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The transmission of US cyclical developments to the rest of the world

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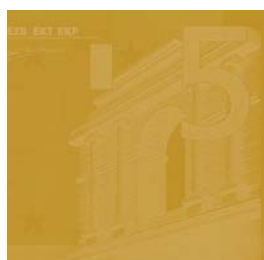
THE TRANSMISSION OF US CYCLICAL DEVELOPMENTS TO THE REST OF THE WORLD

by Stéphane Dées
and Isabel Vansteenkiste



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by Stéphane Dées ²
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Abstract

The US economy is often considered to play a pivotal role in global growth. Such a view has persisted despite the falling contribution of the US economy to global growth (from almost 30% in 1950 to around 20% at present). In this paper, we analyse the veracity of this conjecture and consider the implications of cyclical developments in the US economy on the rest of the world. Overall we find that while US economic developments would indeed affect the rest of the world, developments in most countries and regions remain primarily affected by idiosyncratic shocks as well as by global factors, which do not originate from a single country.

Keywords: *Business Cycle, Global VAR model, Markov-switching model, Factor models.*

JEL Classification: *E32, E37, F41*

Non-technical summary

The US economy is often considered to play a pivotal role in global growth. Such a view has persisted despite the falling contribution of the US economy to global growth (from almost 30% in 1950 to around 20% at present). In this paper, we analyse the veracity of this conjecture and consider the implications of a slowdown in the US economy on the rest of the world. Overall we find that while a slowdown in the US economy would indeed negatively affect the rest of the world, developments in most countries and regions remain primarily affected by idiosyncratic shocks as well as by global factors, which do not originate from a single country.

In this paper, we go beyond the existing studies by considering, for a range of regions of the world the following three aspects: (i) the magnitude and (ii) the speed at which US shocks transmit to other parts of the world as well as (iii) the underlying causes of the co-movements between the US and other regions.

Our main findings are:

- The US business cycle leads that of the other regions, except in the case of the Asian region whose business cycle appears to have moved independently in the past. The latter case is partly explained by the increasing contribution of China, whose economic growth has largely remained independent of the economic cycles of its main trading partners. The increasing trade integration within the region may possibly also make the Asian economies more immune from developments in the rest of the world.
- For all regions, except emerging Asia, linkages with the US appear stronger than suggested by pure bilateral trade channels. In more detail, for the euro area it is estimated that a 1 pp of GDP negative US demand shock would decrease euro area GDP by slightly over 0.25 pp while if we consider only bilateral trade relations it would depress euro area GDP only by 0.1 pp.
- A negative shock to the US economy transmits faster than a positive one, with a high US growth phase taking between 2 to 10 quarters to spill over and a low growth phase between 1 and 3 quarters.
- Finally, looking at the factors affecting regional developments, we confirm the results of the existing literature in that common and country/region specific shocks appear to have played a larger role in determining GDP fluctuations than inter-regional spillovers do.

1 Introduction

Many observers worry that when the US economy sneezes, the rest of the world catches a cold. A quick glance at the data seems to provide some tentative support for this view at least in the recent period, since the growth rates of the world excluding the US seem to be moving similarly to the one of the US – albeit not in lockstep (see Figure 1).¹ The 5-year rolling correlation between the US and the world's GDP growth excluding the US confirms an increased importance of the US economy to the world's business cycle despite the US decreasing contribution to global growth (from almost 30% in 1950² to around 20% currently).

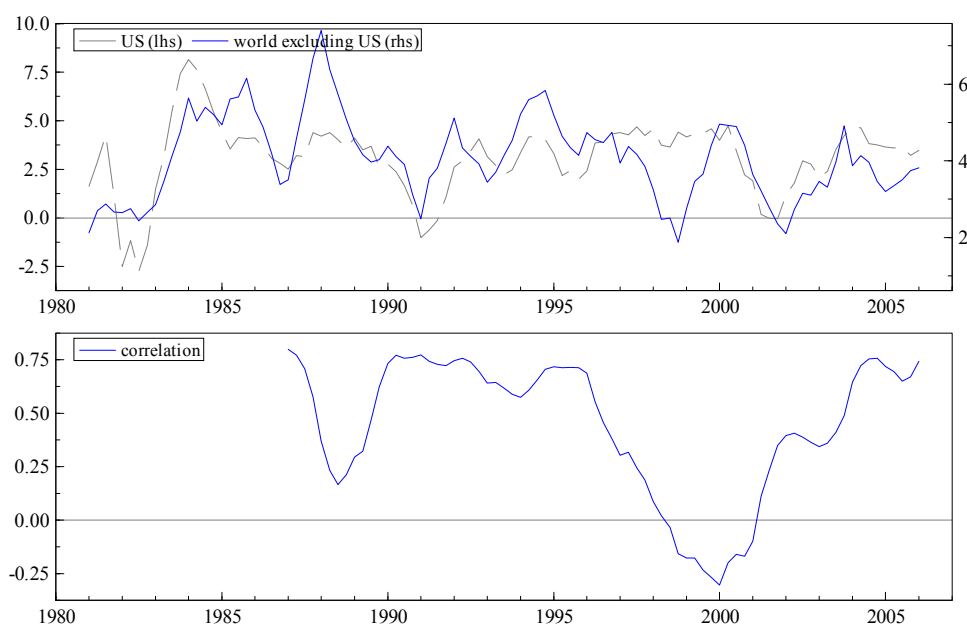


Figure 1: US and world excluding US real GDP growth (top panel) and the 5 year rolling correlation thereof (bottom panel)

Such strong comovements are difficult to explain in terms of trade linkages alone. Indeed, while trade integration and trade flows have increased further globally, the impact of trade developments on regions' GDP growth remains too limited to explain the recent global correlation between the US growth and the world's GDP excluding the US. New channels such as financial or confidence channels should have played an important role. From a policy making perspective the ability to gauge the timing and the magnitude of spillovers in economic activity across the various regions in the world is of particular relevance as it contributes to better assess the developments in the own domestic economy. It is therefore important to determine the speed and size of the

¹Note that the negative correlation which occurred around 1998-1999 can at least partly be attributed to the Asian crisis. Indeed, when considering rest of the world growth as measured by global growth excluding US and non-Japan Asia, the correlation with US real GDP growth is no longer negative but reaches around 0.2 for this period.

²See Maddison (1995).

spillovers that could occur following a shock originating from the US economy. For this purpose, in this paper we examine the comovements between the US and the world excluding the US over the past twenty-five years.³

In order to analyse the impact of US economic developments on the world excluding the US, we review first the empirical literature on the business cycle linkages between the United States and the world excluding the US. Next, we present our own empirical findings focussing on three aspects of the sensitivity of the global economy to the US namely (i) the magnitude of the sensitivity of the global economy to US shocks, (ii) the speed at which such US shocks are transmitted and (iii) the underlying causes of the comovements between the US and the other regions. To quantify the sensitivity of the global economy to the US we first consider the trade linkages and integrate thereafter other factors (such as financial and confidence channels) that may have influenced the linkages. To gauge the overall effect, we rely on a Global VAR model. This allows us to consistently model interdependencies and measure them empirically. As regards the speed of the shocks, we make use of a non-linear Markov-switching model. Such a model is particularly useful as it enables us to determine not only whether or not the US business cycle leads other regions' cycle but it also allows for the possibility that positive US shocks are transmitted at a different speed than negative shocks. Finally, to determine the causes of the linkages, a decomposition of the variance of GDP cycles into three sources is provided (namely into common, spillover and idiosyncratic shocks) by means of a Factor Structural VAR. We prefer this approach to alternatives, such as decomposing business cycle fluctuations into regional, global and idiosyncratic shocks as we are mostly interested in the role of spillovers. In all cases, the analysis is performed for seven regions of the world, namely the euro area, Japan, Latin America, Emerging Asia, Other Developed Economies (Canada-Australia-New Zealand), the United Kingdom and the Rest of Europe (Switzerland, Norway, Sweden and Denmark).

2 Review of existing findings and studies

International business cycle linkages have been the subject of a plethora of works using a wide range of techniques going from calculating simply cross correlations to unobserved components and dynamic factor models to uncover the characteristics as well as the degree of synchronisation of economic activity fluctuations in industrialised countries.

The earlier works – making mostly use of the cross correlations of real activity growth rates – focussed on analysing the degree of integration between industrial economies. In general, these studies found that albeit high, the correlation of growth rates among G7 economies has not increased over time, despite increased integration of the industrial economies through more trade in goods and services and more global financial markets (see Doyle and Faust, 2002).

In order to explain the stable correlation despite the increased global integration, a next strand of studies focussed on different methodologies that allow for a distinction between movements in GDP driven by common factors and cross country spillover effects. In this vein, Stock and Watson (2003) use a structural VAR to identify common international shocks and the effects of spillovers stemming from country-specific or

³We consider developments over the longest time period possible (namely from 1979Q1 to 2003Q4) for which we have reliable data for the various regions of the world.

idiosyncratic shocks. They confirm that no increase in the synchronization of business cycles among the G7 countries has been observed (over the period covering the 1960s to the end of 2002). They explain this regularity by the fact that there has been a decrease in the prominence and size of common shocks to the global economy. Interestingly, however, correlations appear to have increased among English-speaking countries. Commonality in cycles among Germany, France and Italy on the one hand and the US, UK and Canada on the other hand is also found by Duarte and Holden (2003). They also decompose real GDP of the G7 countries into cyclical and trend components and then use the resulting series of cyclical components to identify static, long-run and short-run relationships by using various statistical techniques. Using such techniques they found commonalities in cycles among Germany, France, Italy on the one hand and the US, UK and Canada on the other hand.

Monfort et al. (2003) find, by estimating a dynamic factor model for the G7 countries, that the output developments in G7 countries are driven to a substantial extent by common shocks.⁴ As regards the main source of common shocks, the authors attribute a significant role to oil price fluctuations. Other similar decompositions have also been presented by Canova and Marriman (1998), Lumsdaine and Prasad (2003) and Kose et al. (2003). All studies uncover the presence of a world business cycle which is an important source of volatility for aggregates in most countries.

Beyond distinguishing between common and idiosyncratic shocks, the literature has also devoted significant attention to the importance and direction of spillover effects. Overall, a consensus appears to arise that spillover effects tend to run from North America to the rest of the world but not in the opposite direction (see Dassel (2002), Monfort et al. (2003) and Papanyan (2005) and Gianonne and Reichlin (2006)).⁵ Moreover, Osborn et al. (2005) find that lower growth regimes from the US seem to be more readily transmitted to the other G7 countries than higher growth regimes. Mitra and Sinclair (2006), by adopting a multivariate correlated unobserved components model, find however, that while linkages between the US and the UK and Canada are positive, they could not find such linkages between the US and European countries.

Taken together, the empirical literature suggests that a large role can be attributed to common shocks in explaining the co-movement of business cycles and that spillovers, if present, run from the US to the other countries but not in the opposite direction.

3 Measuring the size of the sensitivity of the global economy to US economic developments

As mentioned in the introduction, we focus on three aspects of the sensitivity of the global economy to the United States, namely the magnitude, the speed and the underlying causes. In this section, we use various methods to determine the first aspect, namely the magnitude of the sensitivity of the various regions in the global economy to US developments. We focus hereby on demand shocks originating from the US and de-

⁴Giannone and Reichlin (2006) find similar results when comparing the US and euro area cycles.

⁵An exception to these results can be found in Osborn, Perez and Artis (2006) who show that the US economy has been increasingly affected by external shocks, particularly those stemming from the EU, whereas the effects of US shocks on the EU seem to have been stronger in the 1970s and from the mid-1990s onwards.

compose trade effects from overall effects. First we look into the direct trade effects and also consider the extent to which these could be amplified through second-round and third-country effects. Second, we compare these trade effects to the overall effects that account also for additional channels, such as financial linkages. The latter is measured by means of a global VAR model (GVAR) as estimated in Dees et al. (2007).

3.1 Trade effects

3.1.1 Modelling direct trade effects and "echo effects"

The calculations of trade effects are based on the assumptions that economic policies do not lean against the demand shocks and that all prices and exchange rates are fixed⁶. Consequently, the multipliers represent the short-term responses of the world economy and are not relevant concerning long term impacts. We compute first direct trade effects, which are related to the effects only channeled by bilateral trade relationships between the countries where the shock originates and its trade partners. In a second step, we compute "echo effects" (or indirect trade effect), which involve the third markets trade channels⁷. In other words, we try to measure how the response of exports and imports in third markets amplifies the transmission of demand shock from one country to another.

The external trade transmission of a foreign domestic demand shock to country j , ($j = 1, \dots, N$) depends on three factors.

- The shares of trade and domestic demand in GDP: we denote DD_j^Y , X_j^Y and M_j^Y the respective shares of domestic demand, exports and imports.
- The elasticity of domestic demand and imports to GDP (respectively α_j^{DD} and α_j^M).
- The geographical breakdown of exports. We denote x_{ji} exports of country j to country i as a share of country j exports.

For each country j , the response of GDP $\hat{y}_j$ (as a percentage point of baseline) to a domestic demand shock $\hat{\epsilon}_j$ and to exports fluctuations $\hat{x}_j$ is given by

$$\hat{y}_j = \mu_j X_j^Y \hat{x}_j + \mu_j \hat{\epsilon}_j \quad (1)$$

where

$$\mu_j = \frac{1}{\left(1 - DD_j^Y \alpha_j^{DD} + M_j^Y \alpha_j^M\right)}$$

is the traditional Keynesian multiplier.

If exports remain constant, a 1% point of GDP shock on domestic demand ex ante leads to $\mu_j\%$ increase in GDP ex post. This corresponds to the output multiplier of a domestic demand shock in a small open economy for which the rest of the world can be considered exogenous. Similarly, if total exports move up by 1%, GDP increases by $\mu_j X_j^Y\%$.

⁶This *ceteris paribus* condition allows us to only capture pure trade volume effects.

⁷This third market effect is therefore not comparable with the third markets competitive pressure measured by the double weighting scheme used to compute effective exchange rates. These latter static indicators weight the average market share of a trade partner on third markets by the exports geographical structure of the country under competition: this is meant to assess the impact on total price competitiveness of fluctuations in any trade partner prices.

Moreover, in this simple case, exports $\hat{x}_j$ are exclusively determined by world demand as relative prices are assumed to be constant:

$$\hat{x}_j = \sum_i x_{ji} \alpha_i^M \hat{y}_i \quad (2)$$

Stacking equation (1) for all the N countries, we obtain the following matrix representation:

$$\hat{Y} = X\hat{Y} + \hat{\varepsilon} \quad (3)$$

where $\hat{Y} = (\hat{y}_j)$, $\hat{\varepsilon} = (\mu_j \hat{\varepsilon}_j)$ and $X = \left(\mu_j X_j^Y x_{ji} \alpha_i^M \right)_{ji}$ with of course $x_{jj} = 0$.

From equation (3), we can derive two indicators of direct and indirect trade effects of domestic demand shocks.

The **direct trade effects** of 1 pp of GDP shocks within the main countries/regions of the world are given by the matrix X .

More precisely, the bilateral trade impact of a shock in country i to country j is given by $\mu_j X_j^Y x_{ji} \alpha_i^M$. 1 pp of GDP increase in country i stimulates imports demand up to $\alpha_i^M\%$, which then increases country j exports by $x_{ji} \alpha_i^M\%$. Higher exports translates into GDP improvement in country j with the output multiplier $\mu_j X_j^Y$.

The **full transmission of shocks including the "echo effect"** is otherwise taken from the matrix $(I - X)^{-1}$.

3.1.2 Empirical results

The calibration of the parameters used to compute the direct trade effects as well as the "echo effects" is presented in Table 2. The bilateral trade matrix used is reported in Table 1.

Table 1: Trade Weights Based on Direction of Trade Statistics

	US	EA	JP	UK	Rest Eur	ODE	Em Asia	Lat Am	Rest*
US	0	0.192	0.122	0.062	0.029	0.256	0.182	0.149	0.008
EA	0.174	0	0.052	0.255	0.218	0.039	0.132	0.038	0.092
Japan	0.327	0.147	0	0.037	0.019	0.052	0.395	0.019	0.004
UK	0.140	0.602	0.028	0	0.085	0.043	0.074	0.010	0.018
Rest Eur	0.082	0.503	0.034	0.112	0.144	0.027	0.061	0.013	0.024
ODE	0.540	0.068	0.140	0.034	0.011	0.013	0.179	0.011	0.004
Em Asia	0.236	0.190	0.150	0.057	0.022	0.041	0.271	0.014	0.019
Lat Am.	0.449	0.203	0.053	0.024	0.015	0.037	0.073	0.133	0.013

Note: Trade weights are computed as shares of exports and imports displayed in rows by region such that a row, but not a column, sums to one. *"Rest" gathers the remaining countries. The complete trade matrix used in the GVAR model is given in a Supplement that can be obtained from the authors on request. Source: Direction of Trade Statistics, 1999-2001, IMF.

The direct trade effects (Table 3) benefit mostly the main trading partners of the US economy, namely Other Developed Economies (ODE), emerging Asia and Latin America. The size of the direct effect is small for the euro area and the UK and marginal for the rest of Europe. However, the impact of changes in US economic conditions on

Table 2: Calibration of parameters for direct trade and "echo" effects

	X_j^Y	M_j^Y	α_j^{DD}	α_j^M	μ_j
US	0.11	0.14	0.6	2.1	1.4
EA	0.17	0.14	0.6	2.0	1.5
Japan	0.11	0.08	0.6	1.3	2
UK	0.27	0.29	0.6	1.9	1.1
Rest Eur	0.46	0.41	0.6	1.3	1.1
ODE	0.35	0.33	0.6	1.6	1.1
Em Asia	0.42	0.39	0.6	1.3	1.1
Lat Am.	0.20	0.21	0.6	1.4	1.4

Note: X_j^Y (M_j^Y) is the share of exports (imports) in GDP computed from national accounts data (sources: OECD and national sources). α_j^{DD} is the elasticity of domestic demand to GDP. It is assumed to be equal to 0.6. This calibration results in values for μ_j , the Keynesian multiplier, which is in a range consistent with most macroeconomic models. α_j^M is the elasticity of imports to GDP. The values are estimates of long-term elasticities to GDP in standard import demand equations, including real GDP and competitiveness indicators (estimation over the period 1980-2003).

Table 3: Trade impacts of a US domestic demand shock (by 1 p.p. of GDP) on GDP of other countries in percent/regions

Countries/regions	Direct trade effect	Trade effect incl. echo effect
Euro area	0.08 [0.05-0.08]	0.19 [0.13-0.22]
Japan	0.14 [0.09-0.16]	0.24 [0.14-0.27]
Latin America.	0.27 [0.20-0.29]	0.37 [0.25-0.41]
ODE	0.46 [0.30-0.49]	0.57 [0.36-0.62]
Emerging Asia	0.20 [0.13-0.22]	0.37 [0.22-0.42]
Rest of Europe	0.08 [0.05-0.08]	0.25 [0.14-0.29]
UK	0.08 [0.06-0.09]	0.19 [0.12-0.22]
US	1.00 [1.00-1.00]	1.11 [1.07-1.14]

Note: The point estimates of the trade effects (direct and incl. echo effect) correspond to the benchmark parameterisation reported in Table 2. The ranges have been computed as min-max intervals of alternative calibration for α_j^{DD} (the elasticity of domestic demand to GDP), varying between 0.5 and 0.7 and α_j^M (elasticity of imports to GDP), varying between 1 and 2.5



the other countries may be amplified through additional trade-related channels (namely, second-round and third-country effects). In particular, higher import demand from the US also benefits the exports of other countries which thereafter are expected to increase their imports. The dynamics created likewise produces an “echo effect” that propagates to the whole world economy. Once the “echo effect” is taken into account, the output elasticities to US demand changes increase, especially in countries and regions where the direct effect was the lowest. For the euro area and the UK, this elasticity is multiplied by 2. For the rest of Europe, the impact including the “echo effect” is 5 times higher than the direct one.

Table 3 also includes ranges in order to assess the sensitivity of the results to the calibration for α_j^{DD} (the elasticity of domestic demand to GDP), varying between 0.5 and 0.7 and α_j^M (elasticity of imports to GDP), varying between 1 and 2.5. Qualitatively, the results are robust to the calibration chosen. The benchmark values tend to be closer to the upper part of the range as the estimated value for α_j^M - which seems to matter the most - is generally close or higher than 2.

3.2 Overall effects

3.2.1 The GVAR model

In order to account for channels additional to trade, such as financial linkages, price adjustments and economic policy reactions, we use a global VAR model (GVAR) as estimated in Dees et al. (2007).

The GVAR approach consists of specifying and estimating a set of country-specific vector error-correcting models that are consistently combined to generate a global model that can be simultaneously solved for all the variables in the world economy. This approach addresses the problem of consistently modelling interdependencies among many economies through the construction of “foreign” variables, which are included in each individual country model. Thus, each country model includes domestic variables plus variables obtained from the aggregation of data on the foreign economies using weights derived from trade statistics. Because the set of weights for each country reflects its specific geographical trade composition, foreign variables vary across countries. Subject to appropriate testing, the country-specific foreign variables are treated as weakly exogenous during the estimation of the individual country models.

Suppose that there are $N + 1$ countries indexed by $i = 0, 1, \dots, N$, with $i = 0$ for the US, the numeraire country. The GVAR can be written as the collection of individual country VAR(p_i, q_i) models:

$$\Phi_i(L, p_i) \mathbf{x}_{it} = \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \Upsilon_i(L, q_i) \mathbf{d}_t + \Lambda_i(L, q_i) \mathbf{x}_{it}^* + \mathbf{u}_{it}, \quad (4)$$

where $\mathbf{x}_{it}$ is the $k_i \times 1$ (with k_i usually five or six) vector of modelled variables, $\mathbf{d}_t$ is the vector of observed international variables common to all countries, and $\mathbf{x}_{it}^*$ is the $k_i^* \times 1$ vector of foreign variables specific to country i . $\Phi_i(L, p_i)$ and $\Lambda_i(L, q_i)$ are the $k_i \times k_i$ and $k_i \times k_i^*$ matrix polynomials in the lag operator L of the coefficients of the domestic and country-specific foreign variables, respectively. $\mathbf{a}_{i0}$ and $\mathbf{a}_{i1}$ are the $k_i \times 1$ vectors of coefficients of the deterministic variables, here intercepts and linear trends. $\Upsilon_i(L, p_i)$ is the $k_i \times k^d$ matrix polynomial of coefficients of the international variables $\mathbf{d}_t$. $\mathbf{u}_{it}$ is a $k_i \times 1$ vector of idiosyncratic country-specific shocks.

The country-specific models can be consistently estimated separately, treating $\mathbf{x}_{it}^*$ as weakly exogenous, which is compatible with a certain degree of weak dependence across $\mathbf{u}_{it}$.⁸ The country-specific foreign variables $\mathbf{x}_{it}^*$ are constructed as country-specific trade-weighted averages over the values of the other countries

$$\mathbf{x}_{it}^* = \sum_{j=0}^N w_{ij} \mathbf{x}_{jt}, \text{ with } w_{ii} = 0, \quad (5)$$

where w_{ij} is the share of country j in the trade (exports plus imports) of country i .⁹

After selecting the lag length-order p_i and q_i for each country by means of the Akaike Information Criterion (allowing for a maximum lag-order of 2), the $\text{VAR}(p_i, q_i)$ models are estimated separately for each country, allowing for the possibility of cointegration among $\mathbf{x}_{it}$, $\mathbf{x}_{it}^*$ and $\mathbf{d}_t$.

Once the individual country models are estimated, all the $k = \sum_{i=0}^N k_i$ endogenous variables of the global economy, collected in the $k \times 1$ vector $\mathbf{x}_t = (\mathbf{x}'_{0t}, \mathbf{x}'_{1t}, \dots, \mathbf{x}'_{Nt})'$, are solved simultaneously. To do this (4) can be written as

$$\mathbf{A}_i(L, p_i, q_i) \mathbf{z}_{it} = \boldsymbol{\varphi}_{it}, \text{ for } i = 0, 1, 2, \dots, N \quad (6)$$

where

$$\begin{aligned} \mathbf{A}_i(L, p_i, q_i) &= [\boldsymbol{\Phi}_i(L, p_i), -\boldsymbol{\Lambda}_i(L, q_i)], \mathbf{z}_{it} = \begin{pmatrix} \mathbf{x}_{it} \\ \mathbf{x}_{it}^* \end{pmatrix}, \\ \boldsymbol{\varphi}_{it} &= \mathbf{a}_{i0} + \mathbf{a}_{i1}t + \Upsilon_i(L, q_i) \mathbf{d}_t + \mathbf{u}_{it}. \end{aligned}$$

Let $p = \max(p_0, p_1, \dots, p_N, q_0, q_1, \dots, q_N)$ and construct $\mathbf{A}_i(L, p)$ from $\mathbf{A}_i(L, p_i, q_i)$ by augmenting the $p - p_i$ or $p - q_i$ additional terms in powers of L by zeros. Also note that

$$\mathbf{z}_{it} = \mathbf{W}_i \mathbf{x}_t, \quad i = 0, 1, 2, \dots, N, \quad (7)$$

where $\mathbf{W}_i$ is a $(k_i + k_i^*) \times k$ matrix, defined by the country specific weights, w_{ji} .

With the above notations (6) can be written equivalently as

$$\mathbf{A}_i(L, p) \mathbf{W}_i \mathbf{x}_t = \boldsymbol{\varphi}_{it}, \quad i = 0, 1, \dots, N,$$

and then stack to yield the $\text{VAR}(p)$ model in $\mathbf{x}_t$:

$$\mathbf{G}(L, p) \mathbf{x}_t = \boldsymbol{\varphi}_t, \quad (8)$$

where

$$\mathbf{G}(L, p) = \begin{pmatrix} \mathbf{A}_0(L, p) \mathbf{W}_0 \\ \mathbf{A}_1(L, p) \mathbf{W}_1 \\ \vdots \\ \mathbf{A}_N(L, p) \mathbf{W}_N \end{pmatrix}, \quad \boldsymbol{\varphi}_t = \begin{pmatrix} \boldsymbol{\varphi}_{0t} \\ \boldsymbol{\varphi}_{1t} \\ \vdots \\ \boldsymbol{\varphi}_{Nt} \end{pmatrix}. \quad (9)$$

The $\text{GVAR}(p)$ model (8) can now be solved recursively and used for forecasting or generalized impulse response analysis in the usual manner.

⁸ For further details see DdPS.

⁹ See Appendix 1 for more details on the computation of the trade-based weights.

The GVAR model developed in Dees et al. (2007) covers 33 countries, where 8 of the 11 countries that originally joined Stage Three of European Monetary Union on 1 January 1999 are grouped together, while the remaining 25 countries are modeled individually.¹⁰ The present GVAR model, therefore, contains 26 countries/regions estimated over the sample period 1979(2)–2003(4).

The endogenous variables included in the GVAR, when available, are the logarithm of real output (y_{it}); the rate of quarterly inflation ($\pi_{it} = p_{it} - p_{it-1}$), with p_{it} the logarithm of a domestic price index; the real exchange rate ($e_{it} - p_{it}$), with e_{it} the logarithm of the nominal exchange rate against the dollar; the logarithm of real equity prices (q_{it}); a short-term interest rate ($\rho_{it}^S = 0.25 \times \ln(1 + R_{it}^S/100)$), where R_{it}^S is a short annualised rate of interest measured in percent; and a long-term interest rate ($\rho_{it}^L = 0.25 \times \ln(1 + R_{it}^L/100)$), where R_{it}^L is a long-term annualised rate of interest (typically a long-term government bond yield) measured in percent. The time series data for the euro area were constructed as cross section weighted averages of $y_{it}, \pi_{it}, q_{it}, \rho_{it}^S, \rho_{it}^L$ over Germany, France, Italy, Spain, Netherlands, Belgium, Austria and Finland, using average Purchasing Power Parity GDP weights over the 1999–2001 period.

The vector of common international variables $\mathbf{d}_t$ includes only the logarithm of oil prices. With the exception of the US model, all individual models include the country-specific foreign variables, $y_{it}^*, \pi_{it}^*, q_{it}^*, \rho_{it}^{*S}, \rho_{it}^{*L}$ and oil prices (p_t^o). Based on the results of appropriate tests, these variables are included as weakly exogenous. The specification of the US model differs from that of the other countries in that oil prices are included as an endogenous (rather exogenous) variable, while only $e_{US,t}^* - p_{US,t}^*, y_{US,t}^*$ and $\pi_{US,t}^*$ are included as weakly exogenous foreign variables. The endogeneity of oil prices reflects the large size of the US economy. The omission of $q_{US,t}^*, R_{US,t}^{*S}$ and $R_{US,t}^{*L}$ from the vector of US-specific foreign financial variables reflects the results of tests showing that these variables are not weakly exogenous with respect to the US domestic financial variables, in turn reflecting the importance of the US financial markets within the global financial system.

3.3 Comparing trade and overall effects

The overall effects of a US demand shock on the rest of the world are derived using the GVAR model described above. The model has 134 endogenous variables, 71 stochastic trends and 63 cointegrating relations. All the roots of the GVAR either lie on or inside the unit circle. The long-run forcing assumption is rejected only in five out of 153 cases. Dees et al. (2007) report the results for various tests of structural stability, the critical values of which are computed using the sieve bootstrap samples obtained from the solution of the GVAR. Evidence of structural instability is found primarily in the error variances (47 per cent of the equations—clustered in the period 1985–92). Although linear with a simple overall structure, this is a large and complicated model that allows for a high degree of interdependence. There are three routes for between-country interdependence: through the impact of the x_{it}^* variables, oil prices and the error covariances. The effects through the x_{it}^* are generally large; shocks to one country have marked effects on other countries. Table 4 reports the GVAR mean estimates of a 1 pp positive shock to US GDP on the rest of the countries. In addition to these point

¹⁰ See Dees et al. (2007) for the list of modelled countries. Although not all the euro area countries are modelled, the 8 countries included provide a fairly extensive coverage of the euro area economy.

estimates, Table 4 shows ranges based on 90 percent bootstrap error bounds. Although the ranges are not comparable to the ranges provided in Table 3, they provide measures of uncertainty.

Table 4: Overall impacts of a US domestic demand shock (by 1 p.p. of GDP) on GDP of other countries/regions (error bounds into brackets) in percent

Countries/regions	Mean estimates and error bounds
Euro area	0.27 [0.13 - 0.41]
Japan	0.35 [0.17 - 0.53]
Latin America.	0.65 [0.33 - 0.95]
ODE	0.60 [0.55 - 0.78]
Emerging Asia	0.23 [0.16 - 0.30]
Rest of Europe	0.31 [0.14 - 0.48]
UK	0.12 [-0.05 - +0.29]
US	1.07 [0.99 - 1.14]

Note: GVAR bootstrap mean estimates after 3 years. The ranges correspond to the 90 percent bootstrap error bounds.

The GVAR results show in most countries a higher sensitivity of their output to a shock originating in the US compared with the purely trade-related effects. The point estimates are in most cases higher than the benchmark values for trade-related effects (Figure 2). For the euro area and Latin America, the effect of a US domestic demand shock is around 2.5 times the one based on direct trade effects. It is slightly less (around 1.5) in the case of Japan and Other Developed Economies and it is above 5 for the rest of Europe. Interestingly, the GVAR-implied elasticity of the UK and emerging Asia is very close to the direct trade effect and below the total trade effect. For emerging Asia, this result might be due to different factors. First, the Chinese economy, which represents almost half of the region's output, has remained relatively immune to world economic developments and is providing increasingly a strong impetus to the region as a whole. Second, since the sample used to estimate the GVAR model includes the Asian crisis, it is likely that the results are influenced by this episode, which did not originate from a US shock. Finally, a large share of emerging Asian trade is related to processing trade, whose contribution to overall GDP is lower than traditional trade (when export demand for final Asian products decrease, the Asian imports of the corresponding intermediate goods also decrease leading to a broadly neutral impact on the net trade contribution to growth).

Overall, we find that a 1 percentage point positive shock in the United States would result in an increase in the GDP of the other regions in the world via the trade channel

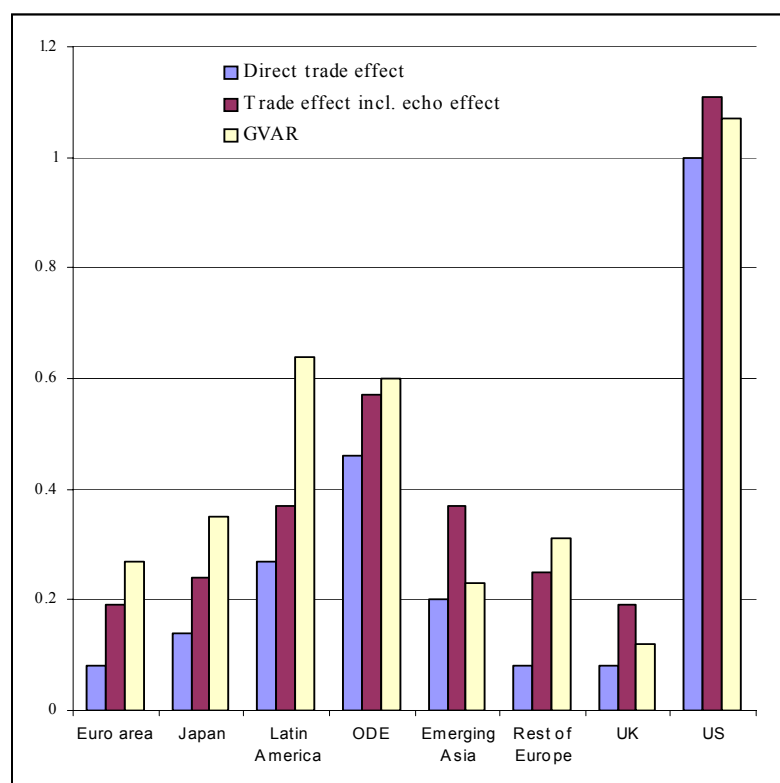


Figure 2: The effects of a US domestic demand shock (by 1 p.p. of GDP) on GDP of other countries/regions (in percent)

comprised between 0.1 to 0.5 percentage points (pp), depending on the region considered. Including also other channels this range would be much higher, namely between 0.2 and 0.7 pp.

4 Measuring the speed of spillover transmission from the US to the world excluding the US

Not only the overall sensitivity but also the speed at which developments in the US business cycle spill over to the world excluding the US may influence global developments. Our analysis shows that the US business cycle leads that of the other regions, except in the case of the Asian region whose business cycle appears to have moved independently.

To derive these results, we make use in this section of a non-linear Markov-switching model, similar to Philips (1991). In a nutshell, the analysis consists of estimating a two-region Markov-switching time series model for the US and each of the other region/country's real GDP growth. Within the model, there are two possible states for each country, i.e. a high and a low growth state. The correlation of business cycles across the two regions will then affect the probability that each region switches from high to low growth regimes. While providing a historical insight into the degree and direction of business cycle synchronisation, it should be stressed however, that such a model cannot attempt to explain the economic forces at work in the transmission of the business cycle. Rather, it attempts to characterize the behaviour of the economies.

We estimate the following two-country Markov-switching model:

$$y_t = n_t + \varepsilon_t \quad (10)$$

$$n_t = \mu_1 s_{1t} + \mu_2 s_{2t} + \mu_3 s_{3t} + \mu_4 s_{4t} \quad (11)$$

where $s_{it} = 1$ if state at date t is i and otherwise it equals 0. The equation moreover allows the error term to be vector-autocorrelated. There are two possible states for each country (a high and a low growth state); the four different combinations of these will be the four different states in the Markov process. In general, we can describe them as follows. *State 1*: both countries are in high growth. *State 2*: the home country is in low growth while the foreign country is in high growth. *State 3*: the home country has high growth and the foreign has low. *State 4*: both countries have low growth. This convention gives the following values to the four μ vectors (whereby h represents the home and f the foreign country)

$$\mu_1 = \begin{bmatrix} \mu_1^h \\ \mu_1^f \end{bmatrix}; \quad \mu_2 = \begin{bmatrix} \mu_2^h \\ \mu_2^f \end{bmatrix}; \quad \mu_3 = \begin{bmatrix} \mu_3^h \\ \mu_3^f \end{bmatrix}; \quad \mu_4 = \begin{bmatrix} \mu_4^h \\ \mu_4^f \end{bmatrix};$$

where $\mu_1 > \mu_2$ for both countries.

In this model the correlation of business cycles across countries is measured through the nature of the transition matrix (see Philips (1991)). For our specific Markov-switching model the transition matrix for the Markov process is a four-by-four matrix of probabilities, π_{ij} , where $\pi_{ij} = \Pr(s_t = j | s_{t-1} = i)$. These probabilities must then sum up to one over j for each i .

In case the business cycles of the two countries are truly independent, then the four-state transmission matrix will look like the following:

$$\begin{bmatrix} \pi_{11}^h \pi_{11}^f & (1 - \pi_{11}^h) \pi_{11}^f & \pi_{11}^h (1 - \pi_{11}^f) & (1 - \pi_{11}^h) (1 - \pi_{11}^f) \\ (1 - \pi_{22}^h) \pi_{11}^f & \pi_{22}^h \pi_{11}^f & (1 - \pi_{22}^h) (1 - \pi_{11}^f) & \pi_{22}^h (1 - \pi_{11}^f) \\ \pi_{11}^h (1 - \pi_{22}^f) & (1 - \pi_{11}^h) (1 - \pi_{22}^f) & \pi_{11}^h \pi_{22}^f & (1 - \pi_{11}^h) \pi_{22}^f \\ (1 - \pi_{22}^h) (1 - \pi_{22}^f) & \pi_{22}^h (1 - \pi_{22}^f) & (1 - \pi_{22}^h) \pi_{22}^f & \pi_{22}^h \pi_{22}^f \end{bmatrix} \quad (12)$$

By contrast, if the two Markov processes are perfectly correlated, then they could be represented by a two-by-two transition matrix. In this case, the four-by-four matrix would look like the following:

$$\begin{bmatrix} \pi_{11} & 0 & 0 & (1 - \pi_{11}) \\ - & - & - & - \\ - & - & - & - \\ (1 - \pi_{22}) & 0 & 0 & \pi_{22} \end{bmatrix} \quad (13)$$

In this case, the values in the second and third row are irrelevant since these states never occur.

The transition matrix can also allow for cases where one country leads the other. For example, suppose the foreign country is always in the same state the home country was in last year. This would be the case where the home country leads the foreign one into and out of recessions. In this case, the transition matrix would look like the following:

$$\begin{bmatrix} \pi_{11}^h & (1 - \pi_{11}^h) & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & (1 - \pi_{22}^h) & \pi_{22}^h \end{bmatrix} \quad (14)$$

A similar matrix can be constructed for the case where the foreign country leads. It is also possible to allow for expected leads of longer than one period. The matrix below illustrates a case where the expected length of the home country's lead into low growth is $1/(1 - \alpha)$ and its expected lead into high growth is $1/(1 - \beta)$:

$$\begin{bmatrix} \pi_{11}^h & (1 - \pi_{11}^h) & 0 & 0 \\ 0 & \alpha & 0 & 1 - \alpha \\ 1 - \beta & 0 & \beta & 0 \\ 0 & 0 & (1 - \pi_{22}^h) & \pi_{22}^h \end{bmatrix} \quad (15)$$

From the above we can see that a great variety of cross-country business cycle transmissions can occur. One possibility that is rather difficult to model, however, is the case where two countries alternate their leads into and out of recessions. If the home country is a clear leader (as in the case illustrated above), one state will always be followed by the same other state. However, if the two countries alternate leads, then this would not be the case. The result is owing to the fact that the Markov process is first-order; only last period's state is allowed to influence the determination of this period's.

For the case where leads alternate, this is clearly not the case. In case this occurs, it will be necessary to look not only at the transition matrix, but also at the smoothed probabilities that generate the estimates. This will show how the states actually evolve over time.¹¹

The Markov-switching model with any of these transition matrices can then be estimated. The model that provides the highest likelihood ratio then presents the most appropriate specification.

The model is estimated for each of the regions/countries under scrutiny and the US (i.e. US-euro area, US-Japan, US-Latin America, etc.). We allow for two possible model setups namely: (i) the business cycles are uncorrelated or (ii) the US leads the cycle of the other region.¹² In the latter case, we can estimate by how many quarters the US leads the cycle of the other region during an upturn and of a downturn. The results are reported in Table 5. A number of common findings emerge. First, for all the regions considered except the Asian region (i.e. Japan¹³ and emerging Asia), the likelihood ratio test reveals that the scenario that the US and the other region/country's cycle are independent can be rejected in favour of the hypothesis that the US leads the cycle of the other country/region. Second, in general, we find that US downturns are transmitted faster to the world excluding the US than upturns. It takes between 1 and 3 quarters for a downturn in the US to transmit to the other region/country whereas it takes between 2 and 10 quarters for an upturn to spillover. Spillovers from the US occur fastest into Latin America whereas they take longest to materialise into the rest of Europe. A similar finding is reported in IMF (2007) where spillovers to Latin America (and Canada) from US shocks are fastest and strongest. These results were obtained from a panel analysis as well as a cross-country and cross-region set of vector autoregression models. However, in contrast to our findings, the authors do find a significant spillover from US developments to Newly Industrialised Countries and the ASEAN-4 countries. However, the effect found is short-lived and relatively muted. Such a difference with our finding may arise not only from a different definition of the region but also a different time-period and estimation technique.

5 Determining the sources of business cycle fluctuations

In order to understand the factors that could explain the above discussed results, in this last section, we estimated a Factor-Structural VAR model for the main countries and regions and decompose the variance of GDP growth into three sources of shocks, namely idiosyncratic, global and spillovers.

¹¹In our case, an inspection of the smoothed probabilities revealed in no case that the lead and lagging country switched.

¹²Estimating the model allowing for the two cases enables to verify if the model that the US leads the cycle of the other region has a log-likelihood which is significantly higher than the model where the cycles are uncorrelated. If this is not the case, it is unclear whether the US indeed leads the cycle of the other region.

¹³For Japan, other studies also have documented its stronger independence from the US business cycle (see for instance Osborn et al, 2003).

Table 5: Results of two-country Markov-switching model estimations (1979Q2-2003Q4)

Country/region	Uncorrelated versus US lead	Number of quarters US leads	
		Low growth	High growth
US - euro area	35.94*	2	7
US - Japan	3.65	–	–
US - UK	34.89*	2	2
US - Emerging Asia	5.96	–	–
US - Other Dev. Eco.	40.98*	2	4
US - Latin America	47.27*	1	2
US - Rest of Europe	67.02*	3	10

Note: The null hypothesis for the test is that the cycles are uncorrelated. The test is a likelihood ratio test with a X^2 distribution. * indicates that the null (of no correlation) can be rejected at 99% confidence.

5.1 A Factor Structural VAR

The Factor-Structural VAR (FSVAR) estimated here follows Stock and Watson (2003) and has the following form:

$$Y_t = A(L) Y_{t-1} + \nu_t \quad (16)$$

where $E\nu_t\nu_t' = \Sigma$ and

$$\nu_t = \Gamma f_t + \xi_t \quad (17)$$

where $E(f_t f_t') = \text{diag}(\sigma_{f_1}, \dots, \sigma_{f_k})$ and $E(\xi_t \xi_t') = \text{diag}(\sigma_{\xi_1}, \dots, \sigma_{\xi_k})$.

where f_t are the common international factors, Γ is the $7 \times k$ matrix of factor loadings, and ξ_t are the country-specific, or idiosyncratic, shocks. In equation (17), the common international shocks (the common factors) are identified as those shocks that affect output in multiple countries contemporaneously. We estimate the FSVAR using Gaussian maximum likelihood.

5.2 Sources of business cycles fluctuations

We present here the decomposition of the variance of the 4-quarter ahead forecast error for GDP growth. We distinguish three potential sources: unforeseen common shocks, unforeseen domestic shocks, and spillover effects of unforeseen domestic shocks to other countries. In this context, common shocks are defined as those that affect all countries within the same period. Country-specific shocks can lead to spillovers, but those spillovers are assumed to happen with at least a one-quarter lag.¹⁴ Further, we consider developments during two different sub-periods: 1979-1992 (Table 6) and 1992-2003 (Table 7). The second column of the table presents the standard deviation of the four-quarter ahead forecast errors in a given region. In most country (except in Japan and Latin America), this standard deviation decreased in the second sub-period compared with the first one. This result is in line with the observed decrease in output growth

¹⁴ A potential disadvantage of this approach is that if an international shock affects several countries only with a lag, that effect may incorrectly be interpreted as a spillover.

volatility as reported in the literature (e.g. Stock and Watson, 2003) explained inter alia by weaker international shocks as well as key structural changes (such as new stock management methods and more credible monetary policy). The next three columns of Tables 6 and 7 display the fraction of the forecast error variance for GDP growth due to each of the three potential sources of shocks. In general, we find that spillovers appear to play only a secondary role in determining regions' GDP developments relative to idiosyncratic and common shocks.

Table 6: Variance decomposition of GDP growth based on a Factor-Structural VAR Model: common shocks, own country-shocks, and spillovers (1979-1992)

Country/region	Error s.d.	Fraction due to		
		Common shocks	Idiosyncratic shocks	Spillovers
US	1.46	0.48	0.22	0.3
Euro area	0.73	0.72	0.1	0.18
Japan	1	0.28	0.6	0.12
U.K.	1.16	0.25	0.6	0.15
Emerging Asia	1.64	0.08	0.81	0.11
Other Dev. Eco.	1.55	0.68	0.14	0.18
Latin America	0.84	0.51	0.24	0.25
Rest of Europe	1.46	0.48	0.22	0.3

Note: The entries in the second column are the standard deviation of the four quarter ahead forecast errors in a given region.

Table 7: Variance decomposition of GDP growth based on a Factor-Structural VAR Model: common shocks, own country-shocks and spillovers (1992-2003)

Country/region	Error s.d.	Fraction due to		
		Common shocks	Idiosyncratic shocks	Spillovers
US	0.76	0.38	0.5	0.12
Euro area	0.69	0.53	0.4	0.06
Japan	1.1	0.23	0.44	0.33
U.K.	0.55	0.49	0.48	0.03
Emerging Asia	1.06	0.16	0.75	0.09
Other Dev. Eco.	0.73	0.55	0.15	0.3
Latin America	2.06	0.19	0.52	0.29
Rest of Europe	0.59	0.59	0.33	0.08

Note: The entries in the second column are the standard deviation of the four quarter ahead forecast errors in a given region.

In more detail, the results confirm our findings from the previous subsection by showing that emerging Asia tends to be mostly affected by regional shocks, while common shocks and spillover effects remain relatively limited. In addition, IMF (2007) reports a similar finding, namely that regional factors are important for Asia — which in the case of IMF (2007) includes both Emerging Asia and Japan —, when decomposing business cycle fluctuations into common, regional, national and idiosyncratic

factors.¹⁵ Also Kim et al (2003) note the importance of a regional cycle in Asia whereas Yamagata (1998) stresses the absence of contemporaneous co-movement between the US and Asian business cycle, however the author does note that there seems to be a lagged spillover from the US to the Asian business cycle.

In contrast to the findings for Asia, the developed economies (the euro area, ODE and Rest of Europe) are less affected by domestic shocks but appear more sensitive to common shocks. Spillover effects explain almost 1/3 of the variance in the case of ODE, Latin America and Japan, while they are relatively limited in the other countries and regions. Finally, the euro area seems to be more affected by common shocks than idiosyncratic shocks, while it tends to be the opposite in the US case. Compared to the period 1979-92, the most recent period shows an increase in the role of idiosyncratic shocks as opposed to spillovers or common shocks for the US, the euro area and the rest of Europe. Conversely, for Japan the role of spillover effects has increased as the expense of idiosyncratic and common shocks.

6 Conclusion

In this paper, we have analysed the implications of a slowdown in the US economy on the world excluding the US. Our main findings are:

(i) The US business cycle leads that of the other regions, except in the case of the Asian region whose business cycle has been moving independently.

(ii) For all regions, except emerging Asia, linkages with the US appeared stronger than suggested by pure bilateral trade channels. In more detail, for the euro area it is estimated that a 1 pp of GDP positive US demand shock would increase euro area GDP by slightly over 0.25 pp while based on bilateral trade relations it would raise euro area GDP only by 0.1 pp.

(iii) In terms of timing, for all regions, a negative shock to the US economy has been transmitting faster than a positive one, with a high US growth phase taking between 2 to 10 quarters and a low growth phase between 1 and 3 quarters to spillover.

(iv) Finally, looking at the factors affecting regional developments, common and country/region specific shocks appeared to have played a larger role in determining GDP fluctuations than spillovers do. This finding would suggest that although a downturn in the US would indeed negatively affect the world excluding the US, country specific and global factors continue to dominate the outlook.

¹⁵ They contrast however with the findings reported by IMF (2007) using the calibrated Global Economy Model (GEM) which shows the largest effects in Emerging Asia from a reduction in US private demand.

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