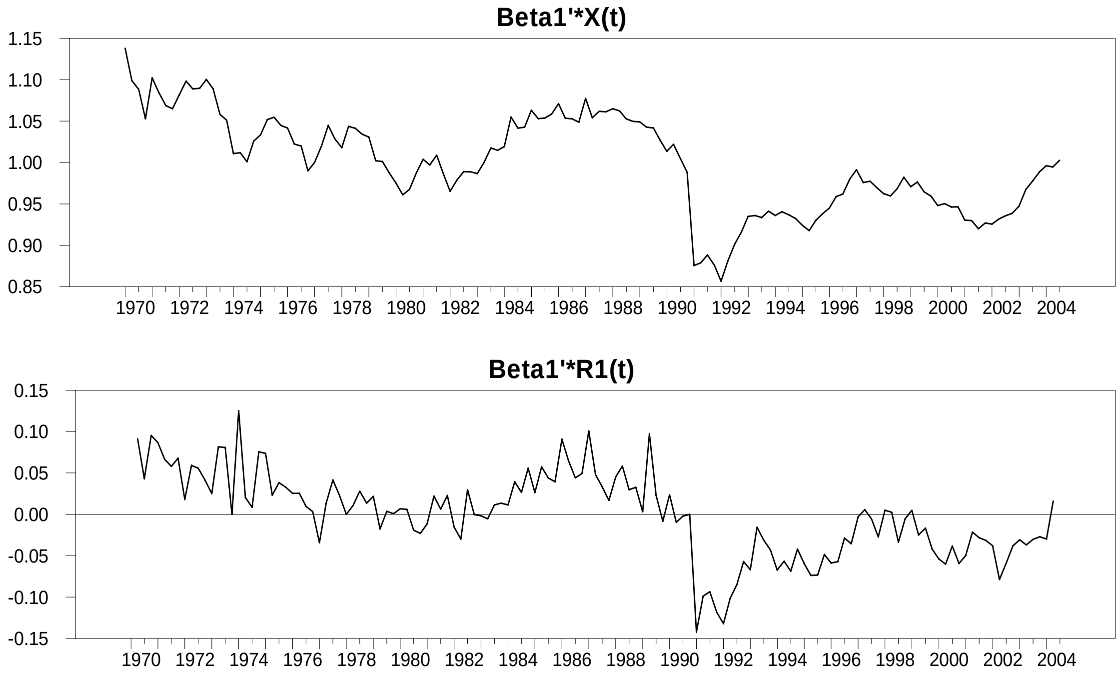
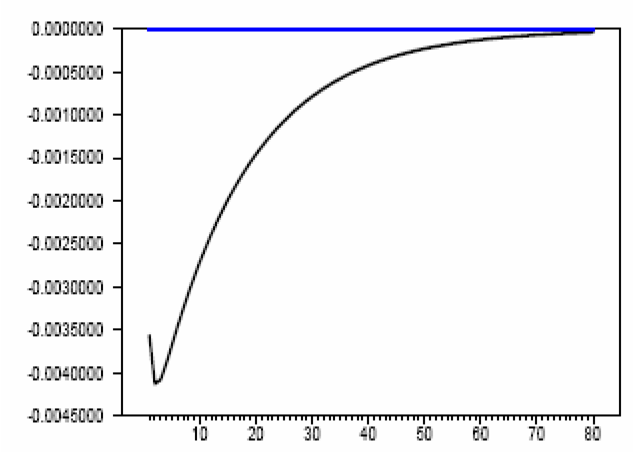
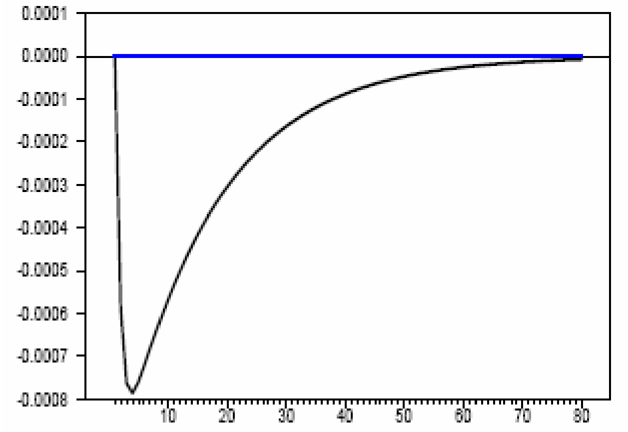


**Figure 6a: Impulse Response Functions for the Common Transitory Shock**

**Response of Europe Real Output**



**Response of the U.S. Real Output**



**Response of Japan Real Output**

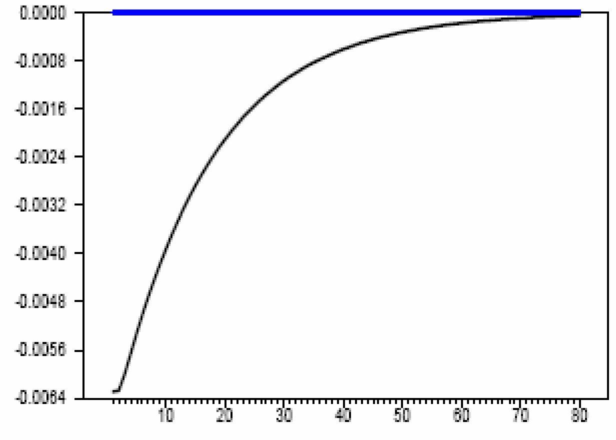
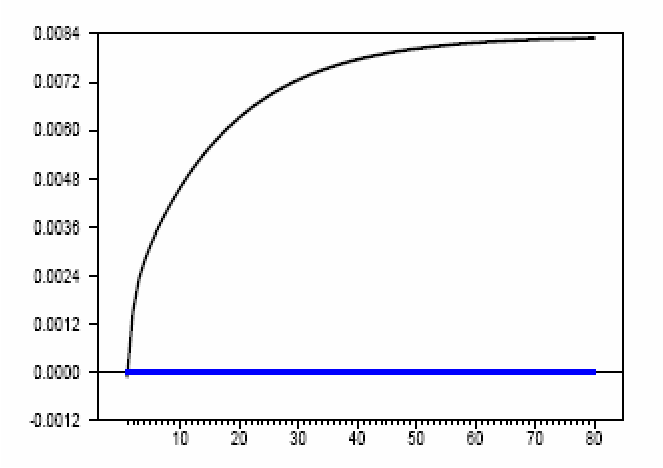
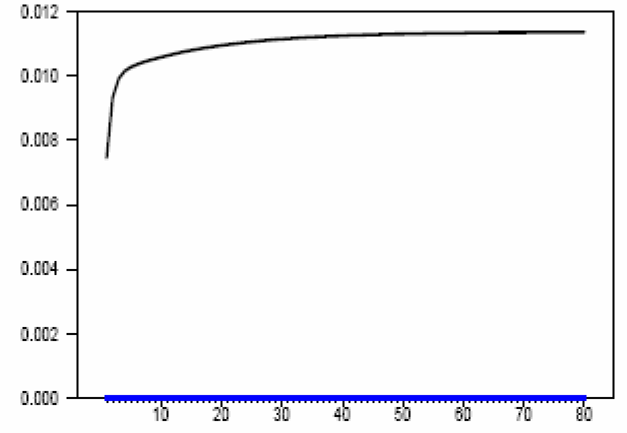


**Figure 6b:** **Impulse Response Functions for Permanent Shock Originating in the U.S.**

**Response of Europe Real Output**



**Response of the U.S. Real Output**



**Response of Japan Real Output**

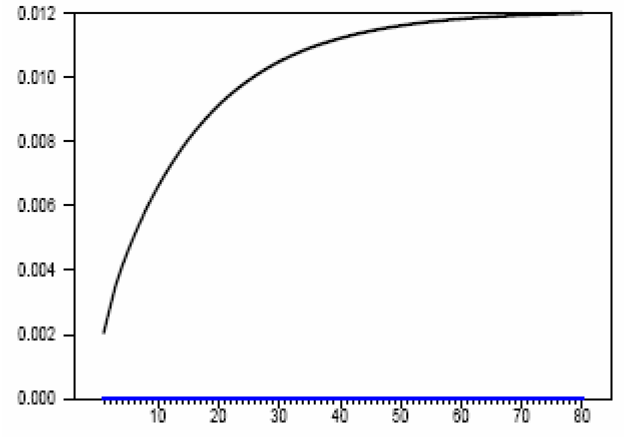
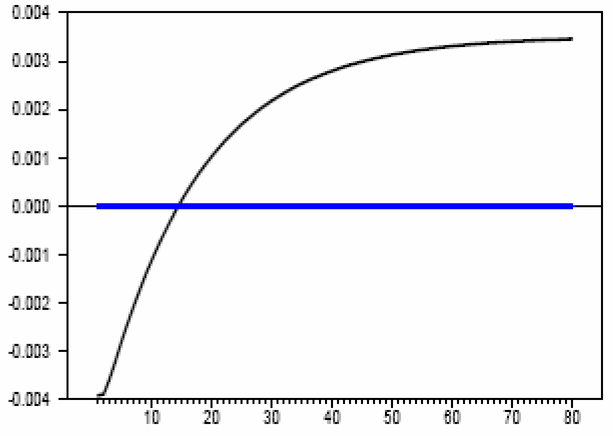
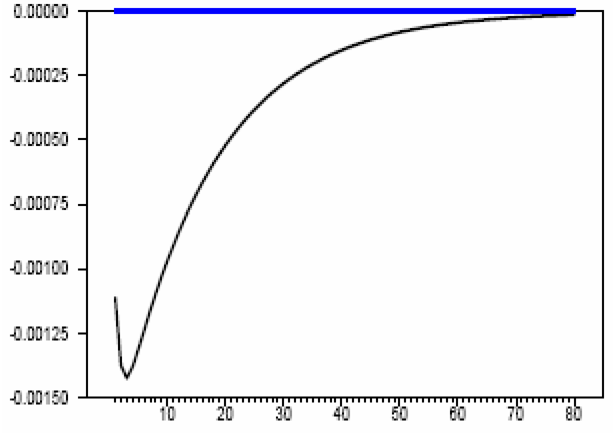


**Figure 6c: Impulse Response Functions for Permanent Shock Originating in Europe or Japan**

**Response of Europe Real Output**



**Response of the U.S. Real Output**



**Response of Japan Real Output**

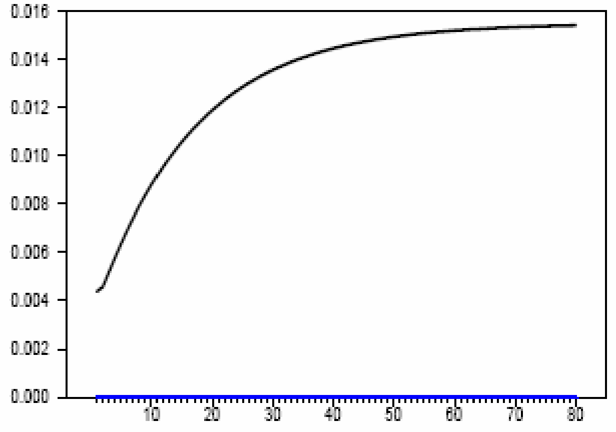
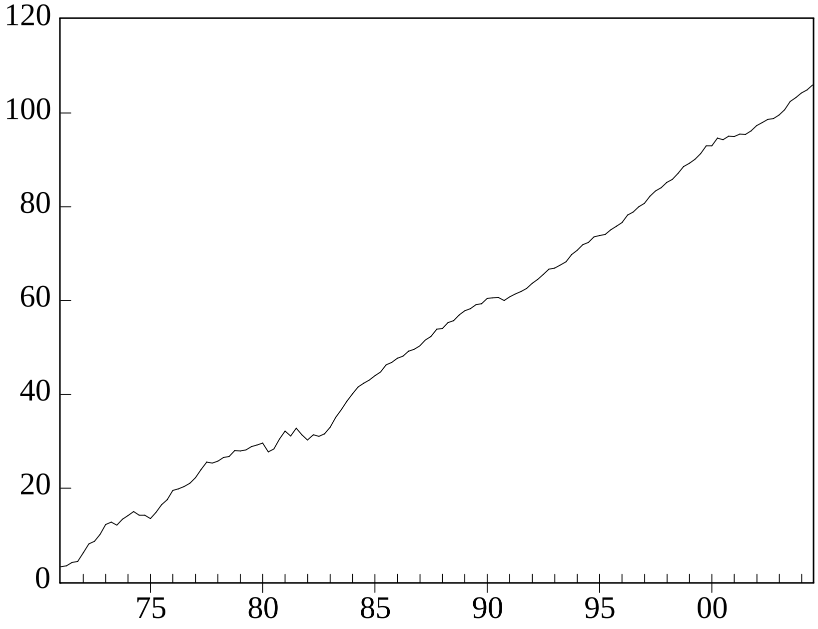


**Figure 7: Common Trends of the System**

**U.S. Driven Common Trend**



**Europe and Japan Driven Common Trend**