If the Unites States sneezes, does the world need paracetamol?

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Abstract

There is an old saying that states that "If the United States sneezes, the rest of the world catches a cold". Against this background, it is argued that some countries, especifically China, can "decouple" from the US economy and sustain strong growth in the face of a US slowdown. In this paper we analyze the extent to which the US economy affects international business fluctuations across countries. A multivariate nonlinear LSTAR model is estimated for the GDP cyclical component of China, France, Germany, the UK and the

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USA. This nonlinear framework allows the business cycles asymmetries to be captured properly in order to identify the synchronization behavior across countries. Our results suggest that there is a relevant influence from the US cycle, since it acts as a source of international business cycle synchronization. However, spillovers from US cycle fluctuations to China are rather modest.

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1 Introduction

In the last few decades, developed economies such the USA, Japan or EU members have intensified trade and financial linkages. These two mechanisms, along with other forms of economic integration, have been considered important channels in the increasing convergence of business cycle fluctuations, since they allow shocks to be transmitted across countries (Frankel and Rose, 1998; Stock and Watson, 2003; Baxter and Kouparitsas, 2005; Calderon et al. 2007; Inklaar et al, 2008)[1]. Nonetheless, in spite of this evidence, from a theoretical point of view, the relation between synchronization of business cycles and these factors remains ambiguous. First, Krugman (1993) and Kose and Yi (2002) argued that more trade may encourage increased specialization of production, thus causing less synchronization of business cycles. Second, Kalemli-Ozcan et al. (2001) claimed that better income insurance attained through greater capital market integration may lead to higher specialization of production and, hence, output fluctuations that are less symmetric. In addition to the above arguments, the empirical literature has suggested that other factors may also affect business cycle synchronization such as monetary integration (Fatás, 1997), fiscal policy (Clark and van Wincoop, 2001) or the exchange rate regime (Bordo and Helbling, 2003).

On the other hand, emerging economies such as China, India or Brazil have undergone rapid growth, thereby changing the structure of international trade. The existence

[1]See a recent survey on the determinants of Business cycles in De Haan et al. (2008)

of these new participants, along with other emerging economies, might also have implications on business cycles and shock transmission across countries. As a result of this new structure of the world, there is a growing debate about the degree of synchronization of the business cycle between developed and emerging economies. Recent empirical evidence finds support for the decoupling hypothesis between developed and developing countries (Doyle and Faust, 2002; Helbling and Bayoumi, 2003; Imbs, 2004; Fidmuc et al., 2008; Kose et al, 2008). However, despite the significant effort made by researchers, from the theoretical and empirical points of view, there is little agreement on whether emerging economies have decoupled from developed countries. Indeed, Wälti (2009) argued that the decoupling hypothesis is a myth. The global financial crisis has reshaped the debates of decoupling. Given the fall in exports and production across emerging economies in response to a sharp decline in demand in major industrial countries, the question is no longer one of whether emerging economies are weakly integrated with developed economies, but whether the former can manage an independent recovery from the impact of the financial crisis. Of particular interest is the case of China- a large economy which is still showing positive growth based on relatively resilient domestic demand.

Related to the decoupling debate, the question of whether the dynamics of recessions are different from those of expansions has a long history. Early studies can be traced back to Mitchell (1927), Keynes (1936) and Burns and Mitchell (1946), who noted that contractions in an economy are quicker and steeper but also shorter-lived than expansions, so that economic activity follows an asymmetric cyclical process. This dynamics demands the use of non-linear models to describe the business cycle fluctuations and to capture the asymmetric realizations properly in order to identify the upswings and downswings as well as the synchronization behavior across countries. From an econometric point of view, although vector autorregressions provide a useful starting point for analyzing multivariate relationships between variables, they fail to account for the nonlinear phenomena present in many business cycle indicators. Furthermore, impulse response analyses based on VARs predict symmetric responses to positive and negative shocks, which is inconsistent with observed asymmetric responses. Three parametric time-series models have been proposed to capture steep, short recessions. The first model, proposed by Hamilton (1989), divides the business cycle into two phases, negative trend growth and positive trend growth, with the economy switching back and forth according to a latent variable. The second model econometrically formalizes the theoretical model by Friedman (1963, 1964) who suggested that recessions are periods where output is hit by large negative transitory shocks, labeled "plucks" by Friedman. The third model corresponds to the threshold autoregressive (TAR) model proposed by Tong (1978). The idea of the TAR model is to approximate a general nonlinear autoregressive structure by a threshold autoregression with a small number of regimes. Granger and Teräsvirta (1993) generalized the TAR model to the smooth transition autoregressive (STAR) model. In this framework, the business cycle indicator alternates between two distinct regimes which represent two phases of the business cycle. Transition between regimes is smooth, so that STAR models can be interpreted as a continuum of states between extreme regimes. It is worth noting that persistence of shocks that lead to recessions is very different in switching models and the ones based on Friedman's view. According to the latter, recessions are entirely transitory deviations from the trend, not movements in the trend itself.

The objective of this paper is to investigate the nature of macroeconomic interdependence between the USA, Japan, China and the three largest European economies (France, Germany and the UK). Although there is a large body of empirical research on business cycle co-movements among developed and developing countries, for the case of the Chinese economy, empirical evidence is rather scarce. The International Monetary Fund (2007) and Kose et al. (2008) analyzed the degree of global cyclical interdependence among industrial countries and emerging economies (including China) and found that global and regional common shocks have accounted for a sizeable percentage of business cycle fluctuations in both industrial and emerging countries. Yet, the relative importance of the global factors has decreased in favor of an increasing importance of regional factors. These papers therefore support the theory of decoupling. Kim, Lee and Park (2009) investigated the degree of economic interdependence between emerging Asia (China included) and major industrial countries. These authors concluded that output shocks from industrial countries have a significant positive effect on emerging Asian economies but interestingly the reverse is also true. According to the authors, this bi-directional interdependence suggests recoupling rather than decoupling.

The structure of the paper is as follows. Section 2 describes the data and presents an overview of the business cycles in the countries under consideration. Section 3 explains the methodology. Section 4 reports the results, and conclusions are drawn in Section 5.

2 Data and stylized facts

Given that our analysis is concerned with the synchronization of business cycles between countries, we need to decide from a variety of filtering techniques the one we will use to decompose output into trend and cycle. The most straightforward filtering technique is the fourth difference of quarterly real GDP (in logs). This indicator of business cycles is known as the "growth cycle". Baxter and King (1999) pointed out that first-differencing removes a trend from a series but potentially at the cost of a shift in the peaks and troughs of the differenced series and large volatility. However, this phase shift may not be too important when comparing cycles across countries, since it is the same for both countries. Baxter and King (1999) further suggested the use of a combination of high-pass and low-pass filters to eliminate the high-frequency noise that the Hodrick-Prescott filter still leaves. If such a so-called band-pass filter is applied, the resulting cyclical component does not contain any fluctuations with high or low frequencies beyond predetermined cut-off points. Filters such as the Hodrick-Prescott, Baxter-King and Christiano-Fitzgerald have recently been critiziced by Gordon (2010) owing to the fact that they might introduce spurious dynamics in the filtered data. Bearing this consideration in mind, we will use first differences to decompose the output series.

In this paper we analyze business cycle synchronization among China, France, Germany, Japan, the United States and the United Kingdom. The data are quarterly real GDP, covering 1978:1-2008:4. As a data source we use the IMF's International Financial Statistics. Data for the China GDP was taken from National Bureau of Statistics of China. The filtered data are plotted in Figure 1. Although, as stated earlier, the recent literature seems to favor the fourth differences over the band-pass filter, Figures 2, 3 and 4 show that the behavior of both cyclical measures is very similar[2].

From Figure 1 one feature becomes very apparent. i.e. the degree of co-movement among the developed countries is clear, at least from the beginning of the nineties. Judging from the patterns of growth fluctuations before the nineties, the Chinese business cycle tended to have longer expansionary periods followed by relatively shorter but much sharper contractions, as the one observed in late eighties.[3] The Chinese cycle also seems to be more volatile. These patterns of China's business cycle have changed significantly since the nineties onwards. The Chinese cycle is characterized by a relatively long span of expansion followed by a long contraction linked to the Asian crisis in 1997-1998. Interestingly, this period appears to be characterized by China decoupling, since the Chinese business cycle seems fairly detached from the business cycles of the other countries

[2]In Figures 2, 3 and 4 deviations cycle stands for the filter data using the Christiano-Fitzgerald band-pass filter.

[3]Contraction in this period is accounted for the economic restrictions carried out by the Chinese government in 1988-1989 due to sharp increase in inflation

throughout most of the nineties, due to the fact that during this period the Chinese economy undergone a rapid growth based on export promotion and foreing direct investment.

Figure 5 illustrates the evolution of the contemporaneous correlation between the USA business cycle and the rest of the cycles that are analyzed using 5-year rolling windows. The correlation with China rose sharply up to 1997. In the years immediately after the Asian crisis, the correlation between the US and Chinese cycles decreased, and remained constant from the late nineties onwards. The contemporaneous correlation for the UK business cycle confirms a generally high level of synchronicity with the USA. Japan exhibits a decreasing correlation with the USA which turned negative after the Asian crisis. It is worth noting the opposite behavior of business cycle correlation between Germany and USA, on the one hand, and France and the USA, on the other. While France appears to be steadily synchronized with the USA, Germany shows a sharp decrease in cycle contemporaneous correlation with the USA. This result is confirmed in Figure 6, which shows a contemporaneous correlation between the German cycle and the rest of the cycles; France and Germany are clearly on a divergence path. This divergence in output correlation might reflect the different competitive positions of the two countries. Germany has gained a significant amount of price and wage competitiveness. According to De Grauwe (2008), part of these divergent developments in prices and wages are the result of divergent national policies, specifically, the German policy of tight wage moderation that began in 1999. Wage moderation in Germany might also explain the decreasing time path of the contemporaneous correlation with the USA and the UK. Finally, Figure 7 presents the evolution of the contemporaneous correlation between the Chinese cycle and the rest of the cycles. that are analyzed. Accordingly, China seems to be detached from all countries with the only exception of the USA, as mentioned before.

Table 1 presents simple causality test between the analyzed business cycles[4]. Granger causality tests are often sensitive to the number of lags used. Here the reported results are for the test using 4 and 12 lags, that is, at least one year long, because domestic factors tend to dominate business cycles in periods shorter than one year. Thus, the transmission effect of external shocks may be offset by spurious common domestic factors. The test results suggest that movements in the US business cycle "Granger-cause" movements in China, France, and the UK cycles at 1- and 2-year lags, whereas they only "Granger-cause" the Japan business cycle only at 2 year lag. In addition, the Chinese business cycle "Granger-cause" France (although very borderline), the UK and the US business cycles only at 2-year lags. These results confirm the conclusions we drew from the business cycle correlations and highlight the fact that although China might play an important role in the transmission of international shocks, the USA exerts the largest influence.

According to Péguin-Feissolle and Teräsvirta (1999), the linear approach to causality testing has low power to detect certain kinds of nonlinear causal relations. These authors propose a statistical method for uncovering nonlinear causal relations that, by construc-

[4] Only the results of causality from the USA, China and Germany are shown. For the rest of the countries the null is not rejected so that Japan, France and the UK do not Granger cause any other country. The results are available upon request.

tion, cannot be detected by traditional linear causality tests. Their approach uses Taylor expansion series to approximate the true nonlinear relationship. Table 2 presents the nonlinear Granger causality test. Tests based on Taylor expansion approximation requires a huge number of cross products and are very data-demanding causing a dramatic decrease in the degrees of freedom when the lag length increases. However, for the Péguin-Feissolle and Teräsvirta (1999) test it is not necessary to take a large number of cross-products or lags on endogenous or exogenous variables to build the test since, as shown by authors, simulation results generally gives appreciable results even for low value of lags. Therefore we choose to take four lags on the variables and three for the Taylor expansion. According to these results, shown in Table 2, there is far more evidence of causality now than when using the linear causality test. Specifically, USA Granger cause all the countries, including Japan and Germany, which appeared not to be Granger cause according to the linear Granger test. The same thing can be said of China, which appears to cause all the other countries with the only exception of the USA. It seems that nonlinearities are an important feature of data in terms of explaining the causal relationship linking the business cycles.

3 Methodology

The possible nonlinearity of business cycles has a long tradition in economics. As pointed out by Teräsvirta and Anderson (1992), the issue of nonlinearity of business cycles is important because it has clear implications on business cycle theory. STAR models are a useful tool to model economic series that are characterized by nonlinearities and multiple equilibria. These models can be formulated as

$$y_t = (\alpha + \sum_{i=1}^{p} \phi_i y_{t-i})(1 - F(\gamma, x_{t-d} - c)) + (\tilde{\alpha} + \sum_{i=1}^{p} \tilde{\phi}_i y_{t-i})F(\gamma, x_{t-d} - c) + \varepsilon_t, \qquad (1)$$

where α, $\tilde{\alpha}$, ϕ_i, $\tilde{\phi}_i$, γ and c are the parameters to be estimated, and ε_t is an i.i.d. error term with zero mean and constant variance σ^2. The transition function $F(\gamma, x_{t-d} - c)$ is continuous, non-decreasing and bounded between 0 and 1. The exogenous variable x_{t-d} is the so-called transition variable and determines the regimes of the endogenous variable.

This STAR model can be interpreted as a regime-switching model allowing for two extreme regimes associated with the values $F(\gamma, x_{t-d} - c) = 0$ and $F(\gamma, x_{t-d} - c) = 1$, each corresponding to a specific state of the economy. [5] When x_{t-d} deviates from the constant threshold value c, there is a transition between regimes whose speed is governed by the parameter γ.

Two popular choices of transition functions are the first-order logistic function:

$$\text{LSTAR: } F(\gamma, x_{t-d} - c) = (1 + exp\{-\gamma(x_{t-d} - c)\})^{-1}, \;\; \gamma > 0, \qquad (2)$$

[5] Thus, the STAR model can be interpreted as a continuum of regimes wihtin the two extreme regimes

and the exponential function:

$$\text{ESTAR: } F(\gamma, x_{t-d} - c) = 1 - exp\{-\gamma(x_{t-d} - c)^2\}, \;\; \gamma > 0. \tag{3}$$

The first one delivers the logistic STAR (LSTAR) model and encompasses two possibilities depending upon the transition speed γ. When $\gamma \to \infty$, the logistic function approaches a constant and the LSTAR model becomes a two-regime threshold autoregressive TAR model, for which changes between regimes are sudden rather than smooth. When $\gamma = 0$, the LSTAR model reduces to a linear AR model. Due its different responses to positive and negative deviations of x_{t-d} from c, the LSTAR specification is convenient for modeling asymmetric behavior in time series. This is not the case of the exponential STAR (ESTAR) specification, in which these deviations have the same effect, i.e. what matters is the size of the shock, not the sign. Consequently, this model is only able to capture nonlinear symmetric adjustments.

Following Granger's (1993) "specific-to-general" strategy for building nonlinear time series models, Granger and Teräsvirta (1993) and Teräsvirta (1994) developed a technique for specifying and estimating parametric STAR models. This procedure can be summarized in four steps (van Dijk *et al.*, 2002): (i) Specification of a linear AR model of order p for the time series under investigation; (ii) Test of the null hypothesis of linearity against the alternative of STAR; (iii) Selection of the appropriate transition function for the transition variable, if linearity is rejected; (iv) Model estimation.

Testing linearity against STAR is a complex matter because, under the null of linearity, the parameters in the STAR model are not identified. Granger and Teräsvirta (1993) suggested a sequence of tests to evaluate the null of an AR model against the alternative of a STAR model. These tests are conducted by estimating the following auxiliary regression for a chosen set of values of the delay parameter d, with $1 < d < p$:[6]

$$y_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} y_{t-i} + \sum_{i=1}^{p} \beta_{2i} y_{t-i} x_{t-d} + \sum_{i=1}^{p} \beta_{3i} y_{t-i} x_{t-d}^2 + \sum_{i=1}^{p} \beta_{4i} y_{t-i} x_{t-d}^3 + \epsilon_t. \quad (4)$$

The null of linearity against a STAR model corresponds to: $H_0 : \beta_{2i} = \beta_{3i} = \beta_{4i} = 0$ for $i = 1, 2, ..., p$. The corresponding LM test has an asymptotic χ^2 distribution with $3(p+1)$ degrees of freedom under the null of linearity. If linearity is rejected for more than one value of d, the value of d corresponding to the lowest p-value of the joint test is chosen. In small samples, it is advisable to use F-versions of the LM test statistics because these have better size properties than the χ^2 variants (the latter may be heavily oversized in small samples). Under the null hypothesis, the F version of the test is approximately F distributed with $3(p + 1)$ and $T - 4(p + 1)$ degrees of freedom.

If linearity is rejected, we need to test for LSTAR against ESTAR nonlinearity. For this purpose, Granger and Teräsvirta (1993) and Teräsvirta (1994) proposed the following sequence of tests within the auxiliary regression (4):

[6] Equation (4) is obtained by replacing the transition function in the STAR model (1) by a suitable Taylor series approximation (see Granger and Teräsvirta, 1993).

$H_{03} : \beta_{4i} = 0 \;\; i = 1, 2, ..., p$

$H_{02} : \beta_{3i} = 0 | \beta_{4i} = 0 \;\; i = 1, 2, ..., p$

$H_{01} : \beta_{2i} = 0 | \beta_{3i} = \beta_{4i} = 0 \;\; i = 1, 2, ..., p.$

An ESTAR model is chosen if H_{02} has the smallest p-value, otherwise the selected model is the LSTAR.

If business cycles are inherently nonlinear, the analysis of the possible cyclical co-movement between countries requires the use of multivariate nonlinear methods. However, the complexity of multivariate nonlinear modeling leads us to test whether economic reasoning and data allow us to simplify this modeling. One possible simplification stems from the presence of common nonlinear components. Let us assume that within a given set of variables there is a nonlinear behavior of each individual variable with respect to the same transition variable. If this is the case, we can test whether there is a nonlinear co-movement within this set of variables. In order to address this issue we test for common LSTAR nonlinearities following the methodology proposed by Anderson and Vahid (1998) based upon canonical correlations. Accordingly, let

$$y_t = \pi_{A0} + \pi_A(L)y_t + F(z_t)[\pi_{B0} + \pi_B(L)y_t] + \epsilon_t$$

be the multivariate version of the LSTAR model, where y_t is the vector of variables under analysis, $\pi_i(L)$ is a matrix polynomial of degree p in the lag operator, ϵ_t is i.i.d., and $F(z_t)$ is a diagonal matrix containing the transition functions for each series. Testing for common nonlinearities consists in testing whether some α exists such that $\alpha' y_t$ does not exhibit the type of nonlinearity which is present in the mean of each individual y_t. The test statistic is based on canonical correlations and is asymptotically distributed as χ^2 with $(3p-1)5s+s^2$ degrees of freedom, where p denotes the maximum lag length and s is the number of common nonlinearities. Rejection of the null hypothesis provides evidence of the presence of at most s common nonlinearities.

4 Empirical results

Before proceeding with the estimation of the STAR models, it is necessary to test for the null of linearity. If linearity is not rejected for a country, we can exclude it from model-building efforts. Table 3 displays the test statistics for the null hypothesis of linearity against STAR nonlinearity. Results appear under the heading *Linearity Test.* These tests are performed for each variable using the American GDP growth rate as the transition variable, i.e. x_t in equations (1) and (4).[7] According to the results, linearity is rejected for all variables using the Granger and Teräsvirta (1993) linearity test with the only exception of Japan, which must be excluded from the rest of the analysis. This result has a twofold implication. First, except for Japan, business cycles exhibit a nonlinear behavior within two extreme regimes and, second, the transition between both regimes

[7]The linearity tests were also estimated by using the other countries as a transition variable. Nevertheless, the case of the USA is where rejection of the null of linearity is clearest, and this is why it is the country that was chosen as the transition variable.

is at least partially driven by the cyclical component of the American GDP.

Adjustment to changes in the transition variable can be either symmetric or asymmetric. As pointed out before, if the transition function is exponential, the implied adjustment will be symmetric, whereas if the transition function is logistic the adjustment is asymmetric. Table 3 presents the Granger and Teräsvirta (1993) tests for choosing between the ESTAR and the LSTAR model (under the headings H_{01}, H_{02} and H_{03}). According to these test statistics, the LSTAR representation of the data is preferred to the ESTAR one, i.e. H_{02} does not present the smallest p-value, for all GDP growth rates. Thus, all cyclical components of GDP respond asymmetrically to the cyclical component of the American GDP.

Once it has been shown that each of the business cycles of China, France, Germany, the USA and the UK present non-linearities and that such linearities are linked to the behavior of the American business cycle, it becomes possible to determine in a multivariate context whether this non-linear component is common to all the countries. The existence of a non-linear common component within the paradigm of stationarity can be compared to the existence of a cointegration vector in the non-stationarity paradigm. In the first case, a non-linear common tendency implies the existence of a linear combination of non-linear variables so that the non-linear component is cancelled out. In a similar manner, cointegration exists when a linear combination of non-stationary variables is stationary. Therefore, in both cases there is co-movement. If the business cycles of the countries that are analyzed share a common non-linear component, there will be co-movement between them, and thus, in theory, none of the countries under analysis would display decoupling with the other countries in the sample. In other words, there is cyclical synchronicity among the countries in the sample.

One useful methodology for such purposes is the procedure for testing for common nonlinear components proposed by Anderson and Vahid (1998). Table 4 presents the results for the common LSTAR nonlinearities test proposed by these authors. These results are obtained using the cyclical component of the American GDP as the (common) transition variable. Taking as standard procedure, five percent as the critical value, the null that there are no nonlinear factors in the system is rejected, whereas the null that there is only one such factor is not rejected. These tests, therefore, provide evidence that the nonlinear behavior of the cyclical component of GDP for the analyzed countries[8] shares a common nonlinearity that is identified with the cyclical component of the American GDP, which therefore acts as a common driving force.

Once the existence of a non-linear common component has been identified, a multivariate non-linear system can be estimated for the set of cycles analyzed under the restraint of the existence of that non-linear common component. Estimating an economic system with common components offers two clear advantages. First, it allows for greater parsimony, which is especially important in the case of non-linear multivariate systems,

[8]Japan has been excluded from this analysis since the linearity test fails to reject the null on the linearity of the Japanese cycle with respect the American one

and, second, knowledge about these common components can also help to understand economic linkages between variables. Table 5 presents the estimated nonlinear system where, according to the result from the common nonlinear test, the transition variable in the transition function is the first lag of the American business cycle.

The common LSTAR transition function appears at the bottom of Table 5, and Figure 8 plots this function (on the vertical axis) against the lagged value of the American business cycle. There seem to be a reasonable number of observations above and below the equilibrium, so we can be reasonably confident about our selection of the LSTAR specification. It is clear, however, that observations are rather clustered in the upper regime, that is, when $F(\gamma, x_{t-d})$=1, so that the dynamics are governed by the sum of the coefficients of both AR branches in (1), that is, $(\phi_i + \tilde{\phi}_i)$. The dominant roots of the upper regimes are locally stable (i.e., the modulus of the unit root are below one), with the only exception of China, which presents a unit root in the upper regime. This might reflect the persistent and high growth of the Chinese economy during the last twenty years.

Figure 9 presents the transition function over time. The dashed areas represents the US economic recession according to the NBER. It is easy to see that the upper regime, $F(\gamma, x_{t-d})$=1, corresponds to periods of economic expansion, whereas the lower regime, $F(\gamma, x_{t-d})$=0, corresponds to periods of economic recession. Even more important, the estimated transition function accurately reproduces each of the periods in which the

American economy went into a recession. The fact that our model captures these important episodes well highlights the importance of the nonlinear models against the linear ones in terms of explaining business cycle co-movements, as well as the robustness of our estimated model.

Although the business cycle of the countries that were analyzed show co-movement, this does not mean that all the countries in the sample react to fluctuations in the American business cycle in the same way. In order to see the extent to which each country reacts to the American cycle, dynamic stochastic simulations must be performed. The standard tool for measuring dynamic adjustment in response to shocks is the impulse response function. The properties of impulse response functions for linear models do not hold for nonlinear models. In particular, the impulse response function of a linear model is invariant with respect to the initial conditions and to future innovations. With nonlinear models, in contrast, the shape of the impulse response function is not independent with respect to either the history of the system at the time the shock occurs, the size of the shock considered, or the future path of the exogenous innovations (Koop, Pesaran and Potter, 1996). In this paper we calculate the impulse response functions by Monte Carlo integration. Figure 10 plots the impulse response function for a positive and negative shock of one standard deviation of the American business cycle, that is, the transition function.[9] There is a clear asymmetric response to positive and negative shocks. The negative shocks are transmitted to the other economies in a far more intense manner

[9] All responses are significant, confidence bands are not plotted.

than the positive shocks. Furthermore, there are important differences among countries. The United Kingdom is clearly the country that is most severely affected by the changes in the American business cycle, whereas China is situated at the opposite end of the scale since it is only very moderately affected by the American business cycle. These findings significantly modulate the degree of cyclical synchronicity between China and the USA. Although at first we obtained evidence in favor of a certain degree of cyclical co-movement, the analysis of the dynamic response allows us to conclude that the degree of synchronicity is rather low.

5 Conclusion

In recent years there has been a considerable amount of debate over the extent to which shocks in the American economy are transmitted to other countries. Increased trade and financial integration, among other forms of economic integration, may have acted as mechanisms of transmission of fluctuations in the American business cycle. A slowdown in US growth is often the precursor to turning points in economic activity that might spill over into other countries. Against this backdrop, it is argued that some countries, particularly China, can "decouple" from the US economy and sustain strong growth in the face of a US slowdown.

In this paper we try to analyze the extent to which the US economy affects international business fluctuations. Since contractions in an economy are quicker and steeper but also shorter-lived than expansions, we adopt a non-linear framework to capture the business cycle asymmetries properly in order to identify the synchronization behavior across countries. A multivariate non-linear LSTAR model is estimated for the cyclical component of the Chinese, German, French, British and American growth of GDP. Our results suggest that the cycle of each of the countries shows non-linearities and that such linearities are linked to the behavior of the American business cycle, which acts as a non-linear common component. Even more important, the estimated transition function accurately reproduces each of the periods in which the American economy went into a recession. The fact that our model captures these important episodes well highlights the importance of the non-linear models against the linear ones in terms of their ability to explain business cycle co-movements, as well as the robustness of our estimated model.

In order to see the extent to which each country reacts to the American cycle, dynamic stochastic simulations must be performed. The impulse response functions show a clear asymmetry before positive and negative shocks. There are also important differences among countries. For example, while the UK clearly responds to shocks in the American business cycle, thereby displaying an obvious cyclical synchronicity, China's response is far more modest.

References

[1] Anderson, H. M. and F. Vahid (1998): "Testing multiple equation systems for common

nonlinear components", *Journal of Econometrics* 84, pp. 1-36.

[2] Arango, L and Melo, L (2006): "Expansions and contractions in Brazil, Colombia and Mexico: A view through nonlinear models", *Journal of Development Economics* 80, pp. 501-517.

[3] Baxter, M. and King, R.G. (1999): " Measuring business cycles: approximate bandpass filters for economic time series". *Review of Economics and Statistics* 81(4): 575?593.

[4] Baxter, M. and Kouparitsas, M. (2005): "Determinants of business cycle comovement: a robust analysis", *Journal of Monetary Economics* 52, pp. 113-157.

[5] Bordo, M.D. and Helbling, T. (2003): "Have national business cycles become more synchronized?", NBER Working Paper No. 10130.

[6] Burns, A.F. and Mitchell, W.A. (1946): "Measuring business cycles", (NBER, New York).

[7] Calderón, C., Chong, A. and Stein, E. (2007): "Trade intensity and business cycle synchronization: are developing countries any different?", *Journal of International Economics* 71, pp. 2-21.

[8] Clark, T.E. and E. van Wincoop (2001): "Borders and business cycles", *Journal of International Economics* 55, pp. 59-85.

[9] De Grauwe, P. (2008): "The Euro at ten: achievements and challenges", *Empirica*, 36, pp. 5-20.

[10] Doyle, B. and Faust, J. (2002): "An investigation of co-movements among the growth rates of the G-7 countries", Federal Reserve Bulletin, October, Federal Reserve Board.

[11] Fatás, A. (1997): "EMU: Countries or regions?", *European Economic Review*, 41, pp- 753-60.

[12] Fidrmuc, J., Korhonen, L. and Bátorová, I. (2008): " China in the world economy: Dynamic correlation analysis of business cycles", BOFIT Discussion Papers 7/2008.

[13] Frankel, J.A. and Rose, A.K. (1998):"The endogeneity of the optimum currency area criteria", *Economic Journal* 108, pp. 1009-1025.

[14] Friedman, M. (1964): Monetary Studies of the National Bureau, the National Bureau enters its 45th Year, 44th Annual Report, 7-25 (NBER, New York); Reprinted in Friedman, M., 1969, The optimum quantity of money and other essays (Aldine, Chicago).

[15] Friedman,, M. (1993): "The plucking model of business fluctuations revisited", *Economic Inquiry* 31, 171-177.

[16] Gordon, J. R. (2010): "The Demise of Okun´s Law and of Procyclical Fluctuations in Conventional and Unconventional Measures of Productivity", Northwestern University, mimeo.

[17] Granger, C. W. J. (1993): "Strategies for modelling nonlinear time-series relationships", *The Economic Record*, 69, pp. 233-238.

[18] Granger C. W. J. and T. Teräsvirta (1993): *Modelling Nonlinear Economic Relationships*, Oxford University Press, Oxford.

[19] Hamilton, J.D. (1989): "A new approach to the economic analysis of nonstationary time series and the business cycle", *Econometrica*, 57, pp. 357-384.

[20] Helbling, T. and T. Bayoumi (2003): "Are They All in the Same Boat? The 2000-2001 Growth Slowdown and the G-7 Business Cycle Linkages", IMF Working Paper 03/46. Washington: International Monetary Fund.

[21] International Monetary Fund (2007): "Decoupling the Train? Spillovers and Cycles in the Global Economy", *World Economic Outlook*. April. pp. 121-160.

[22] Inklaar, R., Jong-A-Pin, R. and de Haan, J. (2008): "Trade and business cycle synchronization in OECD countries, a re-examination", *European Economic Review* 52, pp.646-666.

[23] Imbs, J. (2004): "Trade, finance, specialization and synchronization", *Review of Economics and Statistics* 86, pp. 723-734.

[24] Kalemli-Ozcan, S., Sorensen B., and Yosha O. (2001): "Economic Integration, Industrial Specialization, and the Asymmetry of Macroeconomic Fluctuations", *Journal of International Economics*, 33. pp.107-137.

[25] Kapetianos, G., Y. Shin and A. Snell (2003): "Testing for a unit root in the nonlinear STAR framework", *Journal of Econometrics* 112, pp. 359-379.

[26] Keynes, J. M. (1936): *The General Theory of Employment, Interest and Money*, Macmillan, London.

[27] Kim S., Lee J-W. and Park C-Y. (2009): "Emerging Asia: Decoupling or Recoupling", Asian Development Bank Working Paper Series on Regional Economic Integration, No. 31.

[28] Koop, G., Pesaran H. and Potter S. M. (1996): "Impulse response analysis in nonlinear multivariate models", *Journal of Econometrics*, 74, pp. 119-147.

[29] Kose, M. A., Otrok, C. and Prasad E. (2008): "Global Business Cycles: Convergence or Decoupling?", NBER Working Paper No. 14292.

[30] Kose, M.A. and Yi K. (2002): "The Trade Comovement Problem in International Macroeconomics", Federal Reserve Bank of New York Staff Reports 155.

[31] Krugman, P. (1993): "Lessons of Massachusetts for EMU", In Torres, F. and F. Giavazzi(eds.), *Adjustment and growth in the European Monetary Union.* Oxford; New York and Melbourne: Cambridge University Press.

[32] Péguin-Feissolle, A., and Terasvirta, T. (1999): "A general framework for testing the Granger noncausality hypothesis", Working Paper Series in Economics and Finance, Stockholm School of Economics No. 343.

[33] Shermman H. J. and Kolk DX. (1996): *Business cycle and Forecasting.* Harper Collins College Publishers: New York.

[34] Sollis, R. (2009): "A simple unit root test against asymmetric STAR nonlinearity with an application to real exchange rate in Nordic countries", *Economic Modelling* 26, pp. 118-125.

[35] Stock, J.H. and Watson, M.W. (2003): "Understanding changes in international business cycle dynamics", NBER Working Paper No. 9859.

[36] Tong, H (1978): "On a threshold model". In C.H. Chen (ed.), *Pattern Recognition and Signal Processing*, Sijhoff and Noordhoff, Amsterdam

[37] Teräsvirta T. (1994): "Specification, estimation and evaluation of smooth transition autoregressive models", *Journal of the American Statistical Association*, vol. 89, pp. 208-18.

[38] Teräsvirta, T. and Anderson, H M, (1992): “Characterizing Nonlinearities in Business Cycles Using Smooth Transition Autoregressive Models”, *Journal of Applied Econometrics* 7(S), p.p. S119-36.

[39] Van Dijk, D. Teräsvirta, T. and Frances, P. (2002): “Smooth Transition Autoregressive Models- A Survey Of Recent Developments”, *Econometrics Review* 21, pp. 1-47.

[40] Wälti, S. (2009): “The Myth of Decoupling”, Swiss National Bank.

Table 1: Granger linear causality test

USA does not Granger-cause:					
Lags	China	France	Germany	Japan	UK
4	**0.089**	**0.001**	0.534	0.217	**0.003**
8	**0.075**	**0.005**	0.223	**0.048**	**0.005**
China does not Granger-cause:					
Lags	France	Germany	Japan	UK	USA
4	0.557	0.289	0.587	0.158	0.207
8	**0.091**	0.298	0.458	**0.033**	**0.012**
Germany does not Granger-cause:					
Lags	China	France	Japan	UK	USA
4	0.856	0.161	0.301	0.916	0.842
8	0.884	0.203	0.583	0.266	0.750

Notes: P-values for the F test are reported. Figure in bold implies rejection of the null of absence of causality at the 10% significance level.

Table 2: Granger nonlinear causality test

USA does not Granger-cause:					
Lags	China	France	Germany	Japan	UK
4	**0.000**	**0.000**	**0.081**	**0.092**	**0.000**
China does not Granger-cause:					
Lags	France	Germany	Japan	UK	USA
4	**0.000**	**0.000**	**0.034**	**0.000**	0.150
Germany does not Granger-cause:					
Lags	China	France	Japan	UK	USA
4	0.254	0.161	0.128	0.310	0.204

Notes: P-values for the F test are reported. Figure in bold implies rejection of the null of absence of causality at the 10% significance level.

Table 3: Linearity test

	Linearity Test	H_{01}	H_{02}	H_{03}
China	0.000	0.061	0.506	0.000
France	0.000	0.000	0.019	0.262
Germany	0.036	0.046	0.368	0.098
Japan	0.208	0.107	0.743	0.174
USA	0.000	0.488	0.342	0.000
UK	0.000	0.003	0.198	0.000

Note: p-values are shown. Transition variable USA. Delay parameter d=1. Prob is the p-value associated to the null of linearity.

Table 4: Test for common LSTAR nonlinearities

Null hypothesis	Alternative hypothesis	p-value
The system is linear	At least one of the variables has a LSTAR nonlinearity	0.026
The system has at most 1 common LSTAR nonlinearity	The system has at least 2 common LSTAR nonlinearities	0.129
The system has at most 2 common LSTAR nonlinearities	The system has at least 3 common LSTAR nonlinearities	0.489
The system has at most 3 common LSTAR nonlinearities	The system has at least 4 common LSTAR nonlinearities	0.887
The system has at most 4 common LSTAR nonlinearities	The system has at least 5 common LSTAR nonlinearities	0.998

Table 5: Estimated nonlinear system

$$Dchi_t = \underset{(0.07)}{1.72} Dchi_{t-1} - \underset{(0.07)}{0.71} Dchi_{t-2} + (\underset{(0.01)}{0.01} + \underset{(0.09)}{0.19} Dchi_{t-1} - \underset{(0.09)}{0.27} Dchi_{t-2}) \; \times F(Dusa_{t-1}) + \epsilon_{1t}$$

$$Dusa_t = \underset{(0.07)}{1.19} Dusa_{t-1} - \underset{(0.10)}{0.59} Dusa_{t-2} + (\underset{(0.11)}{0.36} Dusa_{t-1}) \; \times F(Dusa_{t-1}) + \epsilon_{2t}$$

$$Dger_t = \underset{(0.08)}{0.99} Dger_{t-1} + (\underset{(0.02)}{0.01} - \underset{(0.12)}{0.27} Dger_{t-2}) \; \times F(Dusa_{t-1}) + \epsilon_{3t}$$

$$Dfra_t = -\underset{(0.07)}{0.01} + \underset{(0.14)}{0.61} Dfra_{t-1} + (\underset{(0.01)}{0.02} + \underset{(0.12)}{0.20} Dfra_{t-1}) \; \times F(Dusa_{t-1}) + \epsilon_{4t}$$

$$Duk_t = -\underset{(0.01)}{0.01} + \underset{(0.12)}{0.46} Duk_{t-1} + \underset{(0.13)}{0.37} Duk_{t-2} +$$
$$+(\underset{(0.01)}{0.02} + \underset{(0.11)}{0.24} Duk_{t-1} - \underset{(0.21)}{0.44} Duk_{t-2}) \; \times F(Dusa_{t-1}) + \epsilon_{4t}$$

where: $F(Dusa_{t-1}) = (1 + exp[-\underset{(0.67)}{1,90}\, Dusa_{t-1}])^{-1}$

Figure 1: Cyclical GDP components

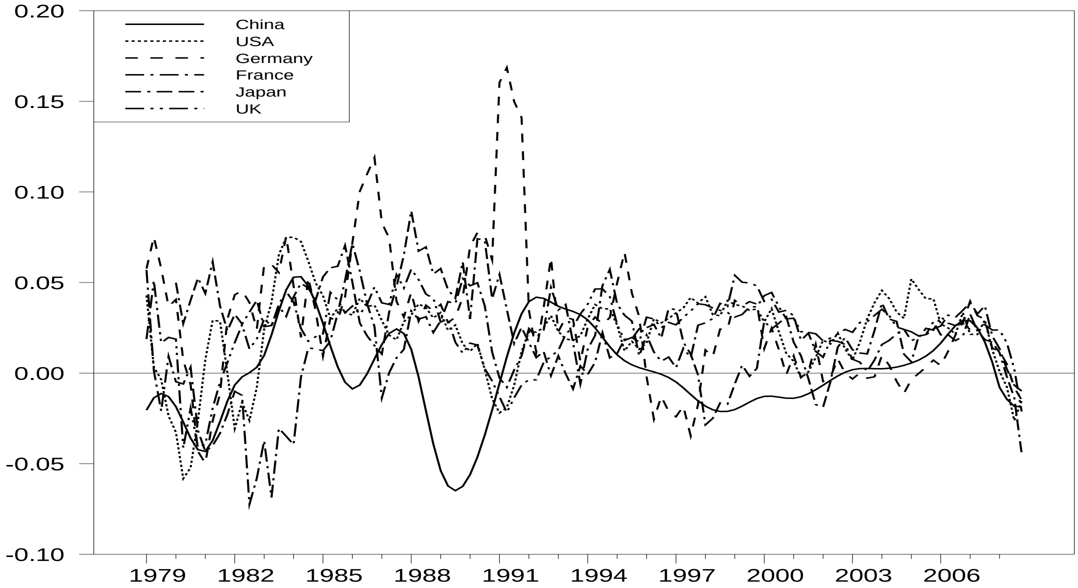
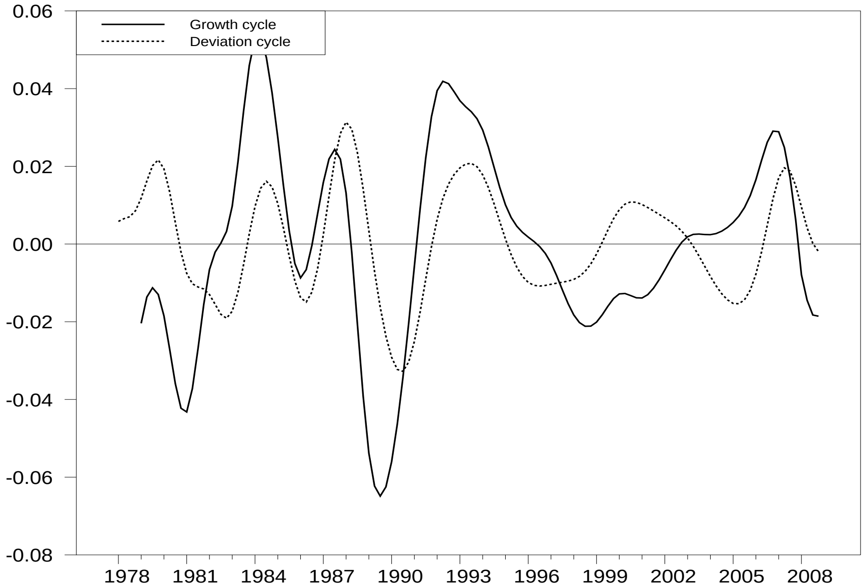
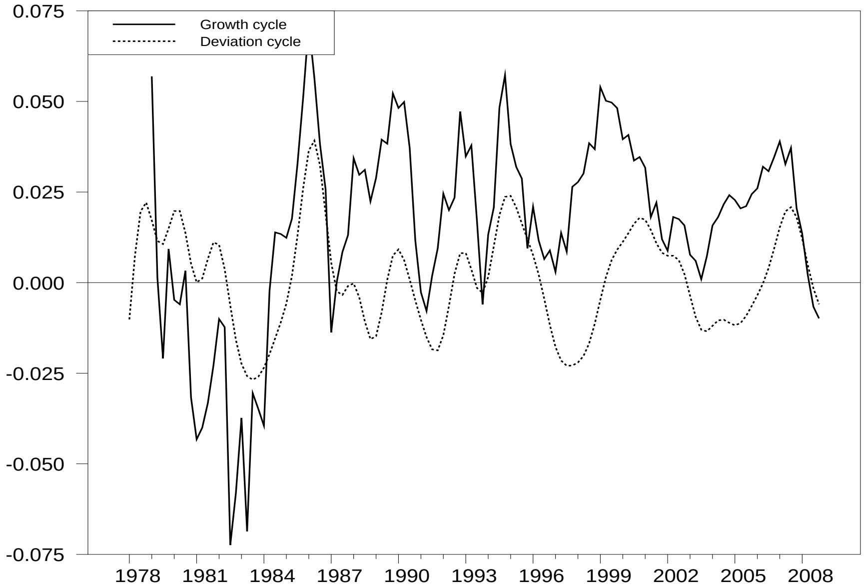


Figure 2: Growth and deviation cycles (I)

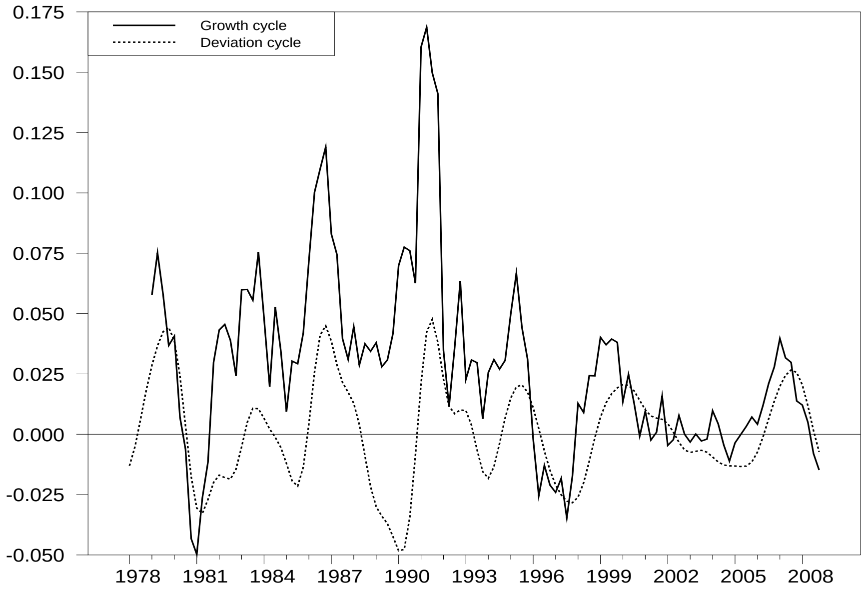


(a) **China**

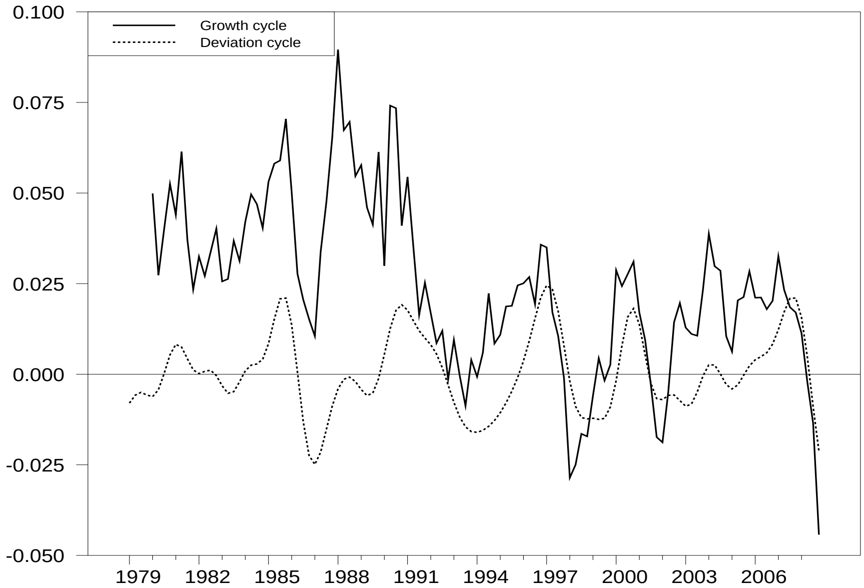


(b) **France**

Figure 3: Growth and deviation cycles (II)

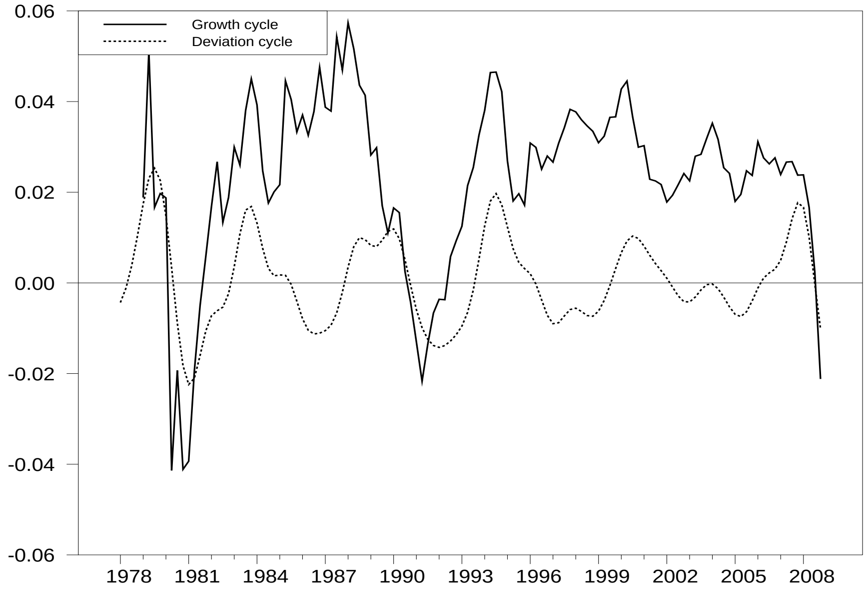


(a) **Germany**

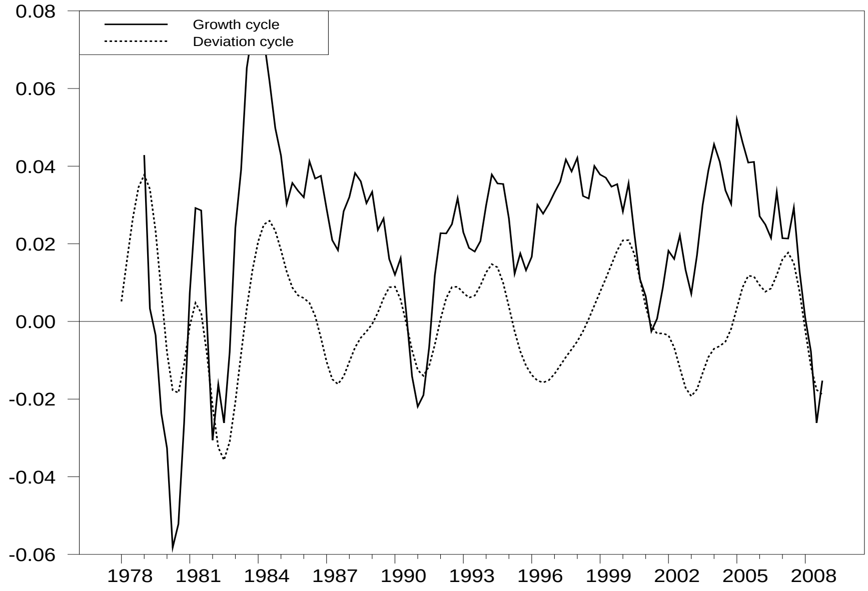


(b) **Japan**

Figure 4: Growth and deviation cycles (III)

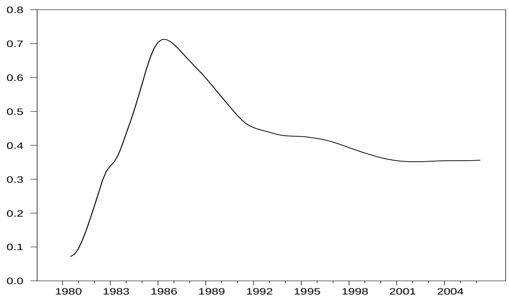


(a) **UK**



(b) **USA**

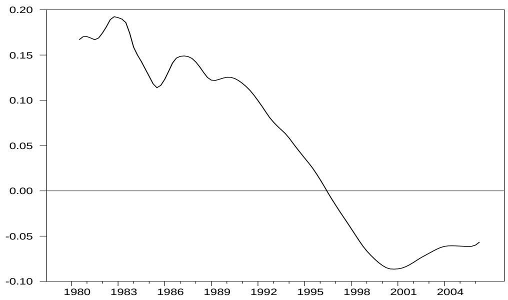
Figure 5: Time Path for contemporaneous correlations (USA)



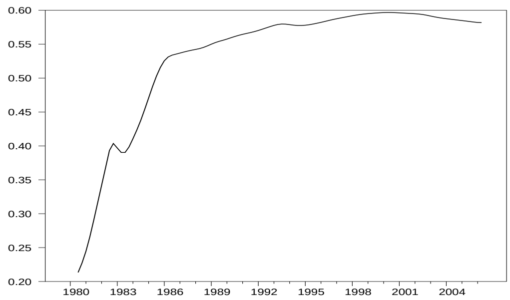
(a) **China**

(b) **France**

(c) **Germany**

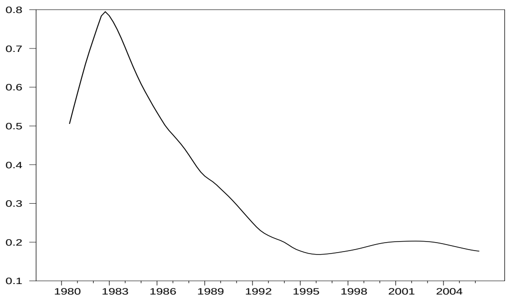


(d) **Japan**



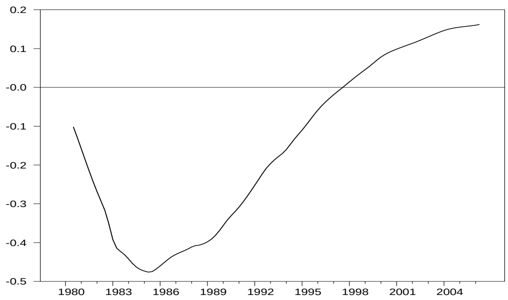
(e) **UK**

Figure 6: Time Path for contemporaneous correlations (Germany)



(a) **China**

(b) **France**



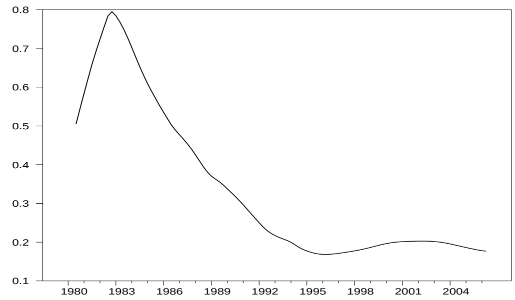
(c) **Japan**

(d) **UK**

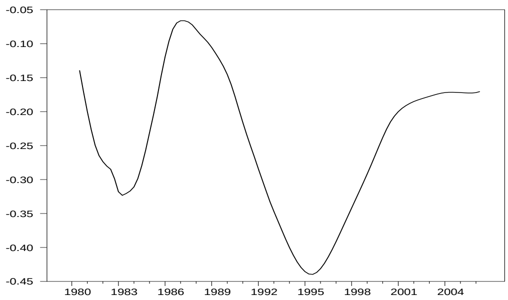
(e) **USA**

Figure 7: Time Path for contemporaneous correlations (China)

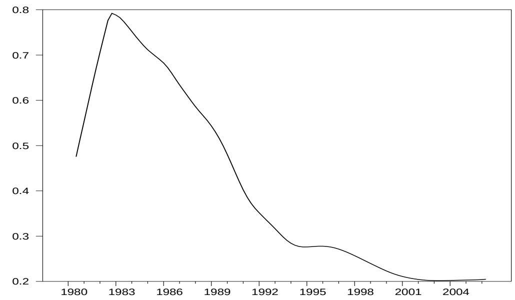
(a) **France**



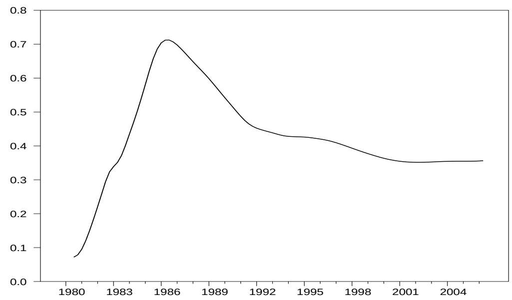
(b) **Germany**



(c) **Japan**



(d) **UK**



(e) **USA**

Figure 8: Transition function

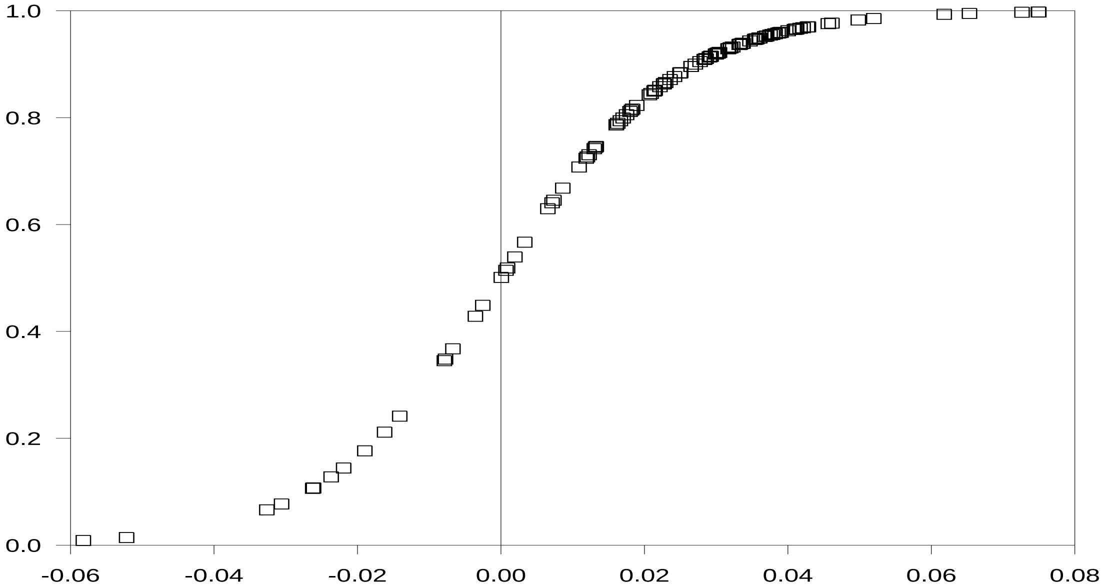


Figure 9: Transition function versus time

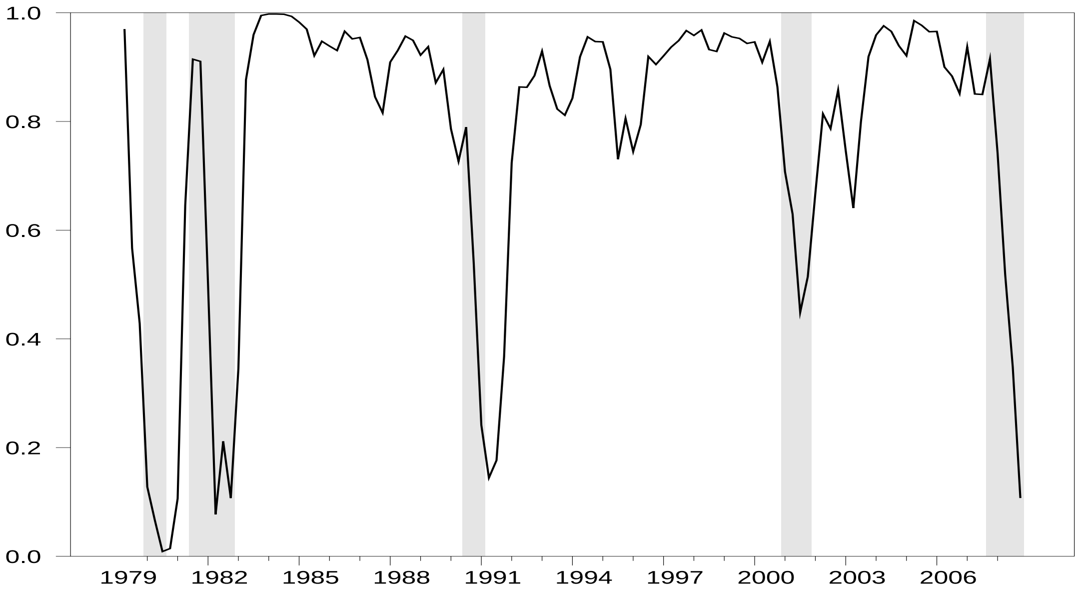


Figure 10: Impulse response functions