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ET DE RECHERCHE

DETERMINANTS OF LONG-TERM INTEREST RATES IN THE UNITED STATES AND THE EURO AREA: A MULTIVARIATE APPROACH

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Determinants of long-term interest rates in the United States and the euro area: a multivariate approach[1] [2]

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Résumé

Cet article présente un examen des facteurs expliquant le niveau des taux à long terme américain et européen entre 1986 et 2005. Dans un premier temps, les déterminants structurels des taux à long terme sont sélectionnés, en traitant d'abord séparément les cas américain et européen. Cependant le cadre univarié ne rend pas compte de l'intégration des marchés et présente certaines limites statistiques. Le passage au multivarié montre un effet d'entraînement du taux à long terme américain sur le taux à long terme de la zone euro, sans réciprocité. Ce modèle nous permet alors d'établir une chronologie des évènements influençant le niveau des taux longs américain et européen. Ainsi, l'éclatement de la bulle Internet, les achats des non-résidents officiels et privés ainsi que l'expansion de la « liquidité mondiale » auraient exercé une pression à la baisse sur le taux long américain et indirectement sur le taux long de la zone euro.

Mot-clefs : Taux d'intérêt à long terme, Conundrum, modèles multivariés.
Codes JEL : E43 C32

Abstract

This article looks at the factors explaining the level of US and European long-term interest rates between 1986 and 2005. We begin by selecting the structural determinants of long-term interest rates, dealing with the US and European cases separately. However, a univariate framework cannot capture market integration and suffers from a number of statistical limitations. Switching to a multivariate setting reveals spillover from US to euro area long-term yields, with no reciprocal effect. The model allows us to draw up a timeline of events affecting the level of US and European long-term interest rates. Accordingly, the bursting of the internet bubble, purchases by foreign agents, both official and private, and the increase in global liquidity all seemingly exerted downward pressure on US long-term interest rates and, indirectly, on euro area long rates.

Keywords: long term interest rates, Conundrum, multivariate model.
JEL Codes: E43 C32

Résumé non technique:

Cet article examine les facteurs d'influence des taux d'intérêt de long terme américain et européen entre 1986 et 2005. Ces taux présentent une tendance à la baisse durant les quinze dernières années. Ceci peut être expliqué par des fondamentaux traditionnels tels que la baisse de la volatilité macroéconomique, des anticipations de basse inflation, ou une transparence accrue des politiques monétaires.
Néanmoins, les taux d'intérêt de long terme présentent une dynamique récente surprenante aux Etats-Unis et en zone euro, pour différentes raisons, à la vue de leurs déterminants traditionnels. En particulier, aux Etats-Unis, les taux d'intérêt de long terme sont restés constants autours de 4% en dépit d'un élargissement des déficits publics depuis 2002, d'un resserrement de la politique monétaire débutée mi-2004, l'amélioration des perspectives de croissance sur cette période. En zone euro, la tendance baissière des taux de long terme est moins surprenante qu'aux Etats-Unis. Entre Juin 2003 et Novembre 2005, la Banque Centrale Européenne (BCE) a gardé son taux directeur à 2%, avec une croissance du PIB entre 2% et 3.5%. Cependant, La concomitance d'évolution à tendance baissière suggère la prise en considération d'une possible transmission du bas niveau des taux d'intérêt des Etats-Unis vers la zone euro.
Ce papier présente trois objectifs. Tout d'abord, le taux américains ne peut être ex ante considéré comme un taux leader. La zone euro et ses huit années de fonctionnement nécessite un cadre économétrique plus approprié qui ne considère pas ce leadership comme un élément donné.
Deuxièmement, la situation de *conundrum* rend l'exercice délicat. Etudier la dynamique du taux d'intérêt de long terme de la zone euro donne des résultats biaisés vu que l'on considère le bas niveau des taux américains comme influençant. Dans le cadre d'un *Vector Error Correction Mechanism* (VECM), incorporant les taux d'intérêt et certains fondamentaux, on examine le lien entre les taux d'équilibre de la zone euro et des Etats-Unis.
Finalement, dans ce cadre VECM nous testons l'impact de facteurs qui pourraient expliquer ce *conundrum* : achats de titres américains, excès de liquidité global, dynamique des marchés boursiers.
La séquence chronologique des événements laisse apparaître les effets des excès de la liquidité sur les taux d'intérêt de long terme américain plus fortement entre 2000 et 2003, puis au début de l'année 2005. L'impact de la demande étrangère de titres américains est la plus forte fin 2003. Les effets des réallocations de portefeuille sur le taux à long terme américains sont importants entre 2001 et 2003. De plus, l'intégration des marchés considérée dans le model montre que le taux d'intérêt de long terme de la zone euro est fortement influencé par le taux américain, et indirectement impacté par ces nouveaux facteurs, mais dans une moindre mesure.

Non technical summary:

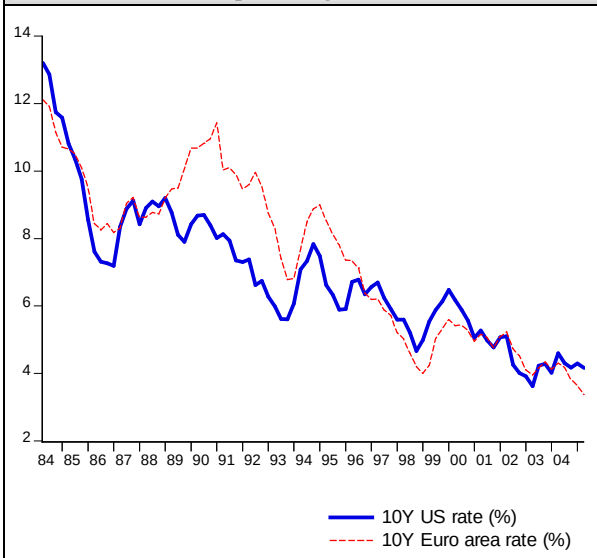
This article looks at the factors explaining the level of US and European long-term interest rates between 1986 and 2005. These rates have trended downward during the last fifteen years. Traditional explanations may have been advanced to justify such a trend: decline in macroeconomic volatility, low inflation expectation, transparency in monetary policy.
However, long-term yields have behaved puzzlingly in the Euro area and in the United States for different reasons, with respect to their traditional determinants on the recent period. In particular, US long-term interest rates have held steady at around 4% despite the presence of several factors that should have sent them upwards, including widening government deficits from 2002 onwards, monetary tightening, which was set in train in mid-2004, the surge in activity and brighter growth prospects. In the Euro area, the downtrend in European long-term interest rates is less puzzling than that of US yields. Between June 2003 and November 2005, the European Central Bank (ECB) kept policy rates at 2%, while Euro area nominal GDP growth fluctuated between 2% and 3.5%. However, the fact that US and European interest rates have followed a relatively similar path suggests that it is worth considering the possibility of spillover from US to European long rates.

This paper has mainly three objectives. First of all, many papers concerning the dynamic of long term interest rates consider the US rate as a leading one. However, the Euro area is now 8 years old and we need a more appropriate econometric model that does not consider this leadership as a given fact.
Second, the conundrum situation on the US rates makes the exercise difficult. Studying the dynamic of the Euro area rate obviously gives biased results since it considers the US low rate as a leading one. In our VECM framework incorporating interest rates and some US fundamentals, we consider the influence of an equilibrium US rate on the Euro rate.
Finally, in this VECM framework we test for the impact of factors that may explain the conundrum. Purchase of US treasury, global excess liquidity or stock markets dynamics.
The chronological sequence of events gives that excess liquidity appears to influence US long-term interest rates more strongly between 2000 and 2003, then from early 2005. The impact of foreign demand for US Treasuries is most intense at the end of 2003, while portfolio switching has a considerable effect on US long-term interest rates between 2001 and 2003. Moreover, the market integration considered in the model shows that, the Euro area interest rate is highly influenced by US rates and is indirectly impacted by these factors, but to a lesser degree.

1. Introduction

Long-term interest rates on US and European government bonds have trended downwards overall in the last 15 years (Chart 1).

Chart 1
US and European long-term interest rates



Sources: BIS and Banque de France

Until end-2001, this trend was in step with the fundamentals, especially the stable inflation outlook and low nominal short-term rates. More recently, though, long-term yields have behaved puzzlingly with respect to their traditional determinants. In particular, US long-term interest rates have held steady at around 4% despite the presence of several factors that should have sent them upwards, including widening government deficits from 2002 onwards, monetary tightening, which was set in train in mid-2004, the surge in activity and brighter growth prospects.

In terms of the monetary policy setting and the business cycle, the downtrend in European long-term interest rates is less puzzling than that of US yields. Between June 2003 and November 2005, the European Central Bank (ECB) kept policy rates at 2%, while euro area nominal GDP growth fluctuated between 2% and 3.5%. However, the fact that US and European interest rates have followed a relatively similar path suggests that it is worth considering the possibility of spillover from US to European long rates.

Various factors have been put forward to explain the current level of US long-term interest rates. They include the accumulation of saving in emerging countries, a global liquidity glut caused by the expansionary monetary policies of several central banks and currency interventions by Asian central banks, portfolio switching by private and official investors prompted by increased risk aversion following the collapse of the internet bubble, and regulatory changes affecting asset/liability management by pension funds and insurers. These factors, it is argued, increased demand for sovereign bonds[6].

There is no consensus on whether one of these factors is principally responsible for the odd behaviour of long-term interest rates. Furthermore, it is difficult to quantify their respective influence

[6] Frey and Moëc (2005) find that net purchases of government bonds by foreign official agents have a substantial impact on US long-term interest rates, in excess of 100 basis points in 2004.

on interest rates for at least three reasons: (i) most of these factors are highly correlated; (ii) they are difficult to measure (liquidity, capital flows, etc.); (iii) since the situation is fairly recent, we lack the distance needed to provide a stable estimate that is robust to the influence of these factors.

Still, some empirical work has been done in an effort to provide some answers on this front. Warnock and Warnock (2005) demonstrate that demand for bonds from foreign investors[7] has had a strongly depressive effect on US long-term yields over the recent period, reducing them by up to 150 basis points (bp) in 2004-2005. The impact of official purchases of US Treasuries reached 100 bp in summer 2004. Bernanke, Reinhart and Sack (2004) consider how the volume of foreign exchange interventions by the Bank of Japan influenced changes in the US long-term interest rate. They demonstrate that the variable has a significant effect, at least in the very short term.
However, little research has been done on the determinants of European long-term interest rates. Although their behaviour has been less of a conundrum than that of US rates, a good understanding of their determinants is still important, notably for the conduct of monetary policy. Those who have done work in this area include Iankova, Lefeuvre and Teiletche (2004) and Hissler (2005), who propose a model for determining the interest rates of several zones, including the euro area. Their research reveals the important role of US long-term yields in explaining the level of European long rates.

Whether they are looking at US or European interest rates, these studies rely on a modelling approach that consists in estimating a reduced-form equation, controlling for several standard macroeconomic factors like inflation, the GDP growth rate and the budget deficit. This framework can be used to estimate the impact of other factors that may explain the level of long-term yields, such as foreign demand for US Treasuries or excess liquidity.
These approaches form a good starting point for analysing and modelling interest rates. However, they oversimplify, especially in assuming constant market interactions, since the broad range of maturities and currencies on which interest rates are based generate interactions that must be taken into account. Investors may make choices by combining two different rationales: they might arbitrage between bond markets, creating a correlation between long-term interest rates in different currencies; and they might arbitrage between maturities, creating a correlation between short and long-term interest rates in the same currency. Capturing the interdependence between bond markets in different currencies seems crucially important to modelling European interest rates. A univariate analysis looks particularly ill-suited to the euro area, because the theoretical euro area interest rate cannot be calculated from an actual US interest rate. In this case, any imbalance in the US long-term interest rate would be transmitted to the European rate.

This article builds on earlier studies and endeavours to improve on them in two ways.

In the first place, we jointly model US and European long-term interest rates. From an *ex ante* standpoint, this strikes us as more appropriate than the univariate framework seen in the literature, for several reasons:

- it captures the integration of US and European markets;
- it provides a way to indirectly identify the impact on the euro area interest rate of factors affecting the US rate. Given the close link between the two markets, the impact of certain factors – notably those responsible for the US interest rate conundrum – is channelled through the US rate before impacting other rates;
- finally, it is generally accepted that the US market occupies a dominant role. A multivariate framework provides a setting in which to test this *ex post*, without making an *ex ante* assumption.

In the second place, we analyse the impact of so-called new factors that might explain the US conundrum as regards the level of European long-term interest rates. We therefore test the significance of several factors that are assumed to be exogenous – non-resident purchases of US Treasuries, equity

[7] The authors construct an aggregate series of net purchases of public and private bonds by foreign official and private foreign investors.

market returns and excess liquidity – with respect to interest rates[8]. To our knowledge, no study has tested the respective impact of these factors. We do that here, and trace a timeline of events that might have influenced long-term interest rates since 2000.

The findings are as follows:

- there is a long-run relationship between US and European long-term interest rates to which only the European rate adjusts;
- the stock market reversal and excess liquidity caused long-term interest rates to trend downwards in the United States and in the euro area;
- net purchases of US Treasuries by foreign official and private foreign investors made a transitory contribution to the decline in US long-term interest rates between 2002 and 2004.

The remainder of the article is made up of four sections. In Section Two we analyse the role of macroeconomic variables that theoretically play a part in the formation of long-term interest rates in the United States and the euro area. In Section Three, we discuss short-run dynamics and the results of dynamic simulations of the model in a multivariate framework. Section Four analyses the influence of exogenous determinants, which we incorporate in the model, of European and US long-term interest rates.

2. Structural determinants of long-term interest rates

According to the theory, certain fundamentals are supposed to play a major role in the formation of long-term interest rates. The approach presented below consists in separately selecting variables that influence US and euro area yields.

2.1. Foundations of the structural equation

In theory, a nominal long-term interest rate Rl_t is equal to the sum of the real interest rate RR_t, expected inflation over the life of the security π_t^e and a term premium ψ_t:

$$Rl_t = RR_t + \pi_t^e + \psi_t \qquad (1)$$

The real interest rate is linked to the expected return on capital, and hence on long-term economic growth, and to monetary policy expectations, which are the source of its cyclical component. Future inflation is determined by the current level of inflation and monetary policy expectations. The term premium measures the influence of investors' portfolio decisions or, more generally, all the factors other than those referred to above that shape bond market supply and demand. A decline in the term premium on a bond market may, for example, reflect:

- switches between bond markets in different currencies or between bond and equity markets;
- an overall increase in liquidity, insofar as this has no impact on inflation expectations;
- increased risk aversion;
- lower macroeconomic volatility;
- saving effects linked to population ageing;
- a decline in the net supply of public or private securities.

The data used in this study are quarterly and run from Q4 1985 to Q4 2005. See Appendix A for a full description of the variables used. ADF and KPSS stationarity tests demonstrate the non-

[8] These variables are introduced one after the other to avoid interactions and to isolate their respective effects. Logically, we should test the effects of these variables simultaneously.

stationarity of the variables. The number of long-run relationships is determined using cointegration tests based on the Johansen method[9] (1988, 1991).

2.1.1. The US case

Previous studies have highlighted the influence of certain variables on the level of long-term interest rates. Equations involving current or core inflation, current or expected budget deficit variables, or short or medium-term rates may all be acceptable in a univariate framework. In these estimates, short-term interest rates (three months or one year), core inflation, GDP, three deficit variables and government debt are considered. The relationship between government debt or the government deficit and interest rates, meanwhile, is the subject of an empirical debate.

For one thing, there is the key question of the distinction between current and expected budget deficits (Laubach (2003), Frey and Moëc (2005)), since the latter may exert a more marked influence than the former[10]. To address this issue, we test not just the conventional budget deficit measures, but also the influence of average expected deficits over five years[11]. Furthermore, part of the deficit's effect may transit through the cycle: during a recession, the deficit increases, whereas long-term interest rates decline under the effects of a more expansionary monetary policy. In an effort to mitigate this problem, we test cyclically-adjusted deficit measures here.

The findings show that:

- irrespective of maturity (three months and one year), the short-term interest rate is significantly linked to the long-term interest rate in the long-run equilibrium relationship. This is consistent with the expectations theory of the term structure: namely, an increase in the short-term interest rate (or expected values for that rate) implies a higher long-term interest rate;
- inflation is significant in the equilibrium equation for the long-term interest rate. This is also consistent with economic intuition;
- the GDP growth rate is not always significant, particularly in the case of the one-year short-term rate;
- all current and expected deficit (to GDP) indicators and the debt to GDP ratio are significant in the long-run equilibrium relationship for US long-term interest rates and have the expected sign.

The selected model links the US long-term interest rate (Rl_t^{US}), the yield on one-year US Treasuries (Rc_t^{US}), the core US inflation rate[12] (π_t^{US}) and government debt (D_t^{US}), in line with Frankel and Chinn (2005).

We used the one-year rate instead of the three-month rate for two reasons: (i) it captures part of the unexplained risk premium shared by the one-year and ten-year rates; (ii) the one-year rate may be considered as an indicator of inflation expectations and monetary policy for the year ahead. The estimated long-run relationship is as follows:

$$Rl_t^{US} = \underset{0.68}{0,88} + \underset{(0,04)}{0,39}\ Rc_t^{US} + \underset{(0,08)}{0,80}\ \pi_t^{US} + \underset{(0,01)}{0,02}\ D_t^{US} \quad (2)$$

$$(R^2 = 0,92)$$

Estimated standard deviations are given in brackets, the coefficients are significant at 5% and the cointegration tests are validated at the 5% level. The signs of the estimated coefficients are consistent with economic intuition:

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[9] All the proposed explanatory factors for each area cannot be tested simultaneously for reasons relating to the control of the degrees of freedom of the estimate. Variables are therefore selected by applying Johansen tests to "groups" of variables. Only variables that appear to be cointegrated with long-term interest rates are chosen.

[10] However, as Iankova, Lefeuvre and Teiletche (2004) emphasise, the two deficit measures are highly correlated as a rule, suggesting that budget forecasts are essentially extrapolations.

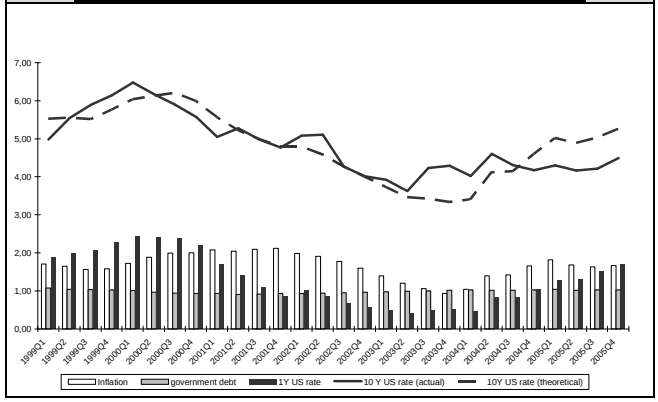
[11] We thank Laure Frey and Gille Moëc for obtaining this semi-annual CBO series for us. We converted it to a quarterly format using the Chow and Lin (1971) method, using the quarterly budget deficit series as a basis and assuming that residuals follow an autoregressive model of order 1.

[12] Provided by the consumer price index excluding food and energy.

- a 100 bp increase in the one-year rate causes a 39 bp increase in the nominal long-term interest rate;
- a 100 bp increase in current inflation causes an 80 bp increase in the long-term interest rate. We are close to an empirical verification of the Fisher effect under static expectations, with the long-term interest rate and inflation changing on a one-for-one basis;
- a 1% increase in the debt-to-GDP ratio causes long-term interest rates to increase by around 2 bp.

Chart 2 plots actual (solid line) US long-term interest rates and the theoretical (dotted line) rates derived from equation (2), as well as the contributions of each of the model's exogenous variables from 2000 onwards.

Chart 2
Actual and theoretical US long-term interest rates



This chart supports the notion that US long-term interest rates are behaving strangely with respect to their traditional fundamental determinants. Equation (2) seems to do a good job of reproducing the observed movement of US long-term interest rates until 2002. But from the end of 2004 onwards, the gap between the two series widens, with the actual interest rate falling some 80 bp below its estimated long-term value. This differential is linked to the lack of response by ten-year yields to the increase in US official rates. The one-year rate, by contrast, does respond to the change in monetary policy. The real conundrum, then, concerns long-term yields.

2.1.2. The European case

Selecting variables represents a major methodological problem in the case of the euro area. Many studies use German interest rates as the pre-Monetary Union reference for the euro area. This gets round the fact that the future euro area Member States moved forward at differing rates in the convergence process in the 1990s. However, using a recompiled pre-1999 euro area rate (Frankel and Chinn (2005), for example, use it from 1995) makes it possible to adopt a uniform approach over the entire period. Eurostat, the statistical office of the European Communities, constructs this series by weighting the interest rates of the countries that created the euro area based on GDP expressed in purchasing power parity. The results detailed below use ten-year and one-year interest rate series that are recompiled using this method[13].

The results concerning the structural determinants of euro area long-term interest rates tend to suggest a dependence on the US market. Iankova et al. (2004)[14] and Frankel and Chinn (2005)[15] also

[13] The pre-1999 one-year and ten-year yields for the euro area are calculated as the weighted average of German, French, Italian and Spanish yields. The weights correspond to the GDP of each country converted using purchasing power parities. Note that analyses conducted in parallel on German yields find similar results as regards the long-run dynamics. However, the short-run dynamics are hard to interpret from an economic perspective.

[14] Estimation period 1990-2003.

[15] Estimation period 1973-1995.

point to this linkage. Of the factors selected[16], only the European one-year interest rate (Rc_t^{ZE}) and US long-term interest rates (Rl_t^{US}) seem to be cointegrated with European long-term interest rates (Rl_t^{ZE}). There therefore appears to be a long-run relationship between European and US long-term interest rates. Granger causality tests demonstrate that the dependence is not reciprocal. Iankova et al. (2004) also show that this dependence holds for all maturities over two years and that it increases with the maturity of the interest rates considered.

In addition, the euro area inflation variable does not appear to be significant in the long-run relationship. Thus, the structural equation selected for the euro area is written[17]:

$$Rl_t^{ZE} = \underset{(0,30)}{1,02} + \underset{(0,04)}{0,58}\ Rc_t^{ZE} + \underset{(0,07)}{0,38}\ Rl_t^{US} \quad (3)$$

($R^2 = 0.94$)

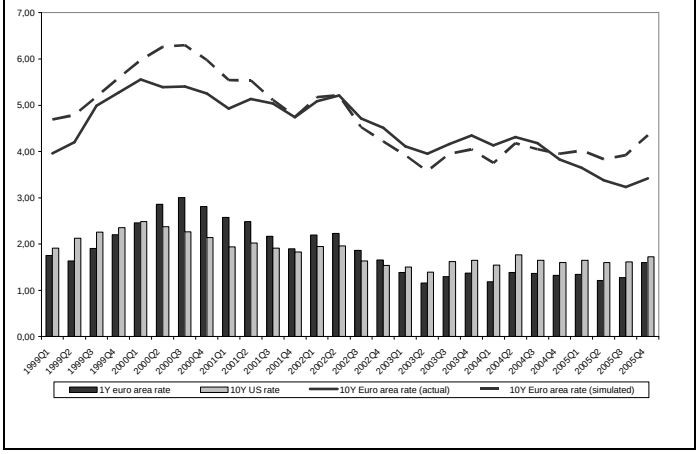
The signs of the coefficients are consistent with economic intuition:

- the model forecasts that a 100 bp increase in the one-year rate leads to 58 bp increase in the ten-year rate;
- a 100 bp increase in US long-term interest rates causes a 38 bp increase in the European long-term interest rate.

Chart 3 compares actual (solid line) and simulated (dotted line) European long-term interest rates from 2000, plus the contributions from the European one-year interest rate and US long-term interest rates to the change in the theoretical long-term interest rate.

Chart 3

Actual and theoretical European long-term interest rates



The difference between the simulated and actual euro area rates is less pronounced than in the United States. Though positive since early 2005, the gap has remained medium-sized (36 bp in first-quarter 2005[18]). This may stem partly from the inclusion of the long-term US yield as an explanatory variable, which definitely captures several systematic factors that affect the bond markets of both zones simultaneously. Note also that euro area long-term yields went up at the end of 2005. This increase may be attributable to i) monetary policy tightening by the ECB, and ii) the rise in long-term

[16] Inflation rate, GDP growth rate, money supply (M3) growth rate, change in the ratio of government debt to GDP.

[17] As before, estimated standard deviations are given in brackets, the coefficients are significant at 1%, and the cointegration tests are validated at the 5% level.

[18] We also estimated equation (3) by replacing the actual US long-term interest rate with the equilibrium long-term rate derived from equation (2). The aim was to provide an initial proxy of the difference between actual and equilibrium European long-term interest rates in the absence of a US bond market puzzle. The resulting gap is automatically larger and stood at 0.52 in Q1 2005. However, it remained smaller than the differential observed for the US rate.

yields in the United States over the same period. It is therefore difficult at this stage to say whether the behaviour of euro area interest rates represents a conundrum[19].

3. Joint modelling of US and European interest rates

In this section we propose to capture and test the interdependence of US and European markets. The univariate equation for the euro area incorporates US interest rates. But while the significance of actual US long-term interest rates for euro area long rates emphasises the interdependence of the markets, it also means that part of US interest rate puzzle is used to explain the long-term equation for the euro area. Two extensions may be considered to correct this.

One option would be to use estimated equilibrium levels for the long-term interest rate of the other market rather than actual interest rates in the last section's univariate relationships[20]. This would have an especially important bearing on the euro area long-tem interest rate, which reacts to the US long-term rate. However, this is an approximate solution. Introducing the estimated US long-term yield into the relationship for the euro area long-term interest rate would ignore the possible direct effects of US fundamentals, which could be a channel of transmission in terms of reducing euro area long-term yields.

The second option is to propose a multivariate framework. This makes it possible to avoid making *ex ante* assumptions about the transmission channels from one market to another and to conduct *ex post* tests of assumptions, notably concerning market integration. The multivariate model therefore has the advantage of not making advance assumptions about which variables are exogenous or endogenous, and makes it possible to consider possible interactions between the euro area long rate and US interest rate fundamentals. Thus, the European long-term interest rate is not merely a function of the actual US long-term interest rate, but also, indirectly, of the equilibrium US long-term interest rate and its fundamentals. We therefore propose extending the results of the previous section to a multivariate framework[21].

3.1. The econometric model

Given the non-stationarity of the variables (see stationarity tests in Appendix A), we consider the possible presence of cointegrating relations. To determine the number r of cointegrating relations, we apply the Johansen and Juselius (1990) trace test, as a result of which two cointegrating relations were retained (see Appendix B.1 for a description of the test and the results). We therefore used a multivariate vector error correction model (VECM), which we present briefly here:

let x_t be a vector of dimension n, integrated of order one. If there is a matrix (n,r) denoted β of rank r, less than n, such that $\beta' x_t$ is stationary then x_t is said to be cointegrated with r cointegrating relations. Engle and Granger (1987) showed that the x_t process then allows for a vector error correction representation of the following form:

$$\Delta x_t = \Gamma_1 \Delta x_{t-1} + ... + \Gamma_p \Delta x_{t-p} + \alpha\beta' x_{t-1} + \Phi Z_t + \varepsilon_t, \quad (4)$$

where Δ is the first-difference operator, Z_t is a vector of variables that are assumed to be exogenous; α is the matrix (n,r) of the speed of adjustment to long-run relationships; β is the matrix of

[19] We thank one of the reviewers for this comment.

[20] See footnote 17.

[21] Note also that in addition to the article's "economic" argument, another more "statistical" argument justifies switching to a multivariate setting. Several authors (Banerjee, Dolado, Hendry, Smith (1986)) have found that the least squares estimator of the cointegrating vector has fairly sizeable biases in small samples. One source of these biases is the presence of a simultaneity bias. Estimating a joint model addresses this problem and supplies more satisfactory estimators for small samples. Further, it is possible to conduct restriction tests on α and β, which have a chi-square distribution. As with all complete models, however, this representation is more sensitive to specification errors.

cointegrating vectors; p denotes the number of lags in the system; Γ_i, i=1…p, are the matrices of short-run coefficients.

Several estimates are carried out to select the relevant variables of vector x_t. Designed to model the joint interaction of different bond markets, this vector mainly comprises two long-term interest rates and two short-term interest rates. It remains therefore to determine the other "economically" relevant variables within the framework of this multivariate model. For this, we use the results from the univariate framework, selecting US inflation and a variable for the US budget deficit.

The "euro area" cointegrating relationship identified in the univariate framework is relatively robust to the switch to a multivariate setting. However, it does not seem possible to obtain an economically relevant equilibrium relationship between US long-term interest rates, US short-term interest rates, inflation and an indicator of the budget imbalance. The coefficients for the short-term interest rate and the budget deficit (current or expected) are non-significant, or their sign is not consistent with economic intuition. Only two models are relevant:

- the first considers US and euro area long-term interest rates, US and euro area short-term interest rates and US core inflation;
- the second considers US and euro area long-term interest rates, US and euro area short-term interest rates, and the US government debt to GDP ratio.

In what follows, we use the model that captures the influence of US government debt on the level of long-term interest rates. Furthermore, following Iankova et al.(2004) and Frey and Moëc (2005), we include the PMI index[22] in the model as a variable representing the state of economic conditions.

3.1.1. Long-run dynamics

We test several restrictions on the cointegrating vectors. This procedure consists in estimating a reduced-form model including the desired restriction. A likelihood ratio test is conducted between the full and reduced-form models. The restriction tests validate the structure of the equations obtained in the preceding univariate analysis[23]. The euro area long-term interest rate adjusts to the US long-term interest rate and the euro area short-term interest rate. The US long-term yield adjusts to the US short-term interest rates and to the deficit variable.

Euro area long-term equation

Variable	Coefficient
Rl_t^{ZE}	1.000
Rl_t^{US}	-0.976
Rc_t^{ZE}	-0.280
constant	0.987

All the coefficients are significant at 1%

US long-term equation

Variable	Coefficient
Rl_t^{US}	1.000
Rc_t^{US}	-0.619
D_t^{us}	-0.085
constant	2.289

All the coefficients are significant at 1%

Table B.2 in the appendices reports the recursive estimates for these coefficients between 1999 Q4 and 2005 Q2. The coefficients are fairly stable. However, we note that over the recent period the deficit variable has lost some of its influence on the US long-term interest rate.

[22]This indicator of business conditions is drawn from an ISM survey of manufacturing companies and is known as a leading indicator of activity. Where it is replaced by year-on-year GDP growth, the findings are largely the same.

[23] The restriction test is not rejected at the 1% level.

3.1.2. Short-run dynamics

We selected the number p of lags for the model's short-run dynamics by minimising the information criteria (Schwartz and Akaike). A multivariate model with one lag is optimal according to these criteria[24]. Also, autocorrelation tests (Q-stat) of the residuals from the model with one lag indicate that these are not autocorrelated. The single-lag model was therefore selected. For the sake of clarity, we only show significant variables in the equations. See the appendices for the full results.

Short-term equation for ΔRl_t^{ZE}

Variable	Coefficient	t-stat
$u_{t-1}^{cointegration\ 1}$	-0.121	-3.11
$u_{t-1}^{cointegration\ 2}$	-0.091	-1.67
$D(Rl_{t-1}^{US})$	0.370	2.58
$D(PMI)$	0.027	2.70
constant	-0.047	-1.29

Short-term equation for ΔRl_t^{US}

Variable	Coefficient	t-stat
$u_{t-1}^{cointegration\ 2}$	-0.101	-2.82
$D(PMI)$	0.052	4.61
constant	-0.055	-1.31

The multivariate model reveals two interesting effects:

- *spillover to the European market*: the residual from the long-run relationship between US and European interest rate values ($u_{t-1}^{cointegration\ 1}$) is not significant in the US long-term interest rate equation but is in the European equation, with the adjustment coefficient estimated at -0.12. This means that a divergence in the level of long-term interest rates in the two areas leads to a partial adjustment in the following period in the European long-term interest rate. This finding suggests that the European rate mainly adjusted to the US rate, without reciprocity, over the entire sample. The European bond market's dependence on the US market could stem from the fact that the euro area government bond market, while comparable in size to the US market, is segmented. This segmentation could make the European bond market relatively less liquid than the US market[25] (Artus, 2006). In addition to this long-term influence, the US interest rate is significantly present in the short-run dynamics of the European rate. The euro area interest rate is thus highly responsive to variations – even in the short run – in the US rate.
- *an arbitrage effect*: this too is present in the model. We see that the European interest rate reacts to the second cointegrating relationship, with an estimated negative coefficient of -0.09, lower than the spillover coefficient and significant at the 10% level. The negative coefficient illustrates an arbitrage effect, given that European yields come under upward pressure when the US rate is below its equilibrium and vice versa.

The combination of these two effects could therefore partially explain why we do not see such a marked conundrum in European rates as in US rates.

In addition, the effect of the PMI index on US rates has the expected sign: at the top of the cycle, short and long-term rates are higher. The level of US activity also affects European long-term interest rates directly, partly explaining the current correlation between US and European long-term interest rates.

Finally, the multivariate econometric framework is more appropriate from an *ex ante* perspective because it allows us, among other things, to consider the integration of US and European markets. The estimates show that US interest rates are not influenced by European rates. Conversely, European rates react in the short term and in the long term to US rates. Thus, the multivariate approach seems more suited *ex post* to modelling the European market than the US market.

[24] Given the number of parameters to estimate, we do not test VARs beyond three lags owing to the degrees of freedom of the model.

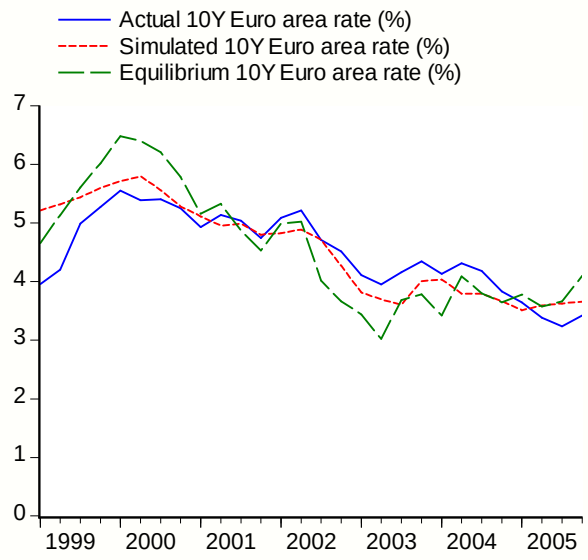
[25] Portfolio selection theory shows that if a market is more liquid and/or larger than another market, it has a directing influence on equilibrium prices on the other market.

3.2. Dynamic simulations of the model

This section looks at the dynamic simulations of the model. Using the multivariate model, we jointly simulate the level of euro area and US long-term interest rates. This means that the simulation of the euro area interest rate is based on the simulated US rate and vice versa.
In the univariate framework, the theoretical euro area interest rate was computed based on the actual US rate at the same instant. This means there is a bias: if the actual US rate is low, the theoretical European rate will also be low. Multivariate interest rate simulations therefore take into account the concomitant determination of interest rates, unlike in the univariate setting.

Chart 4 describes actual and simulated European long-term interest rates from 1999, as well as the equilibrium value for the interest rate, given by the long-run relationship.

Chart 4
Dynamic simulation of European long-term interest rates, 1999-2005

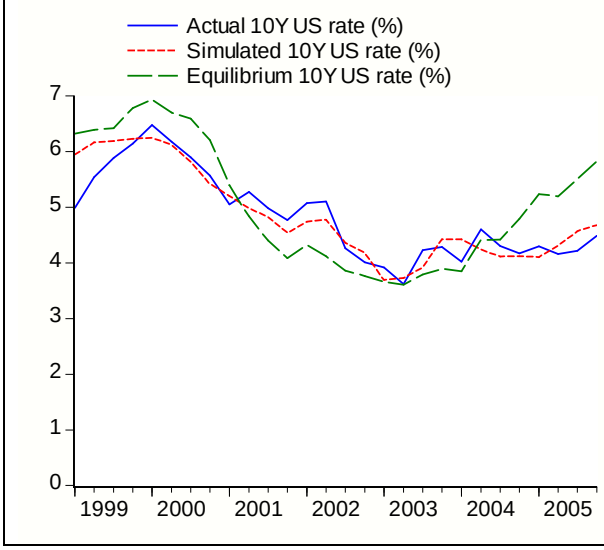


The simulated long-term interest rate can be interpreted as the rate predicted by the model, taking into account both long-run and short-run dynamics. This rate is fairly close to the actual rate, with an average differential of 25 bp with the simulated value between 1999 and 2005.
The equilibrium rate is the theoretical long-term interest rate taking into account only the long-run dynamics derived from the VECM. We find the actual rate to be both overvalued relative to its equilibrium value (2001-2004) and undervalued (1999-2001 and 2004-2005). At the end of the sample, the equilibrium rate is higher than the actual rate, although these sorts of differentials were also observed previously. Thus, the puzzle seems to mainly concern the United States. However, given the effects of negative shocks over the recent period and the unresponsiveness of European long-term interest rates, the long-term rate was 75 bp below its equilibrium value at the end of 2005. The model therefore predicts an upward movement for European long-term interest rates in early 2006.

Chart 5 plots actual and simulated US long-term interest rates from 1999.

Chart 5

Dynamic simulation of US long-term interest rates from 2004-Q3



The simulated long-term interest rate is close to the actual long-term rate, as in the case of the euro area. However, the divergence between the equilibrium value and the actual value of the US long-term interest rate is more persistent and greater in magnitude compared with the European rate. It seems therefore that a number of non-traditional factors exerted a downward influence on US long-term interest rates, notably at the end of 2004 and in the middle of 2005. The differential reached around 130 bp at end-2005 – the widest gap obtained over the sample. Furthermore, the gradual increase in official rates by the Federal Reserve from July 2004 onwards did not have an immediate effect on long-term interest rates, which remained relatively unresponsive[26] over the recent period. Accordingly, the model seems to confirm the existence of a puzzle in the multivariate framework.

The sluggishness of the short-run dynamics is not explained by the model in its current state. We therefore propose in the following section to test variables that would do more to explain this situation. Furthermore, the multivariate framework tells us whether the inertia of US rates due to new factors has an impact on the dynamics of the European long-term interest rate. Research has proposed several approaches in this context. We test the relevance of a number of them in the framework of the multivariate model.

4. New hypotheses to explain the level of long-term interest rates

The results of the previous section suggest that it makes sense to model European and US long-term interest rates jointly insofar as the short and long-run dynamics of the two variables are linked. In particular, it is tricky to deal with the European long-term interest rate without a multivariate model that takes US long-term interest rates into account.

This section is devoted to identifying additional factors that could be taken into account to improve our understanding of the mechanisms that determine long-term interest rates. Specifically, we use the basic model[27] defined by equation (4) and test the influence of factors that are assumed to be exogenous. Our choice of variables reflects various avenues of exploration mentioned in the recent

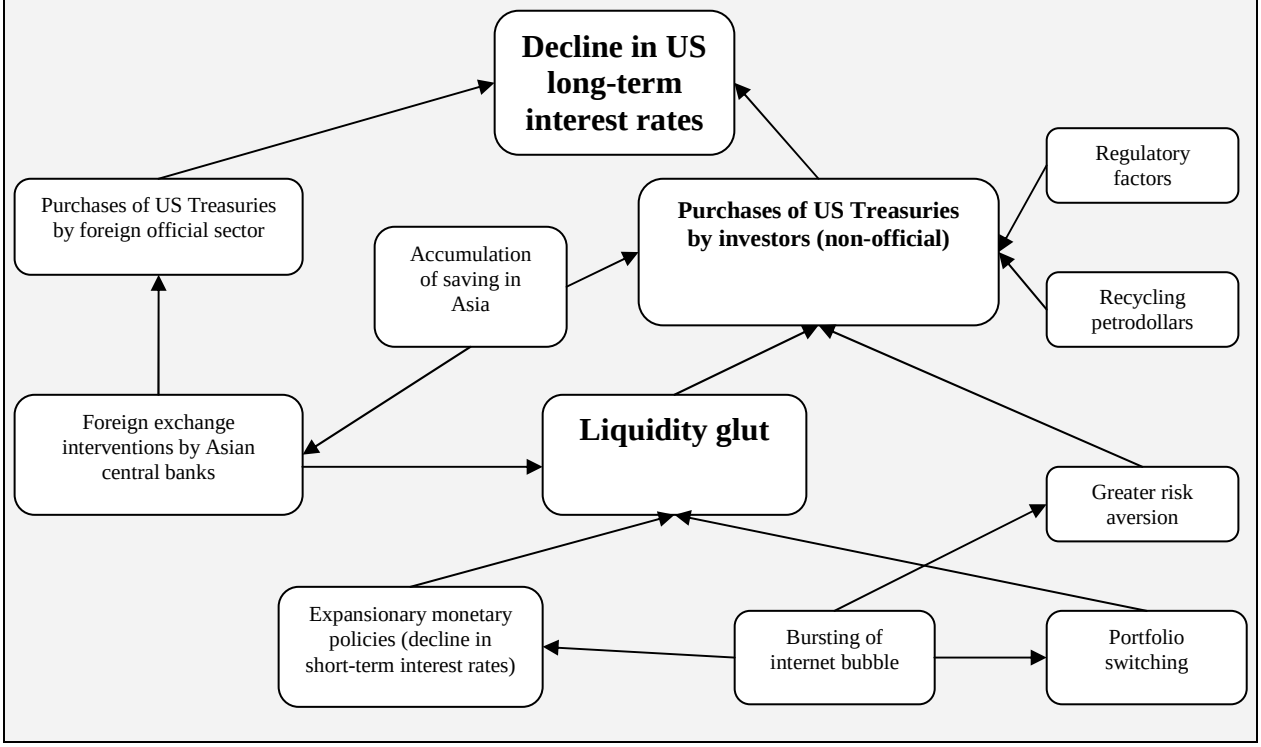
[26] The inertia of European and US long-term interest rates is linked to the fact that the coefficients of adjustment to the equilibrium value, though significant, are of low intensity. Thus, in the case of an adjustment coefficient of 0.1, half the deviation from the equilibrium is absorbed after six quarters.

[27] Without the PMI index to avoid issues of correlation between this indicator and the tested exogenous variables.

research cited above. To our knowledge, no other study has presented a comparison of the effects of these different factors. This is precisely the purpose of this section. Box 1 provides a diagram of interactions between the various potential factors, which can be classified into three main approaches.

Box 1

Mechanisms that could influence long-term interest rates



4.1. Main approaches

Several studies have attempted to shed light on the factors that might explain the current levels of long-term interest rates in Europe and the United States. Chiefly, they aim to explain the increase in demand for sovereign bonds.

4.1.1. A shift in the balance between saving and investment at the worldwide level, or a saving glut

Bernanke (2005) proposed this hypothesis to account for the levels of the US current account deficit and long-term yields. The starting point is the observation that there has been a structural shift in the balance of saving and investment in the world. Chart C.1 in the appendices shows how saving and investment have changed in various groups of countries. We see that the current account deficits of G7 countries widen from 1999 onwards, under the effects of a pronounced decline in the US saving rate, while the current accounts of emerging countries simultaneously post markedly positive balances. This shift is a consequence of the Asian crisis in the late 1990s, after which capital flows, especially foreign direct investment, abruptly dried up, triggering an investment decline in those countries. Over the same period, oil-exporting countries, buoyed by rising oil prices, reported substantial current account surpluses.

These imbalances were at the root of a rapid increase in the foreign reserves of emerging countries (see Chart C.2 in the appendices). Since two-thirds of worldwide reserves are held in dollars, these current account surpluses probably fuelled purchases of US Treasuries by foreign investors, as reflected in the sharp increase in demand for these securities from 2001 onwards.

4.1.2. Excess global liquidity, or a liquidity glut

More generally, the increase in demand for US Treasuries could be the result of a broad-based liquidity glut. Several factors may explain the mismatched growth rates of monetary and GDP aggregates.

The expansionary monetary policies pursued by several central banks stimulated a credit expansion. Meanwhile, Asian central banks prevented their currencies from appreciating against the dollar. Their massive interventions caused the external counterpart to swell, automatically accentuating the monetary expansion.

Quantitative theory suggests, however, that, *ceteris paribus*, excess liquidity should ultimately cause prices to go up. However, the presence of plentiful liquidity has yet to result in a marked increase in consumer prices. In this regard, and as some hypotheses have suggested, the change in liquidity may influence asset prices more than product prices.

4.1.3. Portfolio switching

Several factors may have prompted portfolio switching into bonds. One is the bursting of the internet bubble and the equity market collapse in 2000, which triggered an increase in risk aversion, enhancing the appeal of "less risky" securities like sovereign bonds. A second factor is linked to regulatory changes concerning pension funds and insurers. These entities are now subject to stiffer requirements in terms of covering their liabilities, and this has encouraged them to increase the duration of their assets.

Paralleling the portfolio reallocations, a dollar bias persists in the portfolios of international investors. It may therefore be that the level of US long-term interest rates merely reflects a more marked preference for the dollar over recent years. Thus, portfolios could be switched towards the dollar over the long term. However, this would not rule out the possibility of short-term effects connected with liquidity or global saving (Warnock and Warnock (2005)).

4.2. Testing the hypotheses in the multivariate model

Linking directly to these three approaches, we examine the significance of the impacts of a set of variables in a multivariate model. For this, the model presented in Section 2 is estimated by incorporating several factors, which are assumed to be exogenous, into the equation describing the short-run dynamics of long-term interest rates.

Each of the variables is tested separately[28] even though long-term interest rates probably feel their combined effects. The estimate therefore overstates the impact of each variable. Even so, this exercise enables us to draw up a pecking order for the impacts of the different factors, while still placing ourselves in the most "favourable" setting for these factors. Also, we lack the distance needed to guarantee the durability of the estimate results because some of these factors have had a recent or

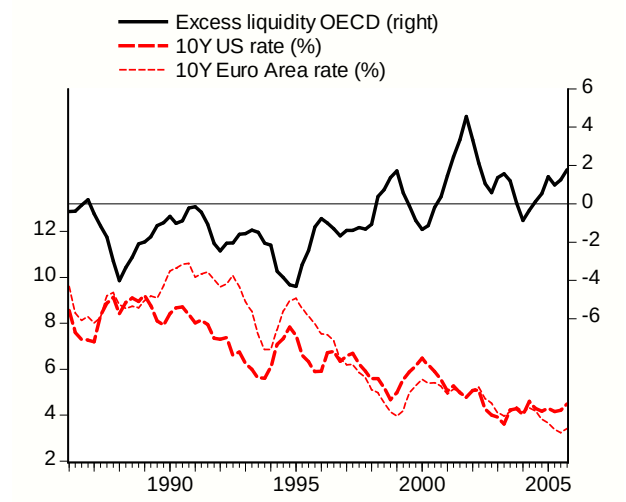
[28] We opted to test the variables separately to avoid biases linked to the probable colinearity of some of these variables. It would have been preferable to test all the factors simultaneously in the same model. However, this would have greatly complicated the estimate – owing to endogeneity and simultaneity biases and problems associated with dealing with all the variables in a joint model, particularly because of the small size of the sample – and could have produced spurious results. We therefore chose this approach, which, while admittedly reductive, gives results that we believe can be more reliably interpreted.

transitory influence on long-term interest rates. The detailed results of the estimates are provided in the Table B.3 in the appendices.

4.2.1. Growth of global liquidity, a significant factor

Excess liquidity is defined as the gap between the growth rate of the money supply for all OECD countries[29] and the OECD GDP growth rate. This measure does not capture all the interventions by Asian banks. However imperfect, though, it does include Japan, whose important role is highlighted by Bernanke, Reihnart and Sack (2005)[30].

Chart 6
OECD excess liquidity and long-term interest rates



Sources: BIS and OECD

The variable shows a fairly clear-cut trend (Chart 6), with monetary aggregates growing on average at a slower pace than GDP before 1998 (end of the Asian crisis). After 1998, the roles reverse.
Chart 1 of Box 2 expresses the impact of excess liquidity on long-term interest rates as a timeline. Excess liquidity seems to have the strongest influence at the end of 2001, at the beginning of 2003, and then again at the end of 2005. In the most extreme cases, excess liquidity could, *ceteris paribus*, have reduced US long-term interest rates by up to 75 bp in 2001-Q4 and 80 bp in 2005-Q4.

Liquidity also appears to have exerted a downward influence on euro area interest rates (Chart 5, Box 2), reducing them by 50 bp in 2001-Q4 and 65 bp in 2005-Q4.

4.2.2. Purchases of US securities by foreigners have a transitory impact

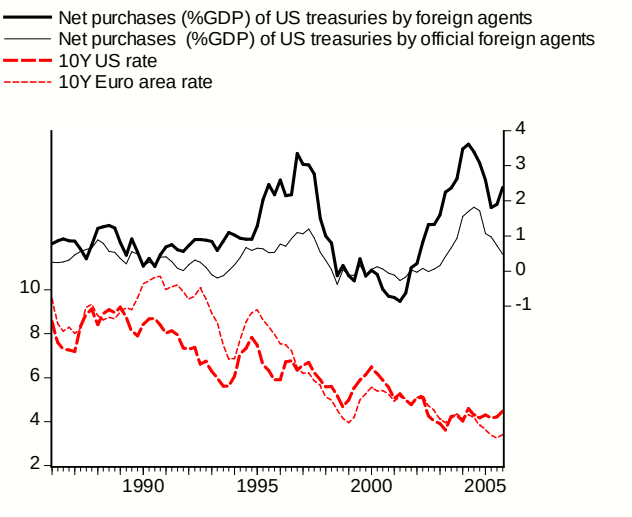
In this section, we look at net purchases of US Treasuries by official and non-official foreign agents. These nominal variables are compared against US GDP.

[29] A "global" monetary aggregate does not exist. However, the OECD provides a proxy: for each zone, the monetary aggregate indices are combined with other domestic indices to create a composite index with a fixed base (1995=100). The weighting assigned to each zone is calculated from the monthly averages of the domestic monetary aggregate in 1995 converted into US dollars using the purchasing power parity of US GDP in 1995.

[30] The OECD index includes the following countries: Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, Netherlands, New Zealand, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States.

Chart 7

Net purchases of US Treasuries and long-term interest rates



Sources: BIS and US Flows of Funds accounts

The assumption that net purchases by foreign official agents are exogenous seems reasonable insofar as this variable may be considered as price inelastic. Official purchases, particularly those by Asian central banks, have more to do with maintaining a currency's exchange rate against the dollar than with pursuing an investment strategy. However, for these purchases to exert a downward influence on the level of interest rates, they have to create, at least in part, additional demand for securities. But since the level of interest rates reflects a market equilibrium, this should not be the case. Instead, we would expect that an increase in net purchases by one category of agents would be mirrored by a corresponding decline in net purchases by other agents, leaving the level of rates unchanged.

The change in net purchases of US Treasuries by foreigners in the official and non-official sectors may reflect the growth in global liquidity and the accumulation of saving in emerging countries. It is representative of the global appeal of the US Treasuries market and of the wider US bond market (Chart 7, Box 2)[31].

The integration in the model of net purchases of US Treasuries by foreigners is significant. The sharp increase in purchases by the rest of the world is estimated to account for a 30 bp decline in US long-term interest rates in Q1 2004. The same goes for purchases by foreign official agents (Charts 2 and 3, Box 2). However, these effects appear to be basically transitory compared with the impact of liquidity. Also, they appear to be smaller than those derived from the estimates of some other studies. Frey and Moëc (2005), for example, estimate the impact of these purchases at around 100 bp. Several points may explain the gap between these two estimates:

- Frey and Moëc (2005) incorporate purchases of US Treasuries by foreigners in the long-run dynamics, which assumes an influence not in terms of the change (or acceleration) but in terms of the level.
- The 115 bp gap indicated by Frey and Moëc (2005) does not describe a differential with respect to an equilibrium (or long-term) interest rate, but a differential assuming constant purchases of securities at the 1999 level. However, the 1999 level is arbitrarily chosen and is one of the low points of the series for the sample in question. This very low 1999 benchmark makes for a large gap between the theoretical and actual rates. Our estimate of an impact of around 30 bp is calculated without assuming a reference year, which would implicitly assume an equilibrium level for purchases of US securities by foreigners.
- Also, Frey and Moëc (2005) estimate their model at a semi-annual frequency, whereas we use a quarterly frequency, and this too affects the value of the differentials.

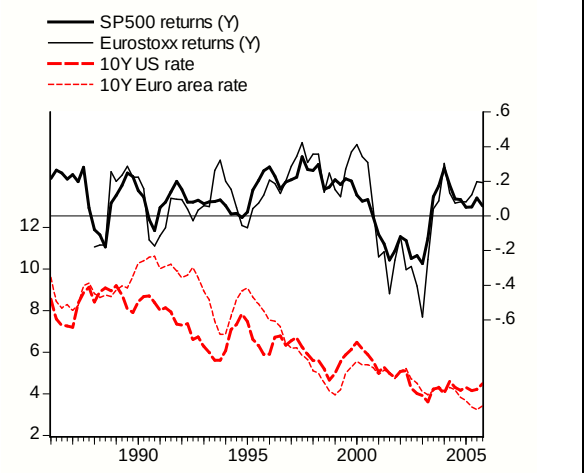
[31] According to Warnock and Warnock (2005), foreigners held 50% of outstanding US Treasuries and 20% of the overall US bond market in 2004.

Euro area interest rates are not exempt from this impact, because of market integration and the US market's leadership position. However, the influence is smaller, particularly in the case of purchases by official agents (15 bp in 2004-Q1, cf Chart 6 in Box 2).

4.2.3. Negative impact of equity markets

The introduction of equity markets into the model may be viewed in two different ways. First, this variable may be seen as a cyclical indicator like the PMI index in the basic model (Section 3), since equity prices theoretically reflect profit expectations and hence the economy's more or less advanced position in the cycle. Second, this variable may be introduced from a portfolio management perspective, with a more or less marked appeal for equity markets that could influence the level of demand on bond markets in two ways.

Chart 8
Market indices and long-term interest rates



Source: BIS

Through a market spillover effect: if dividend expectations remain unchanged, a decline in long-term interest rates – hence an increase in bond prices – leads to a change of the same sign in equity prices. In this case, bond and equity prices move in the same direction. An arbitrage effect may also occur, where a fall in prices on one market prompts a switch to the other market, causing the two to fall out of step. In this case, bond and equity prices move in different directions.

Caused by increased risk aversion, the bursting of the internet bubble in 2000 (Chart 8) made investors move to the bond market, prompting a decline in long-term interest rates (arbitrage effect). The influence of the US equity market is tested here through the return on the S&P500, while the influence of the European market is tested through the return on the Eurostoxx[32]. The US market return appears to have a downward influence on the two bond markets, reflecting arbitrage-related switching effects.

Accordingly, the fall in the US equity market is estimated to have reduced US long-term interest rates by 75 bp in 2003-Q1 (Chart 4, Box 2). Its impact was then gradually reabsorbed in 2004 and 2005, easing to just 20 bp in late 2005.

The markets also have a negative impact on euro area long-term interest rates, reducing them by around 50 bp (maximum impact in 2003-Q1, Chart 8 of Box 2). The Eurostoxx index has a similar impact on the key variables but affects interest rates to a lesser degree. This significance is deemed not to reflect the European equity market's direct influence on all interest rates so much as the increased integration of the European and US markets.

Boxes 2a and 2b below summarise the findings described above.

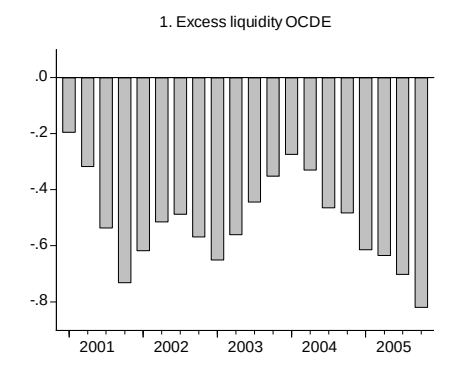
[32] The return on the Eurostoxx is tested from 1987, the first year available for the history of this index.

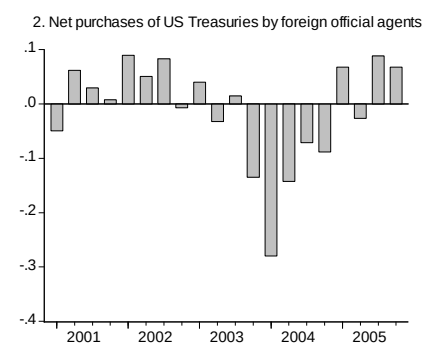
Box 2

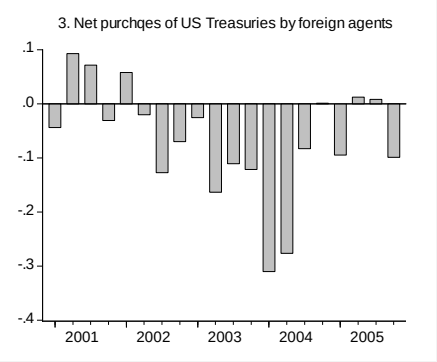
Impact[33] of different factors on the level of long-term interest rates

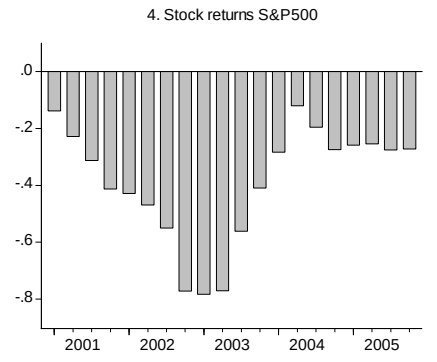
(source: Banque de France)

US 10-yr yield

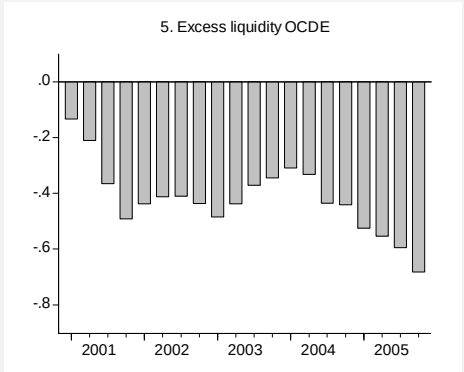


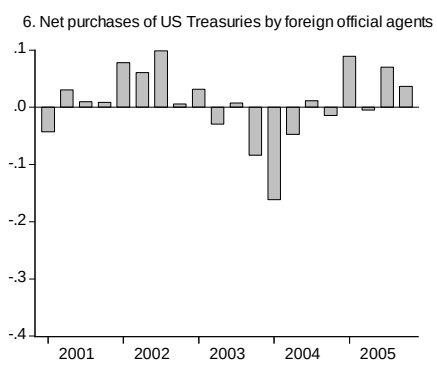


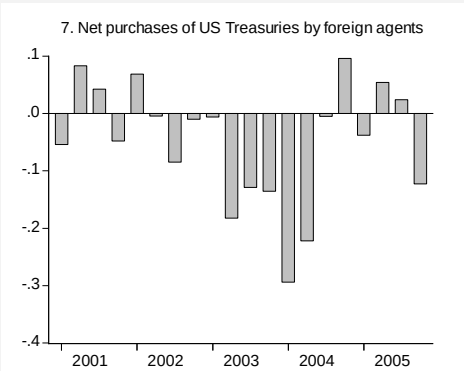


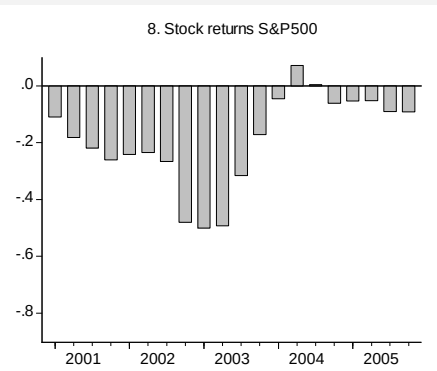


European 10-yr yield









[33] The impact of an exogenous variable on the level of long-term interest rates is calculated as the difference between the dynamic simulations of the models with and without the exogenous variable in question.

5. Conclusion

Our findings show that a range of factors, including excess liquidity, foreign demand for US securities and stockmarket performance, play a non-negligible role in the formation of US and European long-term interest rates.

We use a multivariate econometric framework that allows us to take account of the integration of the US and European markets, and to quantify the direct impact on European interest rates of factors that mainly affect the US market. From an *ex post* perspective, this approach seems more suited to modelling the European bond market than the US market.

Although the overall effect on long-term interest rates probably reflects a combination of these three factors since early 2000, we can sketch out a timeline of the main effects (i.e. *ceteris paribus*) of these variables. Thus, excess liquidity appears to influence US long-term interest rates more strongly between 2000 and 2003, then from early 2005. The impact of foreign demand for US Treasuries is most intense at the end of 2003, while portfolio switching has a considerable effect on US long-term interest rates between 2001 and 2003. The chronological sequence of specific factors that exerted a downward influence on US long-term interest rates over recent years therefore appears to be excess liquidity and portfolio switching, followed by foreign demand, then excess liquidity again.

The market integration considered in the model shows that, because of its follower characteristics, the euro area interest rate is also indirectly impacted by these factors, but to a lesser degree. Also, only the interaction between US and European bond markets is modelled here. Interdependence with other markets, like Japan, could also be examined in follow-on research.

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Appendix A: Description of data

Variables	Description	Type	Sources	ADF H0: unit root	KPSS H0: stationary
Rl_t^{US}	Ten-year interest rate, secondary market in Treasury Notes & Bonds, United States	Average over the period	*Bank for International Settlements*	-2.23	1.16***
Rl_t^{ZE}	Ten-year interest rate, secondary market in government bonds, euro area	Weighted average (of member states) over the period)	*Bank for International Settlements, Banque de France*	-0.96	1.12***
Rc_t^{US}	One-year interest rate, secondary market in Treasury Notes & Bonds, United States	Average over the period	*Bank for International Settlements*	-1.99	0.77***
Rc_t^{ZE}	One-year interest rate (based on public securities before 1999, then on Euribor), euro area	Weighted average (of member states) over the period)	*Bank for International Settlements, Banque de France*	-1.02	1.00***
π_t^{US}	Inflation rate based on CPI excluding food and energy, United States	Year-on-year change	*OECD main economic indicators*	-0.84	1.05***
$def5_t^{US}$	Expected federal deficits for the next five years, United States	As a ratio of forecast US GDP, quarterly format	*Congressional Budget Office, Banque de France*	-1.95	0.56**
D_t^{US}	Gross stock of government debt, United States	As a ratio of US GDP	*OECD Economic Outlook*	-1.88	0.30
Z_1	Indicator of excess liquidity based on M3 money supply and nominal GDP, OECD	Differential between quarterly growth rates	*OECD Economic Outlook*	-4.24***	0.71**
Z_2	Net purchases of US Treasury Notes & Bonds by foreign official agents	Quarterly flow as a ratio of US GDP	*Treasury International Capital System*	-3.81***	0.11
Z_3	Net purchases of US Treasury securities by the rest of the world	Quarterly flow as a ratio of US GDP	*Flow of Funds Accounts of the United States*	-1.94	0.18
Z_4	Stockmarket return based on the S&P500	Quarterly growth rate	*Bank for International Settlements*	-6.89***	0.20
Z_5	Stockmarket return based on the Eurostoxx	Quarterly growth rate	*Bank for International Settlements*	-8.05***	0.11
Z_6	Spot price of a barrel of Brent	Year-on-year change	*OECD Economic Outlook*	-3.30**	0.27

Note: *, **, and *** denote a rejection of the null hypothesis at the 10%, 5% and 1% levels respectively. The stationarity tests are carried out with a constant and without a trend over the period 1985-Q4 to 2005-Q4.

Appendix B: estimates and tests

Trace test

This tests the null hypothesis of r cointegrating relations against the alternative of k cointegrating relations, k being the number of variables tested. The test statistic is:

$$LR_{tr}(r/n) = -T\sum_{i=r+1}^{n}\log(1-\lambda_i)$$

where T is the number of observations and λ_i is the ith largest eigenvalue of the matrix $\gamma\alpha'$.

Table B.1 reports the values of the statistic (third column) for r=4,…,0. The fourth column reports the critical value corresponding to the 5% level (these values are taken from Osterawld-Lenum (1992)). To select the number of cointegrating relations, we test all the possible values of r, beginning with r=4. Here, we cannot reject the hypothesis of at most two cointegrating relations. However, we reject the hypothesis of at most one cointegrating relation. We therefore conclude that there are two cointegrating relations.

Table B.1: cointegration tests

Number of cointegrating relations	Eigenvalue	Likelihood ratio	Critical value at 5%	Critical value at 1%	t-Prob.**
None*	0.374525	96.70085	69.81889	77.81884	0.0001
1 at most*	0.321819	58.69213	47.85613	54.68150	0.0035
2 at most	0.219626	27.23651	29.79707	35.45817	0.0960
3 at most	0.079206	7.150017	15.49471	19.93711	0.5603
4 at most	0.005736	0.465963	3.841466	6.634897	0.4948

* hypothesis rejected at 1%

Table B.2: full VECM estimates without exogenous variables:

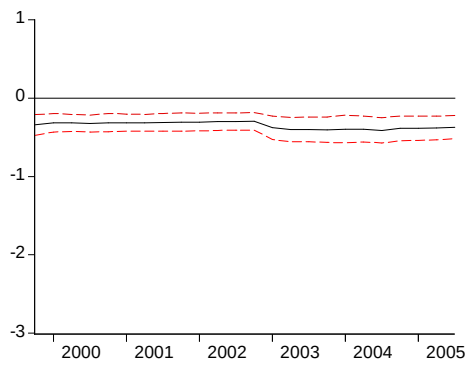
Equations:	D(Rl_t^{ZE})	D(Rl_t^{US})	D(Rc_t^{ZE})	D(Rc_t^{US})	D(D_t^{us})
u_{t-1}^{coint1}	-0.120785 [-3.10847]	0.000000 [NA]	-0.358955 [-4.34602]	0.000000 [NA]	0.343158 [2.76606]
u_{t-1}^{coint2}	-0.091990 [-1.67152]	-0.101541 [-2.82442]	-0.116484 [-1.44417]	-0.104459 [-1.23061]	0.618887 [5.49236]
D(Rl_{t-1}^{ZE})	0.210976 [1.25339]	0.047165 [0.24521]	0.054722 [0.22617]	0.103905 [0.38016]	0.136585 [0.40900]
D(Rl_{t-1}^{US})	0.369049 [2.58201]	0.203158 [1.21874]	0.357670 [1.70575]	-0.109942 [-0.46415]	-0.291334 [-1.00663]
D(Rc_{t-1}^{ZE})	0.019711 [0.17734]	-0.007427 [-0.05848]	-0.056173 [-0.35162]	-0.059183 [-0.32794]	-0.046741 [-0.21197]
D(Rc_{t-1}^{US})	-0.039191 [-0.40950]	0.160450 [1.46716]	0.037666 [0.27381]	0.396190 [2.54949]	0.154879 [0.81570]
D(D_{t-1}^{us})	0.073008 [1.23919]	0.079725 [1.18422]	0.147466 [1.74135]	0.022030 [0.23028]	0.056786 [0.48582]
μ	-0.047626 [-1.29018]	-0.055378 [-1.31283]	-0.060157 [-1.13374]	-0.036623 [-0.61099]	0.075293 [1.02808]
D(PMI)	0.026838 [2.70069]	0.052376 [4.61236]	0.007308 [0.51160]	0.050862 [3.15209]	-0.001531 [-0.07767]
R^2	0.42	0.38	0.33	0.23	0.51

Table B.3

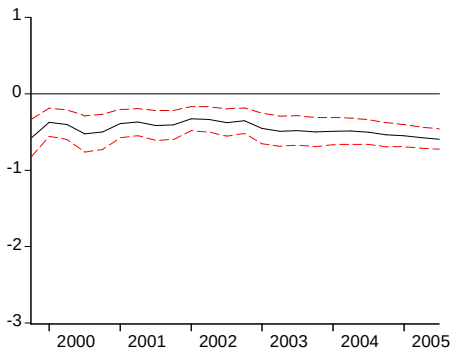
Stability of long-run coefficients of the VECM[34]

Coefficient of Rl_t^{US} on Rl_t^{ZE}

Coefficient of Rc_t^{ZE} on Rl_t^{ZE}



Coefficient of Rc_t^{US} on Rl_t^{US}



Coefficient of D_t^{US} on Rl_t^{US}

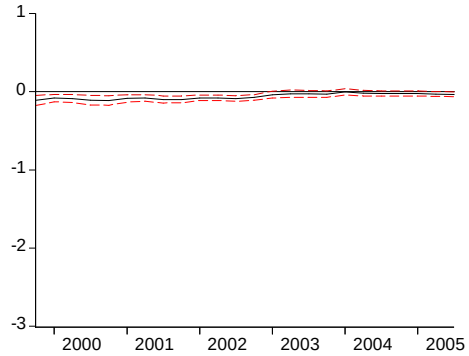


Table B.4

Model estimates based on different scenarios (1986-2005)

	ΔRl^{US}	ΔRl^{ZE}	ΔRc^{US}	ΔRc^{ZE}
Scenario 1 Excess liquidity in all OECD Member States	-0.054^{**} (0.02)	-0.030^{*} (0.018)	-0.068^{**} (0.03)	-0.020 (0.02)
Scenario 2 Net purchases of US Treasuries by foreign official agents	-0.121^{*} (0.06)	-0.090^{*} (0.05)	-0.070 (0.09)	-0.132^{*} (0.07)
Scenario 3 Net purchases of US Treasuries by the rest of the world	-0.083^{**} (0.03)	-0.080^{**} (0.03)	-0.035 (0.05)	-0.090^{**} (0.04)
Scenario 4 Return on S&P500 (%)	0.423^{**} (0.007)	0.346^{**} (0.006)	0.242 (0.01)	0.490^{*} (0.22)

Note: *, **, and *** denote a rejection of the null hypothesis at the 10%, 5% and 1% levels respectively.

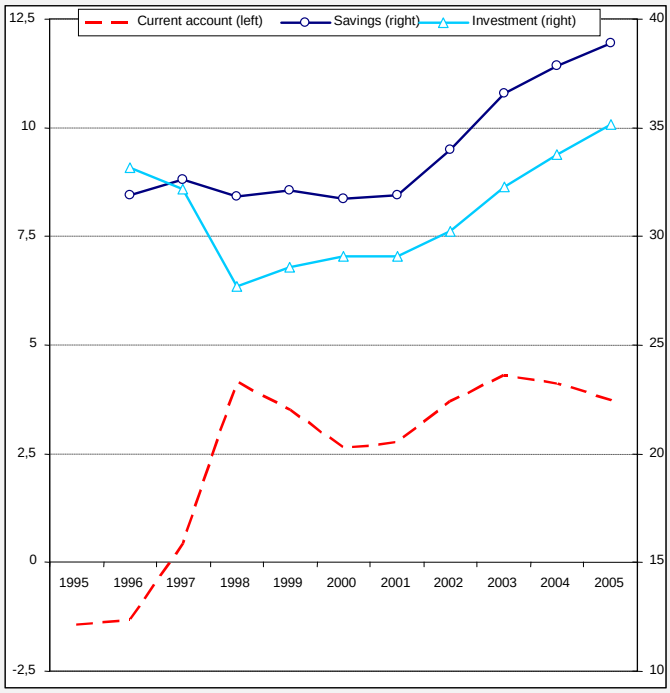
[34] The charts are obtained using recursive estimates of the VECM presented in Section 3. The recursive estimates begin in 1999Q4 in order to maintain a satisfactory number of degrees of freedom.

Appendix C: Charts

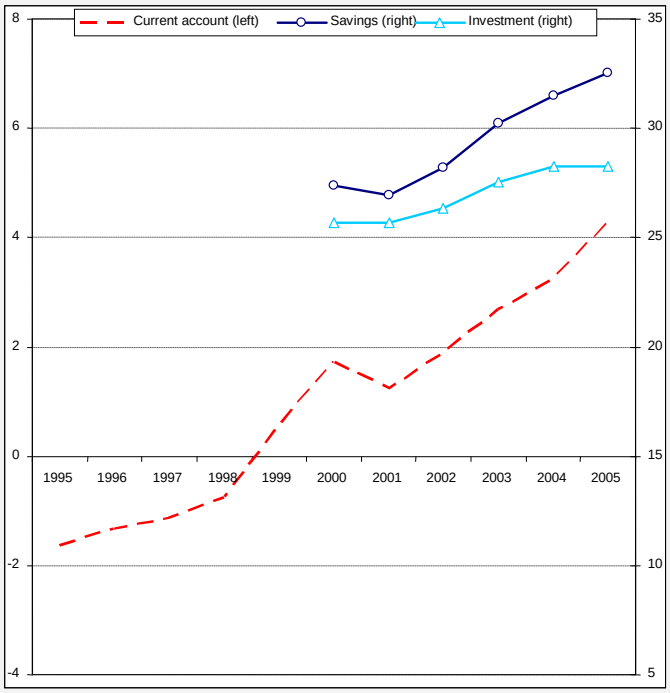
Chart C.1

Saving, investment and current account balance (% of GDP)

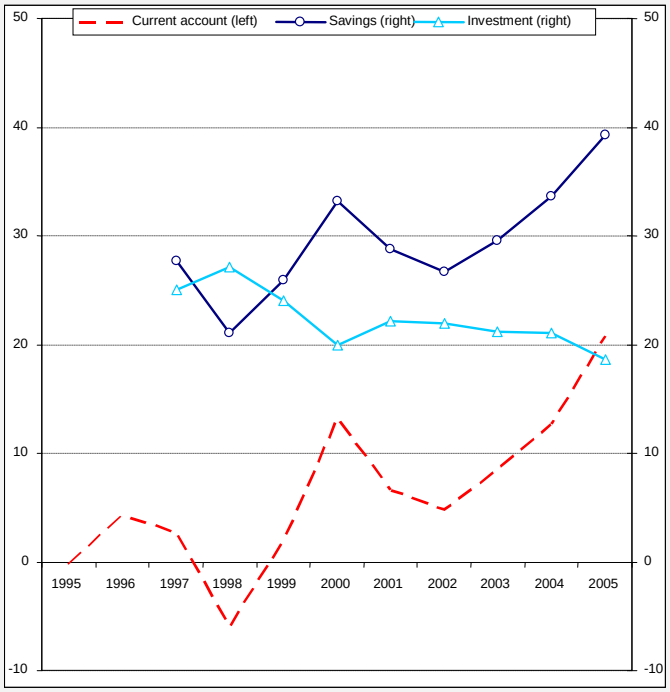
Dynamic Asian economies



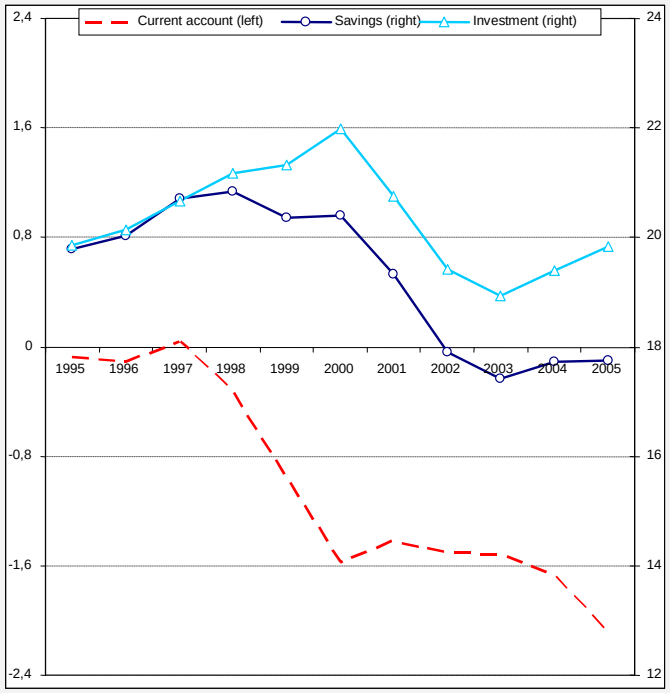
Emerging countries



Oil-exporting countries



G7 countries



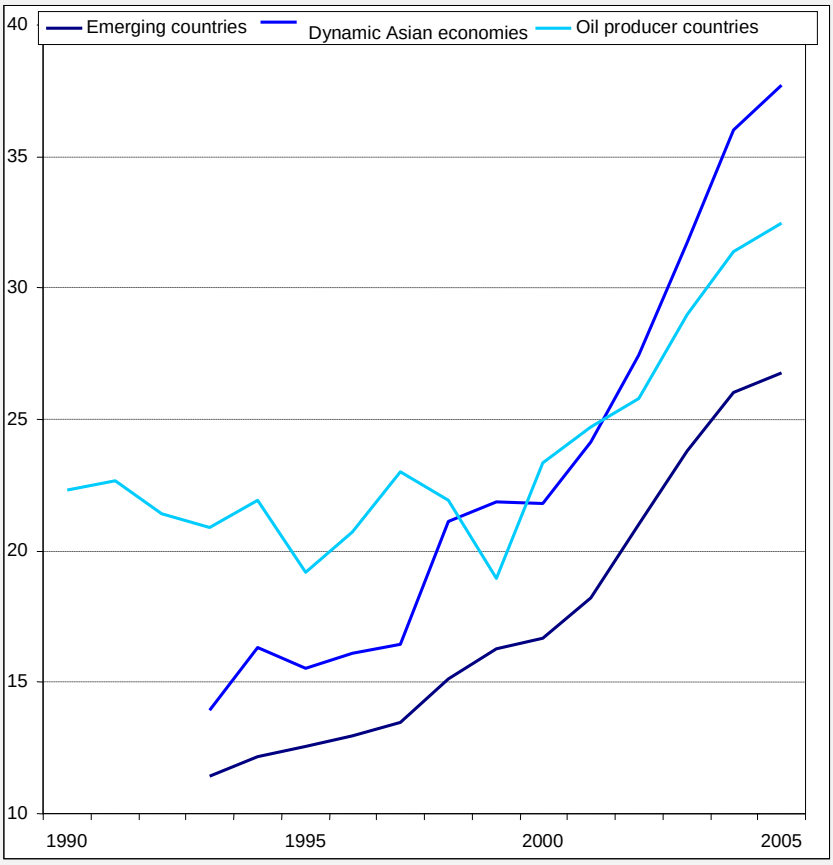
Source: IMF, *World Economic Outlook*

Note 1: The letters (r) and (l) refer to the right-hand and left-hand scales of the chart respectively.

Note 2: The World Economic Outlook Database includes 175 countries, including 29 "developed" countries, with the other 146 countries qualified as emerging. The G7 is made up of the seven largest developed economies, namely the United States, Japan, Germany, France, Italy, the United Kingdom and Canada. The dynamic Asian economies comprise 23 Asian countries, including China, Japan and India. The oil-exporting countries include the 11 members of OPEC plus 13 other large countries that are not OPEC members. See the statistical appendix of the IMF World Economic Outlook database for the exact list of countries.

Chart C.2

Foreign reserves (% of GDP)



Source: IMF, *World Economic Outlook*

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