TRANSMISSION OF SHOCKS AND MONETARY POLICY IN THE EURO AREA. AN EXERCISE WITH NIGEM

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ABSTRACT

Global macroeconometric models can be a powerful tool for economic analysis and forecasting in various scenarios. This paper analyses the NiGEM model and its application to the euro area, placing particular emphasis on the study of the relative situation of the member countries' economies. The findings of the paper show that NiGEM provides for different reactions by the European economies to common exchange- and interest-rate changes, owing to their different economic structures. Notwithstanding the potential interest of these findings, the design and evaluation of shocks in NiGEM may be seen to call for a high degree of caution if NiGEM is to be considered a reliable and useful instrument.

I. INTRODUCTION

The aim of this paper is twofold. First, to describe and evaluate rigorously the NIESR macroeconometric model (NiGEM). And further, to report the result of the model for the euro area when various shocks are introduced. This latter aspect not only enables the workings of the model to be understood, but also seeks to derive therefrom an analysis of interest in the new setting of the euro area.

The presence of different economic structures explains the different effects of shocks in each country. The growing integration of product and capital markets that is increasingly evident in Europe means that shocks are transmitted from one country to another via their trade and - in particular - financial relations. The speed with which financial variables respond to any shock and anticipate the economic situation in subsequent periods means that their effects are rapidly felt in the economies.

Open-economy macroeconomic models are often an extremely stylised representation of national economies and this is a serious limitation when drawing relevant inferences at a practical level. As a result, macroeconometric models of the world economy have proliferated, with a large number of equations and profuse modelling of interdependencies that are estimated and updated to enable forecasting exercises to be performed and quantitative responses to be given to relevant economic policy questions. The advantage NiGEM offers is not only its ongoing updating and development and its wealth of modelling detail (which, as we shall see, can also be an obstacle to its use); NiGEM's main virtue is that its forward-looking approach allows financial variables to respond immediately to present and anticipated shocks and to transmit their effects with speed.

In principle, then, NiGEM is a powerful tool for analysing a number of widely varying economic scenarios and quantifying their effects on a large number of variables and countries. However, the simulation of shocks in the model comes up against considerable obstacles and limitations of which users should be mindful when making practical inferences from the analysis.

The first part of the paper (sections II and III) describes the structural characteristics of NiGEM and the main shock transmission mechanisms, discussing the related modelling virtues and flaws. It should also be borne in mind that the program is constantly evolving, a meritorious feature but one which involves an effort as regards monitoring the model. Moreover, interpreting the exercises requires extreme caution since the result may, in some cases, alter as new versions are incorporated.

The practical application of the model (section IV) illustrates the characteristics, problems and limitations pointed out in the previous sections. Analysis focuses on the effects of different shocks in the euro area. Monetary Union entails a change in monetary regime as the exchange rate among the member countries is locked and there is a common monetary policy. This likewise entails a change in agents' expectations, which should be reflected in the economy. NiGEM allows the euro area to be satisfactorily simulated, as is subsequently explained, and the changes in expectations to be endogenised.

In the simulation exercises the shocks are analysed from the standpoint of the two aims of the paper: to observe how the transmission mechanisms function in NiGEM and to obtain an idea of the effects the shocks - whether common or idiosyncratic - exert in the euro area on the various member states. The results are of great interest and allow certain relevant conclusions to be drawn as regards identifying the main transmission mechanisms of shocks (monetary and non-monetary) envisaged for the euro area.

In sum, as explained in greater detail in the conclusions, NiGEM can be a highly useful tool for economic analysis. But one must be aware of its limitations and exercise care both in the design of shocks and in the verification of its results and the interpretation thereof.

II. ESSENTIAL CHARACTERISTICS OF NIGEM

"We see models as a central organising part of our work on policy analysis. They are useful tools for making consistent analyses, and they are repositories of significant amounts of knowledge. They are also useful in that they can provide a quick first answer to a policy question as long as they describe the world and are used with common sense". Ray Barrell, NiGEM model Director, *Modelling the World Economy,* NIESR, April 1999.

NiGEM (National Institute Global Econometric Model) is a quarterly model for the world economy devised by the National Institute of Economic and Social Research in London. It is designed to analyse the effects of different shocks or economic policy actions via simulation exercises[1]. Its equations are estimated as error correction mechanisms, so that the error correction term reflects the long-run equilibrium of the system and the associated adjustment dynamics reflect the different short-term reactions of each country.

The economies of all the OECD member countries are separately modelled in detail, and the rest are modelled by blocs and more schematically[2]. It should be stressed that there is no specific bloc for the euro area with its own estimated behavioural equations, but only definitions aggregating the respective variables of the member countries. Users can choose whether, in the simulation they wish to perform, the euro area exists or not and which countries make up the area, thereby altering the definitions of the area's aggregates. Nonetheless, the economies making up the euro area have the same nominal interest rate and the nominal exchange rate is irrevocably locked across the area, thus satisfactorily characterising the existence of a single currency.

The structure of the models of each country or group of countries is common. Agents have rational expectations (consistent with the model) about future inflation, interest rates and exchange rates, but nominal rigidities are in place which slow down the process of adjustment in the face of unexpected events. In the long run these rigidities disappear and the model displays nominal neutrality.

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[1] NiGEM can also be used to perform forecasting exercises for the world economy. The model used for forecasting is not exactly the same as that used to perform simulation exercises. Some equations are replaced by simpler expressions allowing for greater adjustment to the data and, therefore, greater predictive power in the short term, at the expense of sacrificing the attainment of a long-run equilibrium level consistent with the rest of the model. Section III highlights the essential differences between the two models.

[2] The G7 countries and Spain are the economies modelled in greatest detail, with some 60-90 equations and definitions for each. The remaining EU countries, Norway, Iceland, Switzerland, Australia, New Zealand, South Korea, Mexico, China and the Visegrad economies (Poland, Hungary and the Czech Republic) are also individually modelled, but in somewhat less detail. The rest of the world is divided into blocs covering more or less homogeneous areas whose economies are modelled more schematically, or only their current-account balance. These blocs are: East Asia, Latin America, Africa, Developing European countries, OPEC and Other developing countries (mainly the Middle East). The model is completed with the inclusion of a sector that determines world oil supply and demand and oil prices, and with behavioural equations for world food prices, non-food agricultural products, and metals and minerals.

The essential characteristics of the model are described below:

1) <u>NiGEM is a demand model.</u> Output is determined on the demand side both in the short and in the long run. There is a potential production function in the main economies and prices and wages react to the presence of an output gap and unemployment, but it is not guaranteed that output will reach its potential level at the end of the simulation period.

2) <u>NiGEM is a world general equilibrium model.</u> NiGEM places great emphasis on interdependence between countries, which occurs through the international trade of goods and services, through the financial markets and through the international stocks of assets. In each period trade flows balance out endogenously at the world level[3]. Similarly, period by period, the model achieves consistency of the stocks of foreign assets and liabilities (which are part of private-sector wealth) and of the income arising thereon in global terms. This consistency, along with the intertemporal constraint of governments which prevents an explosive trajectory for the deficit and public debt, ensures the stability of world assets and liabilities in the long run.

3) <u>Agents have rational expectations consistent with the model about the behaviour of future variables.</u> NiGEM incorporates agents' forward-looking character in three realms. (1) Factor costs: nominal wages and the user cost of capital depend on expected future inflation. (2) Foreign exchange markets: nominal exchange rates follow uncovered interest rate parity and depend on the expected future exchange rate and on the domestic-foreign interest-rate spread. (3) Financial markets: the long-term nominal interest rate is determined according to expectations theory, in terms of the short-term nominal interest rates expected in the future. Expectations about future variables are consistent with the model and are obtained by solving the model forwards imposing a terminal condition for each of these variables. Once the course of each variable has been obtained consistent with the model, its expected value coincides with the value obtained for the variable at a future point in time, such that a course consistent with its terminal condition or long-run equilibrium is described. Lastly, it should be indicated that NiGEM, at the user's discretion, allows the forward-looking nature of the resolution to be eliminated, enabling the model to be solved "backwards". However, this option imposes an extremely restrictive structure of little interest on the model, since the financial variables do not allow the changes that may arise to be anticipated.

These three primary characteristics define the general structure of NiGEM as an open-economy IS-LM model enlarged to include the following crucial elements in the transmission of shocks:

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[3] Given a discrepancy between the volume and/or world value of exports and imports of both goods and services, each country's volume of exports and/or the world price of exports is adjusted.

a) a complex and consistent system of international interdependencies,

b) wealth effects, related to worldwide capital flows,

c) overshooting of the exchange rate, which follows uncovered interest parity,

d) rational expectations about future financial variables, enabling them to react rapidly to any expected shock.

These characteristics, in particular the global nature of the model and the significance of the forward-looking financial variables in the adjustment, determine the essential transmission mechanisms of the various shocks.

The scope of application and potential of NiGEM as an instrument for performing simulation exercises also depend on the characteristics of the model. What type of simulation exercises can be performed with NiGEM? Owing to the profile of standard users (central banks and international institutions), economic policy variables occupy a priority place among the shocks that can be designed. Indeed, both fiscal policy and monetary policy are explicitly modelled in NiGEM. Also, exercises can be performed in which the value of any variable can be altered or the residual of its behavioural equation modified.

Nonetheless, it is important to stress that the design of shocks must be carried out with great care so that the equilibrium conditions of the model are not upset. Thus, although different specifications of monetary and fiscal policy rules may be used, the suppliers of the model advise against using certain options (as they may generate great instability in the model or because they are not sufficiently tested, such as the option that eliminates the automatic stabilisation included in direct tax rates or Taylor's rule for monetary policy). Further, it should be borne in mind that, on one hand, large-scale shocks may place the model on an unstable path that prevents its solution; and, on the other, exogenous changes in the forward-looking financial variables (interest and exchange rates) may distort the equilibrium conditions and make solution of the model impossible since, as will be seen, they act as the main determinants of the adjustment mechanisms in the model.

All these points will be evidenced in the simulation exercises, but first a broad-brush description of the model's structure and functioning is in order.

III. DESCRIPTION OF THE MODEL

This section sets out to explain accompanying Scheme 1, which summarises what we understand to be the structure of the model and the adjustment and solution mechanisms in NiGEM. First, the main components of the national economies are briefly described. By way of illustration, the equations relating to the Spanish block (July 1999 version) are included. Subsequently, financial flows and the way in which NiGEM adjusts and derives the short-term equilibrium are analysed, to conclude with a digression on how the long-term equilibrium is obtained and on the behaviour of the forward-looking variables and the central role in the transmission of shocks. Lastly, the monetary policy rules envisaged in NiGEM are described in detail.

III.1. MODELLING OF THE NATIONAL ECONOMIES

The modelling of each country or group is specified in three blocks: domestic demand, external demand and supply. These are described below.

III.1.1. The Domestic Demand block

This is the block that determines national output. The main national accounts identities, defined in real terms, are:

National Demand = $DD_t = C_t + PSI_t + DS_t + GC_t + GI_t$

National Income = $Y_t = DD_t + X_t - M_{t,}$

PRIVATE CONSUMPTION COMPONENTS

Private consumption (C_t) is the main component of demand and therefore includes the main channels for the transmission of changes in the economy. Consumers evaluate their current level of real disposable income ($RPDI_t$) and their real net financial wealth (NW_t/CED_t). As Table III.1 at the end of this section shows, the estimates accept the long-run unit elasticity of the sum of both for all the countries, but the individual elasticities differ from country to country, as does the speed of adjustment in the long run[4]. In some countries the nominal interest rate (e.g. Italy), especially the long-term rate, or inflation (e.g. France) are also significant factors in the long run. The behavioural equation of real Spanish private consumption is as follows:

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[4] Spain shows one of the lowest wealth elasticities (0.09, compared with 0.20 in Germany and Italy, 0.16 in the United States and 0.14 in France). The speed of adjustment in the long run is reflected in the coefficient of the error correction mechanism (ECM) of the related equation, and it also varies greatly from country to country: in Germany it is 15% quicker than in the United States, double that in France and triple that in Spain, while in Italy it is more than four times slower.

$\Delta InC_t = 0.003 + \text{dummies} + 0.56 \ \Delta InC_{t-1} + 0.07 \ \Delta InRPDI_{t-1} - 0.12 \ [InC_{t-1} - 0.91 \ InRPDI_{t-1} - 0.09 \ In(NW_{t-1}/CED_{t-1}) \ ]$.

Real personal disposable income (RPDI) is obtained by adding up wage compensation (COMP), net public-sector transfers (TRAN) and other personal income, and deducting direct tax (TAX), all deflated by the consumption expenditure deflator (CED).

NiGEM assumes it is the private sector which ultimately receives, under the caption "other personal income", (1) domestic profits, which are a fixed proportion of nominal GDP, (2) the income on net external assets, the average of income on external assets less that on external liabilities for the latest year (which depends essentially on short-term interest rates and on the return on world external liabilities, as is explained later), and (3) the interest on public debt held by the domestic private sector (98% of the total in Spain's case).

Financial wealth (NW_t) is an important variable and its components are addressed in great detail. These components are public debt held by the domestic private sector ($DEBTP_t$), net external assets in national currency ($NA_t \ RX_t$) and other assets, less liabilities ($LIABS_t$). They are described briefly below.

NiGEM assumes that all public debt is held by individuals[5] and is net wealth, and that Ricardian equivalence does not hold. The value of the debt increases because the private sector purchases new issues and because long-dated debt gains in value proportionately to the decline in long-term nominal interest rates: $\Delta DEBTP_t = 0.98 \Delta DEBT_t + 0.85 \ [0.55 \ (LR_{t-1}/LR_t - 1) \ DEBTP_{t-1}]$.

Net external assets (NA_t) are modelled in detail and internationally connected, as is explained later. Their course depends fundamentally on changes in stock market prices, exchange rates, nominal GDP and the current-account balance.

Other assets include cash (CASH) and stock market portfolios, which gain in value as equity prices (EQP) rise. Cash is a fixed proportion of M1 of the previous period which grows at the same rate as nominal GDP: $CASH_t = 0.43 \ M1_{t-1}(Y_t \ PY_t - Y_{t-1} \ PY_{t-1})/(Y_{t-1} \ PY_{t-1})$. The stock market index falls as long-term nominal interest rates rise, and in the long run it

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[5] Only a small percentage of such debt (2% in Spain's case) is in foreign private hands and is part of the country's external liabilities.

performs like the nominal output of the G7[6]. $\Delta ln\text{EQP}_t = -0.30 -0.011\ \text{LR}_t +0.20\ \Delta ln\text{EQP}_{t-1}$ $-0.051\ \Delta\text{LR}_t +0.005\ \Delta\text{LR}_{t-1} -0.096\ [ln\text{EQP}_{t-1} - ln(\text{YG7}_{t-1}\ \text{RX}_{t-1})]$

The increase in liabilities in the personal sector (LIABS_t) is equivalent to the average quarterly increase in nominal personal disposable income over the last three years.

<u>Wealth effects are very important adjustment mechanisms in the model</u>: they connect the financial markets, the current-account balance and the public sector to the real economy. The value of net financial wealth depends on financial variables, which in NiGEM are determined in markets with rational expectations about the future. Consequently, any shock that changes expectations will cause a revaluation of wealth and will thus affect today's consumption: consumers use financial markets to evaluate the future. Wealth effects participate in the transmission of shocks in NiGEM mainly through the following channels:

- given a change in expectations about the future in the financial markets (e.g. a rise in the nominal short-term interest rate), long-term interest rates anticipate this change in the present. As long rates rise, there is an immediate fall in the price of the assets making up wealth, namely public debt and equities, whereby a negative wealth effect on consumption and activity arises.

- given a change in expectations about the future, nominal exchange rates also anticipate the change, and this affects the value of net external assets, which are also part of wealth. In this case the expected rise in the interest rate involves a significant appreciation, entailing several effects. First, the appreciation reduces the current-account balance, revalues external liabilities and reduces the value of external assets. Further, since net external assets are part of the wealth valued in national currency, the appreciation entails a subsequent decline in wealth.

INVESTMENT AND CHANGE IN STOCKS

For the main economies (G7 and Spain), no behavioural equation is estimated for **real private investment** (PSI); rather, it is derived from the supply block on the basis of the law of private capital accumulation (KP): $\text{PSI}_t = \text{KP}_t + \text{KP}_{t-1}(1- \frac{1}{4}\ \text{KPDEP})$, KPDEP is the constant rate of annual depreciation of private capital, gauged for each country[7]. For the remaining countries, in which the supply block scarcely exists, private investment depends

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[6] This equation is similar for all the countries since they have been estimated jointly, imposing restrictions between the equations so that the long-term coefficients for the main economies are equal. When the model is used to make predictions and not for simulation exercises, NiGEM uses the estimated equation for US stock-market prices and imposes that, in the rest of the countries, EQP grows at the same rate as in the United States, augmented by the depreciation of the local currency against the dollar. This equation has been re-formulated in a later version (April 2000) to introduce optional forward-looking expectations about its determinants.

[7] This is 6% in Spain, 5% in Germany, 4.9% in France, 4.1% in Italy, 4.6% in the United States and 9.6% in Japan.

in the long run on real output with unit elasticity and negatively on the long-term nominal interest rate[8].

The **change in stocks** is exogenous.

PUBLIC SPENDING AND DEFICIT.

The modelling of the public sector in NiGEM is simple. All items are exogenous or fixed proportions of nominal GDP except transfers, which respond to the economic cycle, and the payment of interest on government debt. However, <u>the effects of the public sector on the rest of the economy are important</u>. Direct personal income tax (TAX), public transfers (TRAN) and government debt-service payments (GIP) directly affect personal disposable income while the stock of public debt (DEBT) increases wealth, with both determining private consumption. Moreover, the exogenous rate of corporate income tax (CTAX) increases the real user cost of capital while the exogenous rate of indirect tax (MTAX) passes through directly to the consumption deflator, in addition to increasing real wages.

The public deficit is defined as $DEF_t = GC_t\ CED_t + GI_t\ PY_t + GIP_t + TRAN_t - TAX_t - CTAX_t - MTAX_t$. NiGEM is so designed that fiscal deficits turn into an addition to government debt period by period, unless the latter is financed with money. $DEF_t = \Delta DEBT_t + CASH_t$.

As to **public spending**, both government consumption (GC_t) and government investment (GI_t) are exogenous. Government debt interest payments (GIP) increase if the stock of government debt (DEBT) does and if nominal interest rates (long-term [LR] or short-term depending on whether the country's government debt is long- or short-term) increase. $\Delta GIP_t = 0.85\ [LR_t\ \Delta DEBT_{t-1} + (LR_t - LR_{t-23})\ DEBT_{t-24}] + 0.15\ \Delta(R3M_t\ DEBT_{t-1})$. Lastly, real transfers to the private sector rise in proportion to the increase in the unemployment rate (U): $\Delta In(TRAN/CED)_t = 0.012\ \Delta U_{t-1}$.

It is through **government revenue** that the public sector most directly influences the economy. NiGEM includes a <u>fiscal rule which acts as a significant stabilising mechanism</u>: it modifies the direct tax rate (τ =TAX / Nominal Personal Disposable Income) to adjust for deviations by the deficit from its target level[9] and ensure that the deficit achieves a long-run

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[8] Similar behavioural equations have also been estimated for the G7 and Spain and are used when the model is used to make predictions. For instance, the equation for Spain is $\Delta In PSI_t = -0.06 +$ time dummies $+0.8\ \Delta In\ PSI_{t-1} +0.33\ \Delta In(Y - GI - PSI)_t -0.4\ [In\ PSI_{t-1} - In\ Y_{t-1} + 0.025\ LR_{t-1}]$. In this case the supply block is reduced to model employment and wage bargaining for all countries, and capital is only a residual variable that is obtained from investment $KP_t = 1 - \frac{1}{4}\ KPDEP_t)\ KP_{t-1} + PSI_t$. Similar behavioural equations are estimated for Germany, France, the United Kingdom, the United States, Japan and Canada to model private productive investment, but behavioural equations are also estimated for private residential investment. This depends in the long run on personal disposable income with unit elasticity and negatively on the short-term nominal interest rate. The sum of the two is real private investment.

[9] This is equivalent to the deficit level there would have been in the absence of shocks, i.e. that of the baseline, unless it is opted to modify it exogenously.

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equilibrium trajectory. Therefore, this fiscal solvency condition ensures that the stock of debt is not explosive.

$$\tau_t = \tau_{t-1} + 0.2\,(\mathrm{DEF}_{t-1} - T \arg etDeficit_{t-1})\,.$$

Users can opt not to activate this fiscal rule[10] over a certain period for a specific country, but if it is suppressed for the entire simulation there may be no solution when the model is forward-looking. If it is opted not to impose a fiscal solvency condition, the direct tax rate remains fixed throughout the simulation and a deficit may be generated such that the stock of government debt and, through the payment of interest, the deficit itself become explosive.

The rest of government revenue is made up of corporate income tax and indirect tax. Corporate income tax ((CTAX) is an exogenous proportion of profits, proxied by that of nominal output, and indirect tax (MTAX) is defined as an exogenous proportion (ITR) of nominal private consumption.

III.1.2.   External Demand

The basic determinants of the foreign trade variables are demand and relative competitiveness, and both are important world adjustment mechanisms in NiGEM. In all cases competitiveness depends in part on national prices or costs, so that a rise in national prices that is not offset by a change in the exchange rate or in external prices will cause a fall in net exports. As a result, national income will then fall in relation to the baseline or level at which it would have been in the absence of the shock. <u>Net exports act in this way as an adjustment mechanism</u>.

For the **volume of goods exports** (XGI), the relevant measure of relative competitiveness is relative export prices vis-à-vis the other countries exporting to the same markets (PXG/CPX), and demand is made up of the volume of imports in the markets to which the country exports its goods (S).

$\Delta In(\mathrm{XGI}_t/\mathrm{WDQXADJ}_t)$ = 0.07 $-$0.23 $\Delta In(\mathrm{PXG/CPX})_t$ $-$0.28 $[In\mathrm{XGI}_{t-1}$ $-In\mathrm{S}_{t-1}$ $+0.81In(\mathrm{PXG/CPX})_{t-1}]$.

In the long run, a unit elasticity of exports to world demand is imposed for all countries. This value is usually significantly different from unity in other estimates made for specific countries. In particular, in the case of Spain, as in other economies that have recently opened up, exports grow much more than their target markets. That is to say, the

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[10] This condition becomes highly restrictive on the behaviour of consumption (and therefore of GDP) when simulation exercises are performed where a new public deficit target is imposed. Not activating the solvency condition means identifying the fiscal deficit target with the current deficit.

long-run elasticity of exports to world demand is typically far higher than unity: around 1.7 with quarterly data for the period 1976-1996. Imposing unity elasticity distorts the reaction by the external sector to changes in world activity and imposes a relatively much sharper response to changes in relative prices than is actually observed.

Table III.1 shows that, unlike demand elasticity, the relative price elasticity included in NiGEM varies greatly from country to country: like Spain, France and the United Kingdom (excluding oil exports) also have elasticities higher than 0.8, and Japan's is even higher than 1, while it is 0.66 in Germany, 0.49 in Italy and 0.51 in the United States. Any discrepancy between the sum of the volume of goods exports and imports at the world level is distributed proportionately among the exports of each country or group on the basis of their contribution to world trade, via an adjustment variable (WDQXADJ).

Relevant demand in the case of the index of the volume of **goods imports** (MGI) is TFE - national final expenditure (National Income plus total imports), except for Spain and the small economies where GDP is taken directly instead. The relevant competitiveness variable is the ratio of import prices (PMG) to domestic producer prices. The long-run elasticity of imports to the expenditure variable is always significantly higher than unity, and the long-run elasticity to relative prices varies a lot across countries. In Spain it is 0.82, considerably higher than that of its euro-area partners: 0.37 in Germany, 0.59 in France and 0.73 in Italy.

$$\Delta In\text{MGI}_t = 3.59 - 0.29 \, [In\text{MGI}_{t-1} - 1.83 \, In\text{Y}_{t-1} + 0.82 \, In(\text{PMG}_{t-1}/\text{P}_{t-1})].$$

Since the exports of each country depend on world imports, which comprise world demand for exports, world imports and exports will grow jointly in NiGEM.

The indices of **goods export and import prices** (PXG and PMG, respectively) are determined as follows[11]. The export price index is expressed in dollars and depends on relevant world export prices (CPX) and on domestic producer prices (P), converted into dollars with the nominal exchange rate (RX). Dynamic and long-term homogeneity is imposed. For Spain, the behavioural equation of PXG is:

$$\Delta In\text{PXG}_t = 0.9 - 0.5t + 0.59\Delta In(\text{P}_t/\text{RX}_t) + 0.41 \, \Delta In\text{CPX}_t - 0.19[In\text{PXG}_{t-1} - 0.65In(\text{P}_{t-1}/\text{RX}_{t-1}) - 0.35 \, In\text{CPX}_{t-1}].$$

Once again, if there is a discrepancy between the sum of the value of goods exports and imports at world level, this is balanced by adjusting the export prices of each country or group. The price of imports is the weighted average of the export prices of the countries from which imports are made, with the weights based on the volume of bilateral trade.

Exports and imports of services are modelled directly in nominal terms, at their value. Their behavioural equations are similar to those for foreign trade in goods, except for the elasticities of imports with respect to relative prices, which are rather higher in the case of services. Given that REFEX is the real effective exchange rate[12],

$$\Delta In(XSER_t/WDSERADJ_t) = 0.31 + 1.006 \; \Delta In(\text{MSER rest of the world})_t +0.51 \; \Delta /In REFEX_{t-1} - 0.39 \; [In XSER_{t-1} - In(\text{MSER rest of the world})_{t-1} +0.5 In REFEX_{t-1}]$$

$$\Delta In MSER_t = \Delta In(CED/RX)_t +1.51+\text{dummies} -0.43 \; [In MSER_{t-1} - In(CED/RX)_{t-1} - 1.24 In TFE_{t-1}]$$

III.1.3. The supply block: production, costs and prices.

Along with the modelling of international flows of capital and income from net external assets, the modelling of the supply block for the main economies (G7 and Spain) has been one of the most important recent changes in the NiGEM model. Notwithstanding, long-term output continues to be determined, even in these cases, on the demand side: although the output gap is an adjustment mechanism that affects activity via prices, it is not guaranteed to close at the end of the simulation period.

PRODUCTION AND PRODUCTIVE FACTORS

In previous versions of NiGEM, explicit modelling of the production function, that would determine the economy's output in terms of the use of productive factors, did not exist for any country. Implicitly, the function of demand for labour by firms entailed a production function for the whole of the economy with constant returns to scale and of the Cobb-Douglas type. But there was no demand for productive capital, with the stock of

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[11] PXG and PMG are the manufacturing export and import price indices, respectively. The total goods export and import price indices are similar to these, since manufactures are the main component, and are defined as the weighted average of the prices of all their components. In the case of exports, $PXA_t = WDPXADJ_t \; [0.81 \; PXG_t +0.02 \; (0.16 \; WDPO_t +0.84 \; PXG_t) +0.14 \; WDPFDV_t +0.02 \; WDPANF_t +0.003 \; WDPMM_t +0.004 \; WDPFLD_t]$, and for imports $PMA_t = 0.73 \; PMG_t +[\; 0.09 \; (0.77 \; WDPO_t +0.23 \; WDPXG_t) +0.11 \; WDPFDV_t +0.037 \; WDPANF_t +0.02 \; WDPMM_t +0.008 \; WDPFLD_t) \; RX_t$, where $WDP*_t$ are indices of world prices; $WDPO_t$ of oil; $WDPFDV_t$ of food in the developed countries; $WDPANF_t$ of non-food agricultural products; $WDPMM_t$ of minerals and metals; and $WDPFLD_t$ of food in the developing countries. The discrepancy between the sum of the value of exports and imports of goods at the world level is cancelled out by adjusting the prices of individual exports via the adjustment variable WDPXADJ.

[12] NiGEM defines the real (and nominal) effective exchange rate REFEX (EFEX) as a bilateral trade-weighted average of world real (nominal) exchange rates relative to the local currency, converted into 1994-based indices. The conversion to real exchange rates is made by dividing the bilateral nominal exchange rate by the ratio of each country's private consumption deflator (CED) to the domestic trade one, expressed with 1994 as the base year.

capital playing no role but being determined on the basis of the demand for investment, via a law of capital accumulation with a specific depreciation rate for each country. So remains the characterisation of the supply block for all countries and blocs modelled in NiGEM except for the G7 countries and the rest of the European countries, which are modelled as described below.

NiGEM defines **potential output** for the G7 economies as a production function with constant elasticity of substitution σ and constant returns to scale.

Potential output$_t$ = $\gamma [\alpha K_t^{(\sigma-1)/\sigma} + (1-\alpha)(L_t e^{\lambda t})^{(\sigma-1)/\sigma}]^{\sigma/(\sigma-1)}$, where γ is a scale variable, α the weight of capital, K the stock of public and private capital, L employment measured as total hours worked and λ is the exogenous technical progress associated with employment. The parameters are different for each country. The elasticity of capital/labour substitution σ takes values close to one half (0.65 in France, 0.48 in Germany, 0.484 in Italy and 0.43 in the United States).

However, the potential production function for Spain is Cobb-Douglas (σ =1) and does not include an exogenous technical growth rate (λ =0): Potential Output$_t$ =0.022 [$K_t^{0.52}$ $L_t^{(1-0.52)}$]. The fact that the elasticity of capital/labour substitution is considerably higher in Spain than in the rest of the main euro-area economies means that NiGEM attributes much greater facility of substitution between productive factors in Spain, which is rather unrealistic. On quantifying the effects of a shock via a simulation exercise, this translates into a greater variability of capital and labour in Spain compared with the other euro-area countries.

The **capacity utilisation index** (CU) proxies the output gap and is defined as[13] the ratio of national income to potential output, adjusted by a different constant for each country, which represents the presence of excess demand in the long run. For Spain, the output gap or degree of capacity utilisation is

CU$_t$/100 = Y$_t$/(0.022 [KP$_t$ +KG$_t$)$^{0.522}$ + (E$_t$HOURS$_t$)$^{(1-0.522)}$]) + 0.326

Drawing on the potential production function, producer profit maximisation enables the expressions of long-term factor demands to be derived:

InL$_t$ = [σ $In(\beta(1-\alpha))$ –(1-σ)$In\gamma$] + InY$_t$ –(1-σ)λ t - σ InReal wage$_t$

InKP$_t$ = [σ $In(\beta\alpha)$ –(1-σ)$In\gamma$] + InY$_t$ - σ InUSER$_t$

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[13] Once again, there is also a discrepancy here between the prediction model and the simulation model. When the model is used to make predictions, the output gap is defined as the ratio of the industrial production index to a deterministic time trend implying exogenous growth of potential output at 3.6% per annum in the case of Spain. In(CU$_t$/100) = In IP$_t$ – (3.65 +0.009 t). The industrial production index simply follows the trend of GDP: ΔIn IP$_t$ = 0.3 +0.27 ΔIn IP$_{t-2}$ +0.45ΔIn Y$_t$ –0.07 [InIP$_{t-1}$ – InY$_{t-1}$].

where KP is private capital[14], β is the mark-up and USER the real user cost of capital. These expressions are included as the long-term (error correction term) of the equations estimated for the productive factors and ensure that the marginal technical rate of substitution between the two productive factors is equal to their relative costs in the long term.

The demand for **private capital** is

$$\Delta ln KP_t = 0.002 + 0.83 \Delta ln KP_{t-1} + 0.023 \Delta ln Y_t - 0.003 [ln KP_{t-1} - ln Y_{t-1} + ln USER_{t-1}]$$

For the G7 countries, in which the long-term production function is not Cobb-Douglas, the long-term elasticity with respect to the real user cost of capital (σ) is much less than 1, as shown in Table III.1, and therefore the sensitivity of investment in the long run to changes in the real interest rate is also lower.

NiGEM estimates two equations for the productive factor **labour** to capture the different short-term dynamics between hours worked per employee (HOURS) and the number of employees (EE), but they are interrelated and there is only one long-term restriction. The indirect tax rate (ITR) adjusts for the fact that the deflator used to calculate real wages is the GDP deflator and not producer prices.

$$\Delta ln EE_t = -0.48 + \Delta ln HOURS_t + 0.73 \ \Delta ln Y_t - 0.28 \ \ \Delta ln(\text{Real wages}_t / (1+ITR_t)) + 0.37$$
$$\cdot \ \Delta ln(EE*HOURS)_{t-1} - 0.09 [\ ln(EE*HOURS)_{t-1} - ln \ Y_{t-1} + ln \ (\text{Real wages}_{t-1}/(1+ITR_{t-1})) \ ].$$

$$\Delta ln HOURS_t = 1.41 + 0.004 \ Dummy92q1 + 0.103 \ \Delta ln(t-4) - 0.12 \ \Delta ln(\text{Real wages}_t / (1+ITR_t)) + 0.06 \ \Delta ln Y_t - 0.21 ln HOURS_{t-1}$$

The **unemployment rate** is defined as a percentage of the labour force U_t = 100 $(LF_t - E_t)/LF_t$, where the labour force (LF) grows at an exogenous rate (of 0.9% per annum in Spain), which is also imposed on non-dependent employment (= Total Employment(E) - EE).

COSTS OF PRODUCTIVE FACTORS AND PRICES[15]

The **real user cost of capital** is defined on the basis of the price of capital increased by expected real interest rates and depreciation, deflated by the GDP deflator

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[14] KP = K - government capital (KG). Government capital is determined by exogenous government investment as follows: $KG_t = (1 - 0.0058)KG_{t-1} + GI_t$.

[15] This block has been re-estimated and comprehensively revised for the case of Spain in the latest versions of NiGEM. The user cost of capital has been modelled, having previously been absent. In the price equations, nominal homogeneity has been imposed in both the short and the long term (this is essential so that there should be long-term nominal neutrality in the model). This revision has been applied to all prices in the Spanish block, including export and import prices. Moreover, the velocity of adjustment to the long term in the supply block has been substantially increased.

(PY_t) and net of corporate taxes (so that an increase in corporate income tax translates in NiGEM into a greater cost of production by means of the user cost of capital). Given that Π^e_t is the expected future inflation at t, and P_t is the producer price that proxies the price of investment goods (since capital is calculated net of depreciation, at replacement cost),

$$USER_t/100 = P_t [(R3M_t + LR_t)/2 - \Pi^e_t + 4.60] / [PY_t (1 - \text{corporate income tax}_t)].$$

The modelling structure for wages is derived from the **wage bargaining** model in which employers fix employment in terms of the agreed wage. In the long run real wages per hour worked are equal to the productivity thereof (APRODS) but they are also sensitive to the cycle, as reflected in the unemployment rate, albeit with different degrees of sensitivity from country to country, as reflected in Table III.1. In Germany its weight is more than double that in France or even the United Kingdom, Italy has an intermediate weight and the scant influence of unemployment on Spanish wages is particularly striking. The long-term velocity of adjustment also varies greatly across countries; for example, in Germany it is twice as quick as in France, while Italy and Spain take intermediate values. The growth rate of nominal wages also adjusts to expectations of future inflation (short-term nominal wages elasticity with respect to inflation in Table III.1) in a different way from country to country[16].

The fundamental wage variable is compensation from work (COMP) in relation to total hours worked (EE*HOURS). The wage deflator used is the GDP deflator (PY), which is also net of indirect tax here.

$$\Delta ln(COMP/(EE*HOURS))_t = -0.74 + \text{dummy} + 0.65 \Delta ln(COMP/(EE*HOURS))_{t-2} + 0.35 \Pi^e_t - 0.15 [ln(COMP/(EE*HOURS))_{t-1} - ln(PY/(1+ITR))_{t-1} - APRODS_{t-1} + 0.008 U_{t-1}].$$

<u>The unemployment rate is an important adjustment mechanism</u>: if it increases, nominal wages fall and real wages stand below their long-term trend. With lower nominal wages prices grow more slowly, real financial wealth increases and international competitiveness improves, and both entail a rise in capacity utilisation through greater domestic and external demand. These effects gradually stabilise the economy.

Inflation expectations are forward-looking[17], consistent with the model, $\Pi^e_t = \Delta ln CED_{t+1}$. <u>The effect of inflation expectations on wages is an important short-term adjustment mechanism</u>, because a change in nominal wages translates into a change in

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[16] In Germany's case the relevant inflation in the short run is not that expected for the next quarter but actual inflation in the current period.

[17] NiGEM allows simulations to be performed under the assumption that agents have adaptive (backward-looking) expectations about future inflation based on the determinants of its historical trend (past inflation and output gap). For Spain, under this assumption $\Pi^e_t = 0.29\Delta ln CED_{t-1} + 0.36\Delta ln CED_{t-2} + 0.19 \Delta ln CED_{t-3} + 0.05\Delta ln CED_{t-4} + 0.0024 CU_t - 0.0023 CU_{t-1}$.

unit labour costs (ULT)[18] immediately, and the latter is the main explanatory component of price movements (after the inertial component, which is the most important).

Producer (P) and consumer prices (CED) in NiGEM are defined as weighted averages of their components, with weights estimated under the nominal homogeneity restriction in both the short and long term.

Producer prices: $\Delta ln P_t$ = -0.14 +dummy +0.23 $\Delta ln P_{t-1}$ +0.25$\Delta ln ULT_t$ +0.52 Π^e_t –0.12 [ln P_{t-1} – 0.57ln ULT_{t-1} – 0.43ln PMA_{t-1}]

As Table III.1 shows, in most countries (though not in Spain) <u>the capacity utilisation index (CU) or output gap acts as an adjustment mechanism</u>, correcting deviations by national output from the long-term production function via adjustments in producer prices. In some countries such as France and Italy it only acts in the short run, and mention should be made of the high sensitivity of prices in Germany to deviations by output from its potential level.

The growth rate of the GDP deflator is an identity; it is not modelled in NiGEM. It is defined in terms of the two components of GDP, weighted by their relative weights: $\Delta ln PY_t$ = ((TFE_t – X_t)/Y_t) $\Delta ln CED_t$ + (X_t/Y_t) $\Delta ln(PXA*RX)_t$ – (M_t/Y_t) $\Delta ln PMA_t$..

<u>The growth rate of the consumption deflator is the relevant measure of inflation in NiGEM</u>. $\Delta ln CED/(1+ITR))_t$ = 0.034 +dummies +0.89 $\Delta ln P_{t-1}$ +0.11 $ln ULT_{t-1}$ –0.14 [$ln(CED/(1+ITR))_{t-1}$ –0.53 $ln ULT_{t-1}$ –0.47 $ln P_{t-1}$]

For all countries, albeit with different elasticities and different velocities of long-term adjustment, inflation depends essentially on: (1) unit labour costs, i.e. on wages per hour worked (COMP/(EE*HOURS)), (2) import prices, which pass through the change in the exchange rate to producer prices and from the latter to the consumption deflator, and (3) activity: the greater the degree of capacity utilisation, then the higher producer prices and the higher the number of hours worked will be, or correspondingly the lower unemployment and, therefore, the higher wages will be.

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[18] Unit labour costs (ULT) are defined as a hourly wages in manufacturing, which grow at the same rate as wages per hour worked (COMP/(EE*HOURS)) plus a declining time trend whose growth rate proxies productivity growth (1.2% per annum for Spain). One measure of a country's competitiveness is relative unit labour costs (RULT). These are defined as the ratio of Spanish ULT to a weighted average of those of the rest of the world where weights are trade-based.

III.2. PERIOD-BY-PERIOD CONSISTENCY OF THE MODEL: INTERNATIONAL CAPITAL AND INCOME FLOWS IN NIGEM

Having analysed the components of the blocks of equations relating to individual countries, let us move to the second part of Scheme 1: the determination of external flows at the global level. The current-account balance determines the accumulation of each country's net external assets. Given that NiGEM is a global model, the external position has a central place in the model. More specifically, NiGEM requires that the sum of current-account balances at the global level should be zero, as should the sum of trade balances. This restriction determines the period-by-period global consistency of the model, whereby the effort expended by the program in evaluating the flows and the volume of stocks of external assets and liabilities may be understood[19].

NiGEM describes in detail the external assets and liabilities of each country or group of countries along with the income flows on these stocks, modelled via the appropriate rates of return. The assets and liabilities are part of domestic wealth, whereby they act as international shock transmission mechanisms: changes, for instance, in a country's stock market prices affect both domestic wealth and that of the rest of the world. The flows of income arising on assets and liabilities are part of domestic disposable income, likewise acting as propagation mechanisms: changes in a country's interest rate alter the return on world assets and liabilities, thus changing other countries' disposable income. Both income flows and asset stocks are fully connected in the world economy described in NiGEM. A shock to a country's saving or investment alters the saving/investment balance at world level, activating the aforementioned wealth and income mechanisms until a new balance is reached.

The **current-account balance** (CBV) is defined as net exports of goods and services in nominal terms (and in dollars) plus income on net external assets, increased by international offsetting transfers.

$$CBV_t = (PXA_t/100)(XGI_t/100) - (PMA_t/100)(MGI_t/100)/RX_t + (XSER_t - MSER_t) + \text{Income}$$
on net external assets$_t$ + Balance of Payments transfers$_t$.

The determination of the trade balance was described in detail in section II.1.2.. NiGEM defines Balance of Payments transfers such that the value, expressed in domestic currency and in real terms, is equal each period to the average value over the previous year.

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[19] Such meticulously detailed modelling is one of the more recent features of NiGEM. Until 1999, the modelling of stocks of net external assets was very simple and the returns on these were a fixed proportion of the change in their level.

The income on external assets and liabilities is the interest, profits and dividends accrued and paid thereon (IPDC and IPDD, respectively), and their difference forms part of personal disposable income. The return on foreign liabilities is an average, weighted by the weight of each component, of the rates of return thereon: the rate for private liabilities in the form of portfolio investment or foreign direct investment is a fixed one of 3% per annum, that for private liabilities vis-à-vis the banking sector is the short-term nominal interest rate of the related country, and that for public-sector liabilities is the interest on government debt. Lastly, the rate of return on external assets (ROR) tends in the long run towards the rate of return on world liabilities excepting a constant estimated for each country[20]. Any discrepancy between the sum of income on world external liabilities and assets each period is distributed between the income on the assets of each country or group via an adjustment variable.

For each economy, NiGEM calculates the **stock of external liabilities (GL) and assets (GA)** in dollars. The stock of liabilities is revalued each period depending on its composition and on the change in stock market prices and in exchange rates[21], and this revaluation is distributed to the stocks of assets of all countries according to the proportion of world assets (WDGA) they hold.

$$GL_t = GL_{t-1} + REV_t - 0.5\ CBV_t + (GL/(Y*PY/RX))_{t-12}\ \Delta(Y*PY/RX)_t$$

$$GA_t = [GA_{t-1} + (GA_t/WDGA_t)\ WDREV_t + 0.5\ CBV_t + (GL/(Y*PY/RX))_{t-12}\ \Delta(Y*PY/RX_t]\ WDGAADJ_t$$

The stock of external liabilities also rises if there is a current account deficit, or falls if there is a surplus. NiGEM imposes that it does so by half of its value, while the other half is added to the stock of assets, with the opposite sign. The model also includes some capital flows which increase the stock of liabilities and of assets to the same extent and in proportion to the rise in the nominal GDP of the period, so that the ratio of net external assets to nominal GDP remains constant over time if there is no revaluation or current account deficit or surplus. In the absence of external shocks, equilibrium on world asset markets implies that the ratio of net external assets to nominal GDP (and therefore also the ratio of the balance on current account to nominal GDP) must be stable at the end of the simulation period. Finally, any discrepancy between the sum of world external liabilities and

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[20] In the case of Spain, $ROR_t = ROR_{t-1} + 0.2\ [WDIPDD_{t-1}/WDGL_{t-1} - 0.0034 - ROR_{t-1}]$, where $WDIPDD_{t-1}/WDGL_{t-1}$ is the income on worldwide liabilities over the sum of world liabilities.

[21] Public-sector external liabilities (2% of the total in Spain according to NiGEM) are at the issuance value and are therefore not revalued, except to the extent that the local currency appreciates. 36% (as opposed to 49% in the United States) of Spanish private-sector external liabilities are related to portfolio and foreign direct investment. Of this, 26% (one-third in the United States) are in the form of stock market portfolios and rise in value as and when equity prices during the period do, while the rest rise in value in accordance with the long-term trend of equity prices. The remaining 64% of private external liabilities are assumed to be entered into with the foreign banking sector and rise in value insofar as the currency in which they are denominated appreciates.

assets each period is distributed among the assets of each country or group by means of an adjustment variable (WDGAADJ).

III.3. LONG-TERM EQUILIBRIUM: TERMINAL CONDITIONS AND ROLE OF THE FINANCIAL VARIABLES

Long-run equilibrium of the model assumes a stable situation at the global level and in each country. As stressed in the scheme, the financial variables (exchange rates and interest rates) are fundamental to the model adjustment processes. These variables react to any shock (with a "jump"), anticipating their new long-run equilibrium values. From the first period they are situated on a path consistent with such equilibrium, setting in motion the model adjustment mechanisms. Before characterising the long-term equilibrium it is therefore worth explaining how the equilibrium paths of these financial variables are determined.

III.3.1. The financial markets

The formation of **expectations in the financial markets** is a fundamental aspect of the model. These expectations determine the path of the financial variables and affect asset prices. Any shock that changes expectations in the financial markets about the future will affect activity through consumption, via wealth effects and via disposable income (wages), through investment (via factor costs) and through net exports (via competitiveness). The rest of the prices in the economy also react more or less rapidly to exchange rate and interest rate changes, helping to adjust activity.

NiGEM assumes by default that agents in financial markets have rational expectations, consistent with the model, about the future. This forward-looking behaviour means that both the exchange rate and the nominal long-term interest rate jump when changes occur in the economy. The magnitude of the jump will depend on the future effects of the changes anticipated by the financial markets, in such a way that the variables are situated on a path consistent with the equations of the model, with global balance-of-payments consistency and with their own long-term equilibrium values. To avoid explosive paths a terminal condition is imposed for each forward-looking variable, as mentioned above.

LONG-TERM INTEREST RATES

Long-term nominal interest rates (LR) are defined, upon the assumption of perfect anticipation or forward-looking financial markets, as the geometric mean of the short-term interest rates (R3M) of the next 10 years[22]:

$$\ln LR_t = 1/40 \sum_{k=0,..,39} \ln(1+ R3M_{t+k}/100)$$

The effect of a shock to R3M is anticipated in the first period of simulation, but with a reduced magnitude (pre-multiplying by 1/40 each quarter of shock). The more lasting the shock to R3M the greater the size of the change in LR from the outset. Given that Investment and Consumption depend on LR, this changes the effects of the shock on real activity. Investment depends on LR through the user cost of capital. Consumption depends on LR indirectly through (a) the increase in Personal Disposable Income resulting from the increase in interest on public debt and (b) the increase in real wealth arising from the revaluation of public debt and equities.

EXCHANGE RATE

Our experience with NiGEM up until now leaves us in no doubt that the exchange rate is the most important variable in the determination of the model's short-term reactions and, above all, in the achievement and characteristics of long-term equilibrium. Forward-looking exchange rates[23] are defined on the basis of uncovered interest rate parity :

$$ln RX_t = ln E_t(RX_{t+1}) - ln[(1+R3M_t/400)/(1+ USR3M_t/400)]$$

where RX_t is the exchange rate defined in national currency units per US\$ in quarter t, $R3M_t$ the three-month nominal interest rate defined as annual percentage points and $E_t(RX_{t+1})$ the exchange rate of the next quarter expected today. To obtain fulfilment of its terminal condition (or long-run equilibrium) a jump to the exchange rate in the first period of simulation is imposed and the path of the exchange rates is obtained up to the final period using the uncovered interest rate parity equation lagged by one quarter, $ln RX_t = ln RX_{t-1} + ln[(1+ R3M_{t-1}/400)/(1+ USR3M_{t-1}/400)]$, where each period reflects the effects of the changes in the exogenous variables on the exchange rate and interest rate in the previous period, through the structure of the model. The mechanism for solving the model adjusts this initial jump until its sufficient for the resulting exchange rate path to generate a constant growth of nominal exchange rate at the end of the simulation period.

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[22] The alternative is to assume backward looking financial markets, with agents having adaptive expectations regarding short-term rates: $\Delta LR_t = 0,8 \Delta R3M_t +0,2 (R3M_{t-1} - LR_{t-1} +0,5)$.

Monetary policy, whose instrument in the model is short-term interest rates, exerts its effects through the changes in the financial variables: the long-term interest rate, which is an average of future short-term rates and the nominal exchange rate, through uncovered parity.

III.3.2.   Characterisation of the long-run equilibrium

The model's long-run equilibrium, which is determined by the baseline relationships, involves at the theoretical level a situation in which the output gap is closed and, simultaneously, saving and investment are balanced both at the global level (global consistency of the model from period to period) and in each country.

Nonetheless, the global nature of the model, the numerous equations involved in the estimation and its empirical basis shape the way in which the equilibrium is calculated.

First, given the model's computational complexity, in practice the equilibrium conditions are not defined directly by the saving-investment relationship or the elimination of the output gaps in each country, but by **three terminal conditions** imposed on the long-run values of the forward-looking variables:

1.   that the level of prices is changing at a constant rate (constant inflation) at the end of the simulation period.

2.   that the nominal exchange rate is changing at a constant rate (constant depreciation/appreciation, not necessarily none) at the end of the simulation period.

3.   that the long-term nominal interest rate is equal to the short-term nominal interest rate at the end of the simulation period[24]

A second fundamental factor to consider is that the solution of the model is <u>estimated</u> on the basis of the data for each country. Accordingly, the baseline equilibrium is governed not only by the theoretical foundations of the model, but also by the actual behaviour of the various economies. This means that the growth rates of potential output, inflation rates, the accumulation of assets and, therefore, the equilibrium level of the current

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[23] The alternative to forward-looking exchange rates is of no interest except in certain cases, such as when the shock is of such a magnitude that no stable solution exists for the simulation. With NiGEM it is thus possible to choose between the following three options: 1) Fixed nominal exchange rates. 2) Backward-looking exchange rates: exchange rates follow uncovered interest rate parity but with a lag of one period, i.e. without expectations. $lnRX_t = lnRX_{t-1} - ln[(1+ R3M_{t-1}/400)/(1+ USR3M_{t-1}/400)]$, and 3) Constant real exchange rates: the appreciation/depreciation of the nominal exchange rate with respect to the dollar should be equal to the inflation differential with the United States.

[24] This third condition is derived directly from the very definition of the long-term nominal interest rate.

account balance differ across countries[25]. Thus, the equilibrium exchange rate in the long run is not constant, although its rate of change is, and consequently PPP is not fulfilled in the long run[26]. This also means that the real interest rate differs across countries in the long-term equilibrium, with non-zero but constant interest rate differentials, since uncovered interest rate parity (expressed in real terms) continues to be satisfied.

Finally, as regards the simulation exercises, the solving of the model is cut short at an arbitrary point (currently in the period 2017Q1). Although this simulation horizon is generally sufficient to derive an equilibrium path for the forward-looking variables consistent with fulfilment of its terminal conditions[27] and which ensures the global consistency of the balance of payments from period to period, it is not always long enough for the model variables to achieve the long-term relations specified in their behavioural equations (error correction mechanisms). Thus, for example, as we shall see in the simulations in section IV, the output gap is not always closed at the end of the simulation period.

NiGEM is based on a model of the world economy in which both global equilibrium and the terminal conditions are fulfilled. The mechanics of solving the model involve a process of iteration until the model's terminal conditions are fulfilled. This characterisation of the equilibrium is known as the "baseline" and it is the point of reference for analysing the shocks desired. When the simulation has been performed the program saves in a file all the adjustment paths of the variables to enable the various effects of the shock to be analysed in an infinite number of dimensions.

In any event, when analysing the effects of the shocks, the characteristics of the achievement of long-term equilibrium in NiGEM should be borne in mind. As will be seen in the simulation exercises, the results generated may give rise in some cases to problems of interpretation. In particular, when variables diverge from the baseline at the end of the simulation period it is sometimes not easy to identify whether this is a problem connected with the limited simulation horizon or with the fulfilment of the terminal conditions (which may generate imbalances in other variables), or whether such divergences are in fact consistent with the theoretical foundations of the model.

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[25] The latter result (non-zero current account balances) may be striking in the setting of ordinary open economy models, but there are some monetary models of balance of payments equilibrium that enable both the result and, simultaneously, the long-term path of the real exchange rate to be explained. The current account disequilibria are corrected through the depreciation of the real exchange rate, in such a way that the improvements in the trade balance enable the increase in interest payments arising from the accumulation of external liabilities to be financed. When it is considered that the current account balance reaches its stationary state in a situation of deficit (surplus), it follows from the same argument that the real exchange rate will tend to depreciate (appreciate) in the long run.

[26] In particular, euro area inflation in the baseline is 1.84%, compared with US inflation of 2.26%. Given that the nominal euro exchange rate appreciates annually by half a percentage point, this means a real annual appreciation of the euro against the US dollar of eight basis points. However the real effective euro exchange rate is depreciating annually by 0.62%, basically due to the appreciation of the south-east Asian currencies.

[27] If the effect of a shock generates such distortion in the forward-looking variables that the terminal conditions are not fulfilled within the simulation horizon, the simulation does not converge and paths towards equilibrium are not generated for the model variables. In this case no inferences of any kind can be drawn from the results.

III.4. MONETARY POLICY RULES AND TRANSMISSION

The instrument variable of monetary policy is the **short-term nominal interest rate**, expressed in annual percentage points. The instrument of the ECB's monetary policy is the euro-area short-term nominal interest rate (GER3M)[28]. Given the relationship between short-term interest rates and the rest of the financial variables, the effects of monetary policy are transmitted in the first instance through the term structure and the uncovered interest parity to nominal long-term interest rates and the nominal exchange rate, respectively. At the same time, monetary policy in NiGEM is specified through various rules that determine the reaction of short-term interest rates to the prevailing economic conditions.

III.4.1. Monetary policy rules in EMU

The monetary policy rules in NiGEM are defined as deviations by the monetary instrument, the short-term nominal interest rate R3M, from its equilibrium level (R3MT) in response to deviations by certain variables from their target or equilibrium values which, unless they are changed exogenously, are their baseline values.

The long-term equilibrium level (baseline) of the monetary policy instrument is that arising from long-term equilibrium in the money market, based on a simple LM curve[29]:

$$R3MT = -\alpha \, [ln M1T - ln(YT{*}PYT)] = \alpha \, ln(\text{Trend velocity})$$

where α is the long-term semi-elasticity of the demand for real balances with respect to the nominal interest rate, and where M1T and (YT*PYT) are the money supply and nominal GDP levels consistent with the long-term equilibrium or baseline of the model.

The fact that the monetary policy rules are defined as deviations by the interest rate from the baseline is not entirely standard in the literature. Normally it is the change in the interest rate with respect to the previous period[30], and not with respect to its long-term equilibrium, which responds with certain specified weights to the deviations by the variables relevant to monetary policy with respect to their target levels. Moreover, these targets are not normally defined, like in NiGEM, as those that satisfy the long-term equilibrium in the money market, but are instead the targets for such variables set by the monetary authority.

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[28] By construction, GER3M refers to the German rate, which is equal in EMU to the short-term nominal interest rate of the rest of the euro area countries.

[29] This relationship is the long-term demand for money. The quantity of money is obtained endogenously in NiGEM on the basis of its behavioural equation. In the case of Spain, this is: $\Delta ln \, M1_t = \Delta ln \, CED_t \, -0{,}25 +0{,}7 \, \Delta ln(M1/CED)_{t-4} +0{,}6 \, \Delta ln Y_t -0{,}003 \, \Delta R3M_t -0{,}6 \, [ln \, M1_{t-1} - ln \, CED_{t-1} - ln \, Y_{t-1} +0{,}026 \, R3M_{t-1}]$.

[30] As this is not the case in NiGEM, the interest-rate smoothing that is seen in reality and which is typically admitted as one of the objectives of monetary policy cannot be reproduced.

This divergence from the standard rules in the literature makes interpretation and evaluation of the monetary rules contemplated in NiGEM difficult.

At the same time, the monetary policy rules so defined constitute a basic mechanism for the convergence of the model with its long-term equilibrium following a shock: the short-term nominal interest rates will be altered to generate the necessary adjustments until the variables specified in the rule reach their long-term equilibrium. Given that all the rules, except the one similar to the Taylor rule and the inflation targeting rule, are specified with respect to some nominal variable (monetary aggregate or nominal GDP), we understand that it is through the action of these rules that the model's nominal variables are anchored. Otherwise the model would suffer from nominal indeterminacy[31]. This important role for monetary rules in the adjustment towards long-term equilibrium means that in NiGEM the systematic component of the monetary policy is very important, as will be seen in the simulation exercises in section IV. However, the role of monetary policy as an active instrument to achieve price stability is very small in NiGEM. Under the rule the authors of the model recommend and use by default (nominal GDP and inflation targeting), the weight of deviations by inflation from its target or equilibrium level is only 0.5.

NiGEM gives a choice of six rules, which are described below taking as example the specification of each rule for the case of the euro area. The monetary policy rules for the euro area are defined in NiGEM in such a way that the short-term nominal interest rates of the euro area depart from their baseline or equilibrium level (GER3MT) in order to adjust the deviations by the relevant variables from their target or equilibrium values. The euro-area aggregates are simply the sum of the national aggregates, expressed in a common currency. This procedure is also applied to the aggregation of the monetary variables, of the nominal GDPs and of their target levels, while the parameters of the monetary rules become a sort of weighted average of the national parameters. Accordingly, the interest rate of the area is set by the ECB on the basis of an average of the rules of its member countries, which should be taken into account when assessing the monetary policy of the euro area and its effects.

1.   Monetary rule (money-based targeting): the short term interest rate adjusts to the difference between the actual money supply and its target level, although NiGEM specifies the rule for the euro area in terms of the nominal GDP of the area (EMUNOM):

$$GER3M_t - GER3MT_t = 32.9[ln\,EMUNOM_t - ln\,EMUNOMT_t]$$

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[31] In fact, although we are not clear exactly why, this seems to be what happens when attempting to use the Taylor rule included in NiGEM. The model takes much longer to converge and practically never does when the forward-looking characteristic of NiGEM is used. It may be that this is due to the fact that the Taylor rule does not anchor the level of any nominal variable, since it is defined only in terms of the real GDP and inflation (or the rate of change of prices).

where the value of the parameter (32.9) is the value of α for the euro area as a whole. Given that the money supply adjusts endogenously in the model towards its long-term level, this monetary rule is not strictly speaking a reaction function, but rather a mere reflection of how the nominal interest rate adjusts to its equilibrium level as its determinants do the same. Accordingly, this option does not give the ECB an active role in the determination of interest rates or in the stabilisation of the nominal variables.

2. <u>Rule with inflation (nominal GDP and inflation targeting)</u>: in this case the ECB also takes into consideration the divergences between the actual and the target rate of inflation (EMUINFFT), adjusting the interest rate in consequence:

$$GER3M_t - GER3MT_t = 32{,}9[lnEMUNOM_t - lnEMUNOMT_t]+0{,}5[EMUINFF_t - EMUINFFT_t]$$

Under this rule the ECB plays a more active role in the stabilisation of inflation, and it is this one that NiGEM adopts by default.

3. <u>Inflation targeting</u>: introduced in a more recent version of the model (January 2000), this rule is equivalent to the previous one but without the nominal GDP term. It is therefore subject to the potential problem mentioned above of the absence of an anchor for the nominal variables.

$$GER3M_t - GER3MT_t = 0{,}5[EMUINFF_t - EMUINFFT_t]$$

4. <u>Taylor's rule</u>: in the form in which it appears in NiGEM, this rule implies that the ECB reacts to deviations by inflation and real GDP from their respective equilibrium levels, the equilibrium interest rate GER3MT (2.5% per annum by default) also being taken as a parameter:

$$GER3M_t = 2{,}5 + 50 [lnEMUGDP_t - lnEMUGDPT_t] + 1{,}5 [EMUINFF_t - EMUINFFT_t]$$

Despite the attractiveness of this rule as an option for analysis[32], in our experience its practical use in NiGEM is subject to considerable problems; it has been verified that when it is applied with forward-looking expectations it practically never permits model convergence[33].

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[32] NiGEM gives various options when defining the specification of this rule, besides changing the values of the parameters arbitrarily. These options are: a) adding an additional term, the nominal interest lagged by one period, and b) replacing the deviations from the equilibrium level of real GDP by deviations in the growth rate of real GDP from the baseline or also from a specific constant growth rate.

[33] As mentioned above, this may be related to the lack of an anchor in this case for the nominal variables.

5. <u>Constant nominal interest rate</u>: the monetary authority reacts by providing liquidity to keep the nominal interest rate constant. This option is problematic because it means that the financial variables do not adjust the changes in the model. The adjustment mechanisms are thus lost and in most cases model convergence is not possible. This is an option that would only make sense for very specific simulations and for a short period of time.

6. <u>Constant real interest rate</u>: this case is similar to the previous one, but inflation implicitly enters into the reaction of the monetary authority. If inflation increases the authority reacts by absorbing liquidity to increase the nominal interest rate. However, the problems of application are the same as under the previous rule.

In the first four options, the interest rate adjustment is made with respect to a target variable (nominal GDP, inflation, real GDP, etc.). It is important to take into account that these variables do not change even when the shock involves an alteration to the long-term equilibrium, since the target values are defined by default as the baseline values. This introduces a distortion into the adjustment that may, in certain cases[34], be significant. The new equilibrium of the model would not then be consistent with the specification of the rules. The result may be non-convergence of the model or instability or low reliability of the possible solution. To correct this problem requires the estimation of the whole equilibrium path of the target variables and its explicit introduction into the rule, as is done in some of the simulation exercises. In any event, if the shocks are temporary or small it is unlikely that the results will change significantly. That said, this is something that should be taken into account when designing the shocks and interpreting the results.

It appears to us, having assessed the different rules and also taken into account this final point, that rule 2 (Nominal GDP and inflation targeting) is the most appropriate choice. On one hand, it ensures that the model has a nominal anchor and enables it to be solved with forward-looking agents. On the other hand, it gives some scope for activism and in our view is closest to a realistic view of what an active monetary policy might consist of. Finally, the fact that NiGEM adopts it by default is a decisive argument, since experience shows that departure from the standard specifications of NiGEM generates many complications in practice, when simulation exercises are performed.

III.4.2. The monetary policy transmission mechanism

Scheme 2 illustrates the monetary policy transmission mechanism in NiGEM. Two levels may be distinguished. One level captures the effects of changes in expectations on the model's financial variables. And the other level shows how the financial variables act on

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[34] These cases include, for example, permanent shocks that can substantially change the long-term path of prices and, consequently, that of nominal GDP.

the various components of demand and how expectations also affect supply through real factor costs.

Changes in the short-term interest rate have an impact, through expectations theory on long-term rates and, through uncovered interest rate parity, on the nominal exchange rate. Both react immediately, jumping onto a new path compatible with their new long-term level. Thus, for example, an anticipated sustained fall in interest rates in a country will cause the immediate depreciation of its currency. The magnitude of the impact depreciation will depend on the interest-rate differential generated. The anticipation of lower short-term interest rates lowers long-term rates.

These changes on impact in the financial variables set in motion an adjustment process among the various components of demand. The value of financial assets determines the net wealth of individuals which, in the example given, increases due both to the rise in financial asset prices (equity and debt prices will increase in response to the fall in interest rates) and to the exchange-rate depreciation (which revalues external assets). In NiGEM this *wealth effect* is of great importance to consumption decisions. On the other hand, the fall in short- and long-term interest rates reduces the user cost of capital and boosts investment. This involves an expansion of domestic demand *via factor costs*. On the external demand side, the exchange-rate depreciation amplifies the domestic expansionary effect due to the increase in relative import prices and the fall in relative export prices (*competitiveness effect*).

On the supply side, the higher inflation expectations due to the expansion of domestic and external demand are reflected in a lower real factor cost (*expectations effect*), which increases the expansionary effect on supply that was initiated by the fall in the user cost of capital when interest rates fall. This supply expansion reduces the excess demand in the economy and helps to moderate inflationary pressures.

However, in the short term this inflation-expectations effect translates into an immediate increase in nominal wages (see the short term elasticities of nominal wages with respect to inflation in Table III.1) which augments the increase induced by the effect of the demand expansion on unemployment. Producer prices also increase with the reduction in the output gap caused by the expansion of activity. Inflation therefore rises, because its two basic components grow: wages (and, therefore, unit labour costs) and import prices (due to the depreciation).

In subsequent periods, the process of adjustment of the supply and demand components to the higher prices helps itself to moderate the inflationary pressures. Gradually, the effects of the monetary impulse die away although the main variables fluctuate around their path towards equilibrium, as will be seen in section IV.

TABLE III.1. LONG-TERM ELASTICITIES IN NiGEM

	Germany	France	Spain	Italy	US
Private consumption ECM	-0.31	-0.14	-0.12	-0.07	-0.19
ε consumption / real wealth	0.20	0.14	0.09	0.20	0.16
ε consumption / RPDI	0.80	0.86	0.91	0.80	0.84
Exports ECM	-0.27	-0.42	-0.28	-0.49	-0.14
ε exports / relative prices	0.66	0.88	0.81	0.49	0.51
Imports ECM	0.38	-0.26	-0.29	-0.23	-0.18
ε imports / final demand	1.81	1.51	1.83	1.49	2.51
ε imports / relative prices	0.37	0.59	0.82	0.73	0.61
ε KP-output ratio/ user cost	0.48	0.65	1	0.48	0.43
real wages ECM	-0.17	-0.09	-0.15	-0.15	-0.15
semi-ε real wages / unempl.	0.038	0.015	0.008	0.025	0.015
ε short-term nom. wages/infl	0.62	0.36	0.35	0.60	0.49
Producer prices P ECM	-0.16	-0.17	-0.12	-0.26	-0.31
ε P / ULT (=1- ε P /imp. pr.)	0.58	0.55	0.57	0.71	0.74
semi-ε P/ output gap	0.20	s-t 0.008*log	--	s-t 0.14	0.16 (s-t 0.10)
Consumption deflator ECM	-0.13	-0.16	-0.14	-0.31	-0.07
ε CED /unit lab. costs ULT	0.26	0	0.53	0.29	0.80
ε CED / producer pr. P	0.74	1	0.47	0.71	0.10
ε short-term CED / P	0.30	0.20	0.89	0.88	0.15

IV. ANALYSIS OF SHOCKS IN THE EURO AREA WITH NIGEM

The large set of equations which make up NiGEM and its design specifically for the performance of simulation exercises, means that it is possible to consider a large number of shocks that might affect the economy. This section presents some illustrative examples of these shocks to analyse how the transmission mechanisms implicit in the model affect the economy's basic variables.

Particular care is taken in designing the monetary shocks in the euro area, since they enable the workings of the monetary policy transmission mechanism in the model to be observed. The first shock (a temporary monetary tightening) describes in special detail the transmission channels of the monetary policy in particular, and of the model in general, in order to explain how they work and the relative importance of the various adjustment mechanisms in the NiGEM model. The second exercise (a permanent monetary shock) highlights these mechanisms and yields other notions that may be interesting on the model's long-term equilibrium. Subsequently, and more briefly, other types of shock are presented: a permanent supply shock common to all the countries (a rise in oil prices); a common temporary demand shock (a global decline in stock market indices); and, finally, an idiosyncratic temporary demand shock in Germany (a shock to real private consumption), comparing with the effects of the same shock when it affects all the euro-area countries equally.

The monetary policy rule selected for all the simulations is the one NiGEM adopts by default (nominal GDP and inflation targeting), whereby the nominal interest rate reacts to deviations by nominal GDP and by inflation from their target levels.

The analysis focuses on the initial reaction and on the process of adjustment of four main variables: output, inflation, the exchange rate and the interest rate, the latter reflecting the monetary policy reaction to the shocks. The explanation of the adjustment processes emphasises the importance of the transmission mechanisms which, in the case of NiGEM, give certain variables special prominence. More specifically, as will be seen, the exchange rate plays a central role in the adjustment, while the wealth effects associated with the holding of domestic and external financial assets are much more important than in other macroeconomic models. Probably, the reason for the importance of these transmission mechanisms in NiGEM is a result of both the forward-looking aspect of the model and of the requirement for global consistency, both in terms of prices (exchange rate) and of quantities (external financial position).

Two levels of analysis are distinguished: first, the aggregate variables of the euro area, constructed as a weighted average of the values of the member countries[35], are evaluated, and subsequently the different response in each of the four main economies of the euro area is compared with the area aggregate. At this latter level, it is particularly interesting to observe the behavioural equations for each of the countries and, in particular, the different short- and long-term elasticities, which to a large extent determine the different responses in each country. This way of focusing the analysis cannot be used at the euro-area level, since it is a virtual aggregate derived from the weighted sum of the variables of the member countries.

Each shock is accompanied by charts (for the euro area and the individual countries) and a table showing the effects of the shocks on the main variables.

IV.1. MONETARY SHOCKS

Monetary shocks are introduced through a central bank reaction function. Two types of monetary shock are considered: the first is temporary and involves a rise in the interest rate of the area lasting two years; the second involves a permanent fall in the interest rate, induced by a reduction in the ECB's inflation target.

IV.1.1. Temporary monetary shock

The temporary interest-rate shock is introduced through an exogenous one-percentage-point increase in the euro area's short-term interest rate lasting two years. The purpose of this shock is, basically, to explain how the various channels involved in the transmission of a shock (in this case, a monetary one) work and their importance in NiGEM.

It should be stressed that there is a conceptual problem involved in the interpretation of this shock as a monetary policy shock. If the monetary policy rule involves targeting a well-defined level of nominal output and inflation, what sense is there in raising interest rates when there has been no change in the economic situation? It could be argued that the ECB may be anticipating a change in the future situation (e.g. inflationary pressures), but in that case a shock should also be introduced into the model in a subsequent period to validate these fears. Otherwise, the monetary authority would be mistaken in its appreciation of the economic situation[36].

- ***Euro area***

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[35] The weights depend on the weight of the country's GDP in the area as a whole in the baseline, which means that they may vary slightly over time. The weights used are 33% for Germany, 20% for France and Italy and 10% for Spain.

[36] Some of these problems could in principle be solved by temporarily changing the inflation target. However, it would not be easy to justify this change either from a theoretical viewpoint if there were no subsequent shock. In any case, the effects would be very similar to those of the shock considered here.

The upper two charts of figure 1 show the effects on the basic variables of the euro area, in terms of deviations from the baseline, stemming from the exogenous and temporary increase in euro-area interest rates. GER3M shows the deviations by the short-term nominal interest rate, EURO the percentage deviations by the nominal euro/dollar exchange rate, EMUGDP the percentage deviation by the real GDP of the euro area and EMUINFF the deviations by the level of inflation. To complete this information, the table shows the average annual deviations by output and inflation from the baseline[37].

Impact

It should be noted first that the actual rise in the interest rate is smaller than the shock. This is because, under the monetary policy rule, interest rates are adjusted downwards from the outset. The positive interest-rate differential gives rise, on foreign-exchange markets, to expectations of currency depreciation in subsequent periods. This causes a jump on impact in the opposite direction by the exchange rate, which appreciates strongly in nominal and real terms. The appreciation reduces external demand and import prices, with contractionary effects on the level of activity and inflation, respectively. At the same time, the tightening of the money market is transmitted, through the term structure of interest rates, to longer-term rates, producing a fall in investment. Consumption also falls due to the negative wealth effects arising from the effect of the increase in interest rates on the value of financial assets. The reduction in domestic demand exacerbates the contractionary effect on activity. As a result, as seen in Table IV.1, activity in the euro area falls by 13 basis points with respect to the baseline; the effects on inflation are more moderate (five basis points in year 1, rising to seven basis points in year 2). These results imply a short-term sacrifice ratio (the costs in terms of output of reducing inflation by one percentage point) of 2.76%.

The initial fall in activity and inflation gives rise, under the monetary policy rule, to a downward adjustment in the interest rate. As a result, the actual change in the interest rate in year 1 is slightly smaller than the exogenous shock.

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[37] In the case of the euro-area aggregate, the average inflation that appears in the table, is calculated as the weighted average of the four countries, instead of being taken directly from NiGEM. The reason for this is that the method of calculating inflation in NiGEM means that inflation in the area may be higher or lower than in any of the countries, which is not consistent with the notion of average inflation in the area.

Table IV.1 Temporary monetary shock
1% rise in interest rates lasting two years

	EURO AREA	**GERMANY**	**FRANCE**	**SPAIN**	**ITALY**
GDP					
Year 1	*-0.13*	-0.19	-0.09	-0.16	-0.09
Year 2	*-0.31*	-0.4	-0.26	-0.48	-0.32
End period	*0**	-0.01*	0.01*	0.03	0.01*
INFLATION					
Year 1	*-0.05*	-0.05	-0.03	-0.04	-0.06
Year 2	*-0.07*	-0.14	-0.03	-0.04	-0.03
End period	*-0.01**	-0.01*	-0.01*	0.00*	0.00*
SACRIFICE RATIO					
Year 1	*2.76*	3.71	3.51	3.88	1.39
Year 2	*4.19*	2.88	9.99	11.19	10.46
End period	*0.00**	1.75*	-0.88*	-11.05*	-4.55*
Asterisks (*) denote residual deviations, caused by the cutting short of the series					
Average annual deviations from the baseline as percentages (GDP) and as levels (inflation).					

Adjustment

The adjustment process is fairly smooth for the variables that display inertia, like inflation and activity, which show an extended gradual decline. This situation (through the monetary policy rule) generates an additional correction of the monetary shock while it continues and, when the shock disappears, the rate of interest stands below its equilibrium level. This fluctuating behaviour explains, in turn, the path of the exchange rate. The initial appreciation is reversed, with an overshooting of the equilibrium level, in order to close the uncovered parity produced by the shock. These expansionary effects help to stabilise activity around its equilibrium level, while inflation displays a very similar profile. In the long run all the real variables return to their equilibrium level, although the speed with which prices and inflation do so depends upon the sensitivity of prices to the degree of capacity utilisation and unemployment[38].

Comments

This example of a shock highlights certain important characteristics of the monetary transmission mechanism in NiGEM. First, a significant degree of nominal inertia can be seen in the behaviour of inflation. This explains why the monetary tightening takes time to feed through to prices and also the subsequent volatility of inflation with respect to its

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[38] Nonetheless, it can be seen in the charts and the table that the adjustment to the baseline is not perfect. This is because, as indicated in the previous chapter, the cutting short of the simulation period tends to give rise to results of this kind. The asterisks in the final period of this and subsequent tables indicate this fact, i.e. that the deviations from equilibrium are due to the characteristics of the simulation, not to "actual" deviations from equilibrium in the long term.

equilibrium level. In any event, the small effect on the inflation rate, both in the short and medium term, produced by the monetary tightening is notable.

Second, the central role played by the exchange rate in the adjustment is also notable. The exchange rate is forward-looking, so that in the event of a shock it jumps on impact as explained above. At the same time, the multi-country nature of the model and its emphasis on commercial and financial interdependencies should be recalled. Both factors explain why monetary impulses are transmitted to the economy mainly through exchange rate changes.

The charts for this and subsequent simulations show certain characteristics that distinguish NiGEM from smaller macroeconometric models. On one hand, the adjustment gives rise to significant fluctuations by the variables around their equilibrium levels, in contrast to the smoother behaviour in other types of model. On the other hand, deviations may be present in the long-term solution in NiGEM owing to the cutting short of the simulation period, as compared with the neater solutions in other macroeconomic simulation models. These characteristics mean that the results must be interpreted with some caution, since the fluctuations around the equilibrium may distort the interpretation of speed, volatility and persistence in the adjustment mechanisms, which are characteristic of theoretical models. For this reason, the informative content of the tables is limited. Adding the deviations in subsequent periods would introduce fluctuation biases, which would make them difficult to interpret [39].

- *Countries*

The lower two charts in figure 1 show the deviations by the level of inflation and the percentage deviations by domestic output from the baseline for the four main economies of the euro area, and Table IV.1 also shows the effects of the shocks for the various countries[40]. The punctuated line represents Germany, the solid line France, the dotted line Spain and the broken line Italy.

The same mechanisms described above for the euro area also explain the impact reaction and the subsequent adjustment in each country. It should not be forgotten that the euro-area variables are merely an aggregation of the variables of the member countries. In this simulation the main mechanisms that transmit the monetary shock to activity are the competitiveness effect and the wealth effect, while the response and adjustment of prices depends on their sensitivity to foreign prices and to the deviations by activity from its equilibrium level (captured by the capacity utilisation index and the rate of unemployment).

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[39] The fluctuating nature of the adjustment also considerably distorts the correlations between countries, so no information on correlations is given in the tables.

[40] The exchange rate and nominal interest rate are, of course, common to the whole area.

The asymmetric responses to the shock seen across these four countries are therefore basically a consequence of the different efficacy of these mechanisms in each country. The table of elasticities in Chapter III (Table III.1) gives an idea of these effects: the long-term elasticities of one variable with respect to another are indicated by the parameter ε, while the parameter ECM (which refers to the error correction mechanism) gives an indication of the speed of adjustment[41].

The country whose exports and imports have the highest elasticities with respect to relative prices is Spain, followed at some distance by Italy and France. Given the central role of the exchange rate upon impact, this explains why Spain suffers a larger fall in activity than the euro area in the initial years, as seen in Table IV.1 and in Figure 1[42]. In contrast, German and Italian consumption have the highest sensitivity to changes in wealth. Given, also, the high-speed of adjustment of consumption to changes in wealth, the fall in activity in Germany is significant and rapid (19 basis points in the first year), but it recovers earlier than in the other economies. The wealth effect is also significant in Italy, although its speed of adjustment is rather slow. Spain and France have the lowest wealth elasticities and speeds of adjustment, so that the fall in their consumption due to the wealth effect is small.

The weights of exports and imports in GDP are significant in all four economies, and therefore all prices will react to a similar extent to the fall in export prices and the rise in import prices caused by the appreciation of all the currencies in the same proportion (appreciation of the euro). However, the sensitivity of prices to deviations by activity from its equilibrium level varies greatly. Of the four countries, Germany is the one whose wages react most quickly to changes in unemployment and whose prices show least inertia, so that German inflation displays the largest fluctuations and a more rapid convergence with the baseline. Prices in France and Spain have lower elasticities with respect to the recession indicators than Germany, so that inflation in these two countries takes longest to react and to return to its equilibrium. However, as can be seen, the inertia in the French price equations is rather greater than in the Spanish ones. In Italy, the speed of adjustment and sensitivity to the cycle of prices are greater than in Spain and France, but less than in Germany, so that its inflation follows a middle path.

Obviously the different speeds of adjustment of inflation affect the speed of recovery of activity, given that both wages and the user cost of capital adjust to expected future inflation. As a consequence of these different speeds of adjustment, the short-term sacrifice ratio varies across countries.

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[41] Since the euro-area variables are aggregated, there are no elasticities at the euro-area level in the model.

[42] The fact that the production function for Spain is specified as a Cobb-Douglas instead of a CES function, so that factor substitution is more elastic, also contributes to the larger initial contraction of activity. This means that, on impact, wage rigidities affect investment and employment more than in the rest of the euro area.
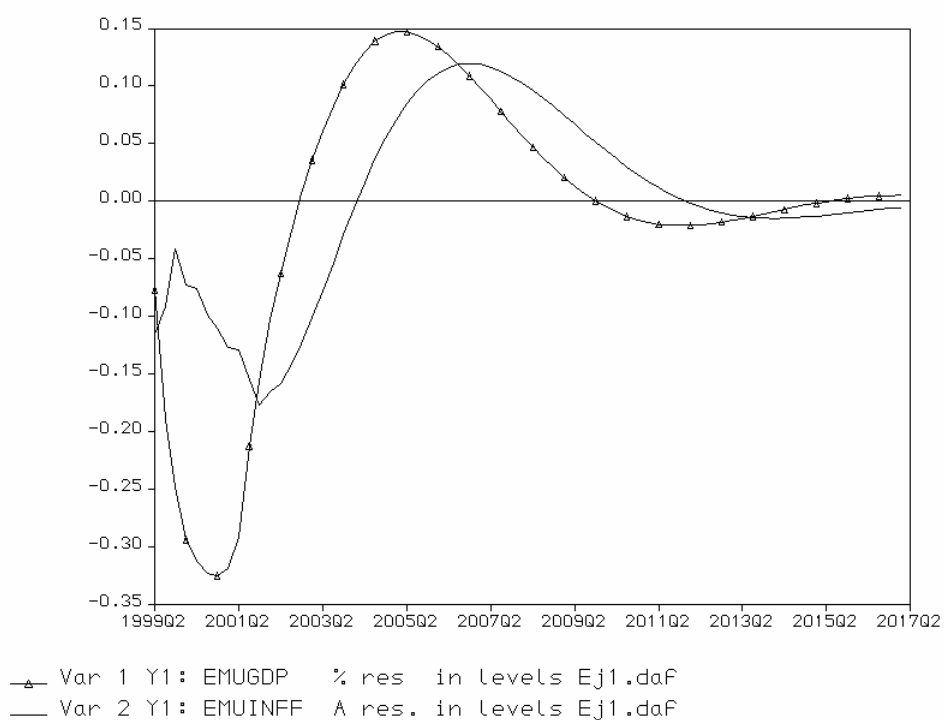
FIGURE 1. TEMPORARY MONETARY SHOCK (EURO AREA)
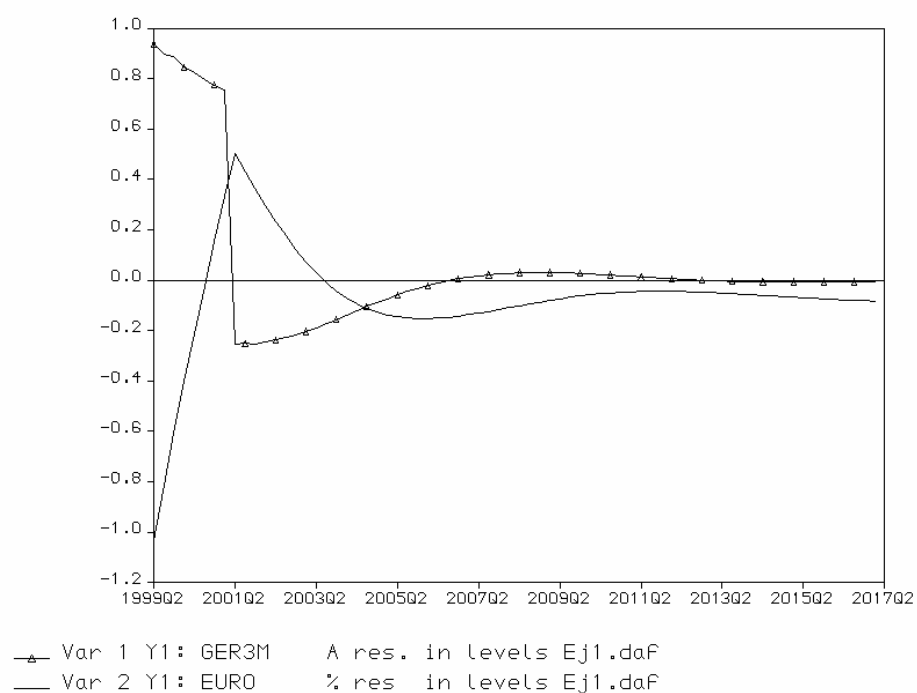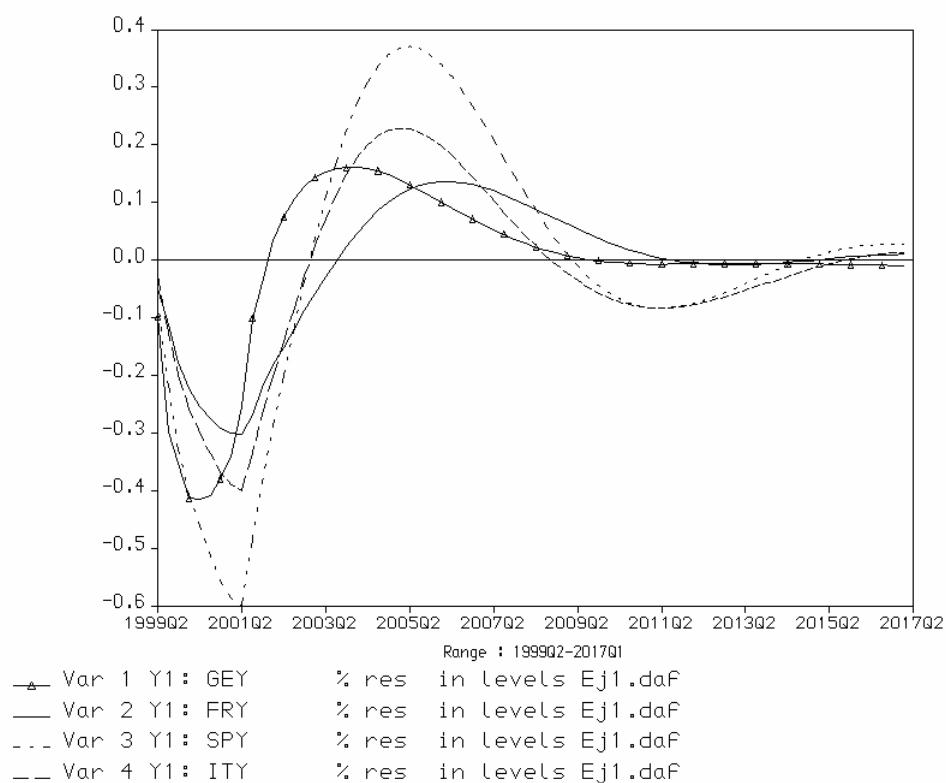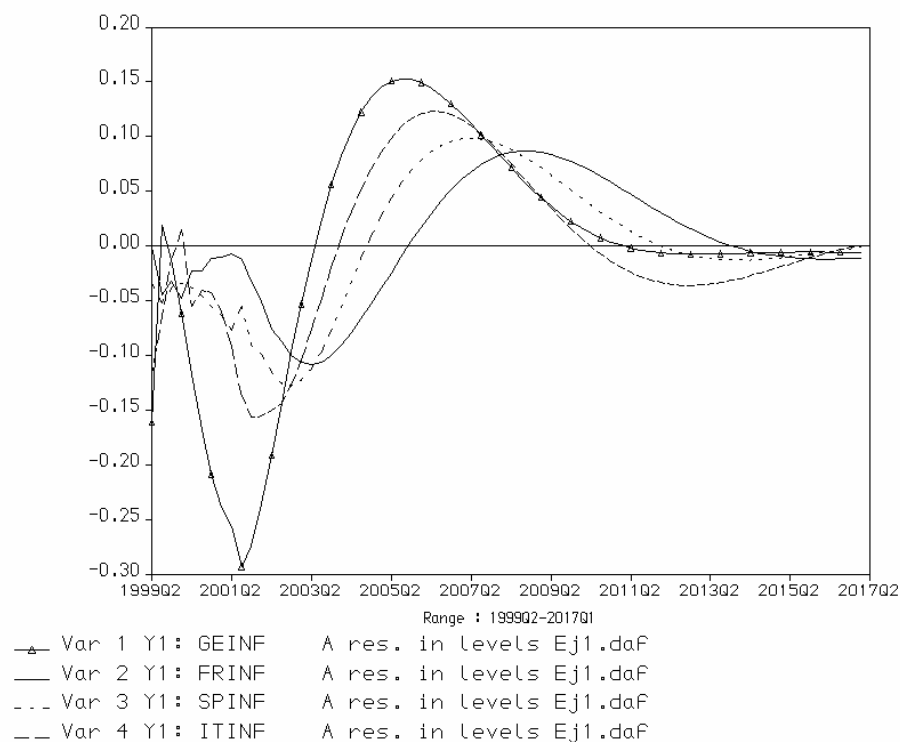


```
__△__ Var 1 Y1: GER3M     A res. in levels Ej1.daf
____ Var 2 Y1: EURO      % res  in levels Ej1.daf
```



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__△__ Var 1 Y1: EMUGDP    % res  in levels Ej1.daf
____ Var 2 Y1: EMUINFF   A res. in levels Ej1.daf
```

FIGURE 1. TEMPORARY MONETARY SHOCK (COUNTRIES)

Range : 1999Q2-2017Q1

```
_△_ Var 1 Y1: GEINF      A res. in levels Ej1.daf
___ Var 2 Y1: FRINF      A res. in levels Ej1.daf
_._ Var 3 Y1: SPINF      A res. in levels Ej1.daf
__ Var 4 Y1: ITINF      A res. in levels Ej1.daf
```


Range : 1999Q2-2017Q1

```
_△_ Var 1 Y1: GEY       % res  in levels Ej1.daf
___ Var 2 Y1: FRY       % res  in levels Ej1.daf
_._ Var 3 Y1: SPY       % res  in levels Ej1.daf
__ Var 4 Y1: ITY       % res  in levels Ej1.daf
```

IV.1.2. Permanent monetary shock (reduction in the euro-area inflation target)

A permanent monetary shock cannot be introduced into the reaction function directly through an exogenous change in the nominal interest rate because this would give rise to a global inconsistency in the model. This is because an exogenous permanent change in the nominal interest rate, with constant inflation and nominal GDP growth targets[43], would also involve an exogenously induced permanent deviation by the real interest rate of the euro area from its equilibrium level which would put pressure on the current-account balance, permanently altering the global equilibrium. At the same time, an exogenous permanent change in the nominal interest rate would be inconsistent with the achievement of the (unchanged) monetary policy targets. The consequence, in terms of the simulation, would be a failure by the real variables to converge, making it impossible for valid conclusions to be drawn from the exercise. It is therefore clear that a permanent fall in the interest rate can only be induced by means of a permanent reduction in the monetary policy targets, namely inflation and nominal output[44].

To make this shock somewhat realistic, we assume that the ECB takes as its inflation target not the aggregate inflation target for the euro area (1.84%), but the German inflation target (1.7%). This entails a reduction of 0.14% in the ECB's inflation target, which will eventually entail a proportionate fall in the nominal interest rate. Specifically, in terms of the monetary policy rule the following is imposed:

$$GER3M_t - GER3MT'_t = 32,9[lnEMUNOM_t - lnX_t] + 0,5[EMUINFF_t - (EMUINFFT_t - 0,14)]$$

where X_t is the path of the target level of GDP compatible with the new inflation target (see footnote).

$GER3MT'_t$ is the new long-term equilibrium level of the euro-area nominal interest rate. This is lower than it was previously as it is the level compatible with the new euro-area inflation and nominal-GDP targets, which are also lower than they were previously.

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[43] Note that the shocks do NOT change the levels of the target variables of the monetary policy rule.

- ***Euro area***

Impact

The reduction in the inflation target thus entails, under the monetary policy rule, a proportionate reduction in the long-term equilibrium level of the nominal interest rate (according to the long-term elasticities estimated for the real balances demand function). Thus, given the way in which the monetary rule is specified in NiGEM (see the discussion in section III.4.1) on impact the nominal interest rate stands above its new long-term equilibrium value, although this does not mean that it is above the value observed before the shock (the previous baseline). This contrasts with the notion that the monetary tightening required to reduce inflation permanently should result in an increase in nominal interest rates.

As seen in figure 2, the 14-basis-point reduction in the inflation target entails, in equilibrium, a permanent equivalent fall in the observed rate of inflation. To the extent that inflation and nominal GDP converge with their new long-term equilibrium values, the monetary policy rule entails a fall in the long-term nominal interest rate (GER3M). Expectations in the markets adapt to the new situation, anticipating a negative interest rate differential on the equilibrium path, which entails a significant appreciation in the nominal euro exchange rate (EURO) on impact of approximately 1.5%. The real exchange rate appreciates by a similar amount, due to inflation inertia; inflation falls on impact due to the cheapening of imports, but not sufficiently to reach its new lower long-term level. The size of the real appreciation (1.3%) entails strong restraint of external demand and a fall in aggregate demand (EMUGDP). During year 1 the sacrifice ratio is rather high (3.91%).

In this case the wealth effect pushes activity in two directions. On the one hand, it exerts a positive, but slow effect, with the fall in interest rates and consequent revaluation of assets occurring gradually. On the other hand, both the appreciation and, to a smaller extent, the fall in activity have negative effects on the accumulation of net foreign assets. The outcome may be a persistent fall in net wealth that even exceeds the fall in the consumption deflator, so that real wealth falls. This is, in fact, the case in the main euro-

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[44] A permanent reduction in the inflation target also entails a permanent fall in the growth rate of the target nominal output and, therefore, a change in the path of its level. This gives rise to certain difficulties in the introduction of this shock in NiGEM, since both variables are exogenous in the model. A new profile for target nominal output induced by the change in the inflation target must be calculated in a spreadsheet and subsequently introduced into the simulation.

area economies[45]. Thus, the wealth effect not only fails to offset the fall in activity, it actually accentuates it.

It is interesting to return to the effects of this shock on the monetary policy rule. On one hand, inflation falls on impact below its new target level, while aggregate demand, dragged down by the real appreciation, also falls, although not by as much as the new target would entail. The first factor would push the interest rate lower, while the second would involve upward pressure. The result of these opposing forces is a slight rise in the nominal interest rate on impact (1.3 basis points), although the real interest rate of the euro area does increase significantly causing activity to contract.

Table IV.2. Permanent monetary shock
14-basis-point reduction in the inflation target

	EURO AREA	GERMANY	FRANCE	SPAIN	ITALY
GDP					
Year 1	*-0,15*	-0,19	-0,1	-0,15	-0,08
Year 2	*-0,18*	-0,24	-0,1	-0,22	-0,1
End period	*-0,1*	-0,13	-0,08	-0,12	-0,05
INFLATION					
Year 1	*-0,04*	-0,04	-0,05	-0,03	-0,05
Year 2	*-0,10*	-0,15	-0,09	-0,06	-0,07
End period	*-0,11*	-0,14	-0,11	-0,09	-0,08
SACRIFICE RATIO					
Year 1	*3,91*	5,16	2,17	5,99	1,46
Year 2	*1,76*	1,64	1,11	3,93	1,37
End period	*0,72*	0,95	0,73	1,40	0,60
Asterisks (*) denote residual deviations, caused by the cutting short of the series					
Average annual deviations from the baseline as percentages (GDP) and as levels (inflation)					

Adjustment

The adjustment process sees the variables move to their new equilibrium levels. The path of the nominal exchange rate is notable, showing a permanent appreciation. The reason for this appreciation is that, from the second period, the new nominal interest rate is lower than the previous one, generating a negative gap in the uncovered interest parity. Inflation falls smoothly and after some fluctuation stands, as was to be expected, at its new

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[45] As there is no net wealth variable for the euro area we cannot evaluate its growth directly, but we can deduce it from the growth of that of the main economies of the euro area. And the clear evidence in the case of Germany and France is that real wealth falls from the outset and persistently. In Spain, where real wealth rises, this does not happen on impact, but it does after a few quarters. In Italy, however, real wealth does not fall until several years have passed. In all cases, in the long run real wealth is below its initial equilibrium level.

target level. The behaviour of activity is more interesting. The initial recession is explained by the real appreciation, from which the economy recovers through, inter alia, the subsequent monetary loosening. However, the new equilibrium level of output is slightly lower than the starting level (0.12% below the baseline).

This long-term result implies that the permanent reduction in inflation has a cost in terms of output[46]. Specifically, the long-term sacrifice ratio produced by the simulation is slightly less than 1 (0.90% on average in the final year). These long-term real effects are also seen in other variables. The new real interest rate in the euro area is 7 basis points higher than the previous equilibrium or baseline. This could be linked to the effects on the global balance of payments equilibrium of the fall in the level of GDP of the euro area. In fact, owing to the significant relative size of the European economy, this increase also has knock-on effects, albeit of a smaller magnitude, in the other countries in the new equilibrium (the real US interest rate reaches an equilibrium at 4 basis points above the previous baseline). The positive real interest rate differential with respect to the baseline at the end of the simulation also corresponds to a change in the real rate of appreciation of the euro[47].

Comments

The first point to note is once again the importance of the exchange rate in the adjustment process. It is clear in this case that this importance does not only stem from the (open economy) design of the model, but also from the forward-looking nature of expectations. Given the model's assumption of rational expectations, the reduction in the inflation target may be interpreted as an announcement that (a) enjoys full credibility and (b) is instantaneously assimilated by agents. Consequently, the exchange rate appreciates considerably on impact (anticipating a negative interest rate differential in subsequent periods). It is through this appreciation in particular, and not so much through the interest rate, that monetary policy primarily exerts its contractionary effect (fall in inflation and in activity).

These arguments can help justify the weak interest-rate response. Yet, it is clear in this case, as commented in section III.4.1, that the monetary rules defined in NiGEM describe a rather inactive monetary policy, especially when compared with the usual rules in the literature on monetary rules. This fact also helps to explain the insensitivity of nominal interest rates to changes in monetary policy targets.

An important point to note is the existence of a positive sacrifice ratio in the long-term. One might expect inflation to have no long-term effect on output, and a sacrifice ratio

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[46] Note that in the table, unlike in the chart, the end-period inflation rate in the euro area is not 14 basis points lower, at the new equilibrium level, but slightly above this latter level. This is due to the way in which the euro-area inflation rate is calculated in the table (see Footnote 37).

[47] At the end of the simulation the real effective exchange rate of the euro is up 0.4%.

equal to zero. Note that this result does not breach the condition of long-term monetary neutrality, but rather that of super-neutrality, since the fall in the rate at which prices increase has effects on the level of activity.

These results are difficult to interpret, basically because of the way in which NiGEM solves the model. It is difficult to know whether the changes in the level of the real variables are permanent or a consequence of the cutting short of the solution. In view of the path of output they do seem to be permanent. If they are, we do not know if this is because a shock of this kind introduces some inconsistency into the solution that is reconciled through disequilibrium in these variables.

It is not easy to interpret these results on the basis of standard economic theory or of the empirical evidence. A moderate but permanent reduction in the inflation target should not generate permanent real effects. What is particularly hard to accept as valid, however, is the fact that a monetary shock generates a permanent change in the interest rate spread of the euro area over the rest of the world and consequently a real rate of appreciation of the euro that differs from the rate prior to the shock.

- ***Countries***

In this simulation, the mechanisms which transmit the shock to the economies and which consequently shape the asymmetric response by activity and prices are the same as in the previous simulation (basically competitiveness and wealth). However, the shock in this case generates a continuous appreciation of the nominal exchange rate and, as mentioned above, this is the main variable through which the restrictive monetary policy action is transmitted to the economies. Moreover, the fact that inflation is permanently reduced means that the role of inflation expectations in the various countries is more important than in the previous simulation.

In Germany (punctuated line in the lower charts of Figure 2) it can be seen that the fall in activity, due to the contraction of external demand caused by the real appreciation, is aggravated by a fall from the outset in real wealth, despite the fall in interest rates. This shows the relative importance of net external assets in German net wealth, which fall in value as a result of the appreciation. Given the importance of the wealth effect in German consumption, the fall in activity on impact and in the long term is largest in Germany (20 basis points in year 1 and 13 basis points in the long term). At the same time, as seen in the previous simulation, German prices and costs are the most rapid to adjust, the adjustment being almost sufficient to offset the real appreciation, so that the German inflation rate is the most volatile and the only one to fully reflect the reduction in the inflation target.

The case of Spain (dotted line) is completely different. Activity also falls by more than the euro-area average, not due to the wealth effect however, but rather because Spain is the country in which the competitiveness effect on external demand as a result of the appreciation is greatest. However, the scant anticipation in factor prices of future inflation, together with the insensitivity of prices to the cycle and the high level of price inertia, means that inflation reacts very mildly (only six basis points in year 2) and in the long term it incorporates only a little over half the change in the euro-area inflation target (9 basis points). As a result, the real appreciation persists, exacerbating the recession (Spain is the only country of the four to have a sacrifice ratio of more than 1: 1.40% as against 0.95 for Germany).

Italy (broken line) is the country least affected by the permanent monetary policy shock and it has the lowest sacrifice ratio (0.6%). In contrast to the case of Germany, the fall in external demand is moderated by a positive wealth effect during the initial years, which reveals a very different composition of wealth, with external assets having a much smaller weight (or liabilities a larger weight). In other words, the positive effect of the fall in interest rates on net wealth is larger than the negative effect stemming from the exchange rate appreciation. Consequently, the Italian recession is easily the smallest in the area. As expected future inflation has a high weight in wages and as prices are highly sensitive to the cycle, inflation reacts rapidly and with high volatility and soon converges on its equilibrium level, which is well above the German level.

The French economy (solid line) has smaller competitiveness effects than the Spanish one and although the wealth effect is contractionary from the outset, it is less strong than the euro-area average. However, prices in France adjust very slowly and end-period inflation is therefore below the target level. The sacrifice ratio is higher than the Italian one (0.70%) but considerably less than those for Germany and Spain.

As in the case of the euro-area aggregate, all the real variables in each economy grow in the long term at the same rate as in the baseline (which differs from country to country: 2.4% in Germany, 2.6% in France, 3.2% in Italy and 3.4% in Spain), but the alteration in their levels with respect to the baseline varies. With different long-term domestic inflation rates, the levels of the real interest rate and the real effective exchange rate vary from one country to another and therefore the change in activity in the long term also varies.
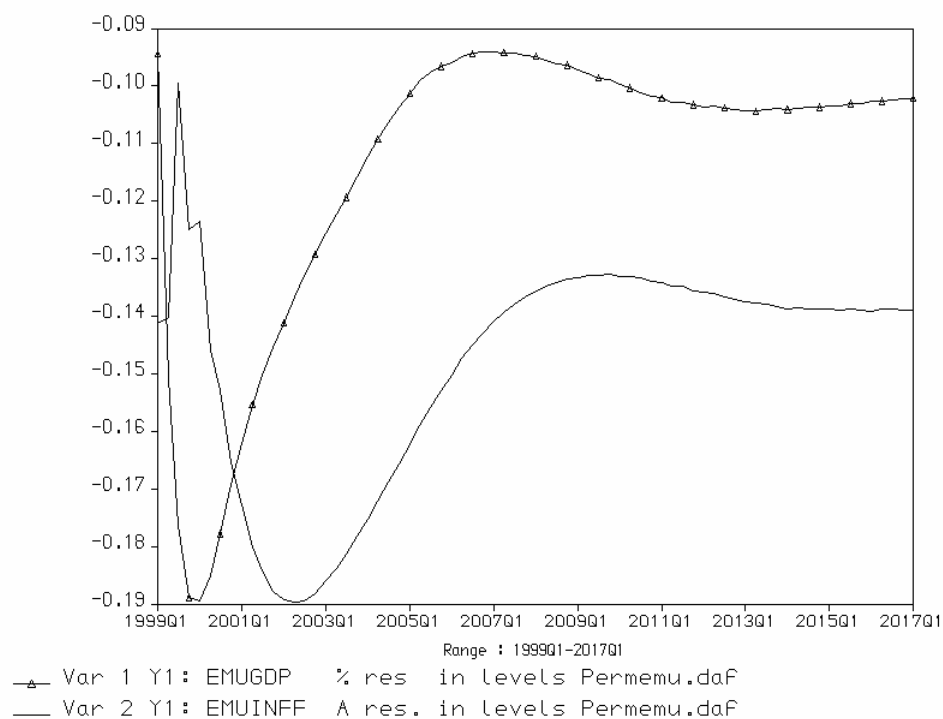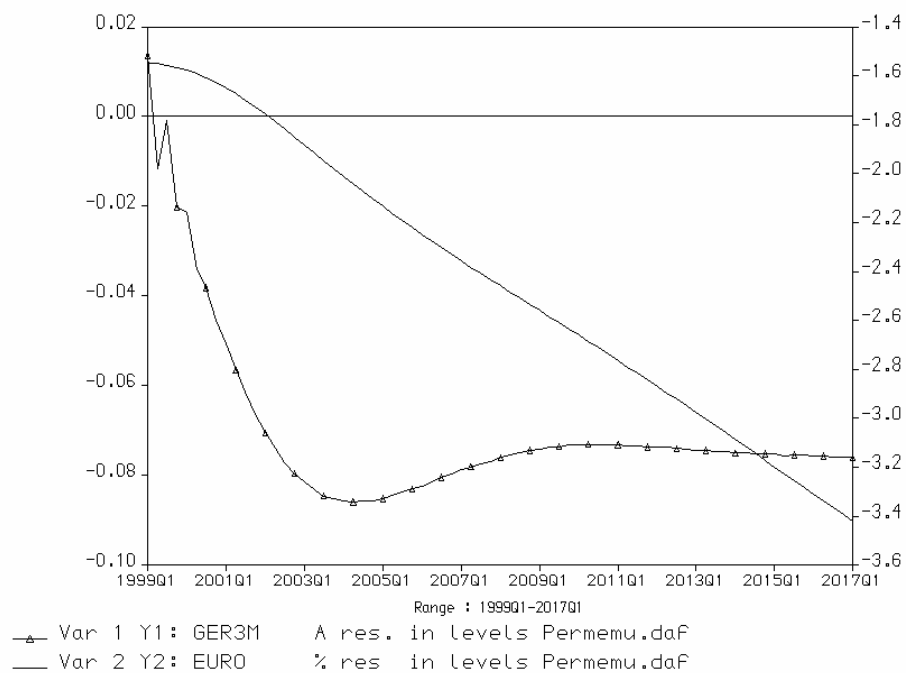
FIGURE 2. PERMANENT MONETARY SHOCK (EURO AREA)

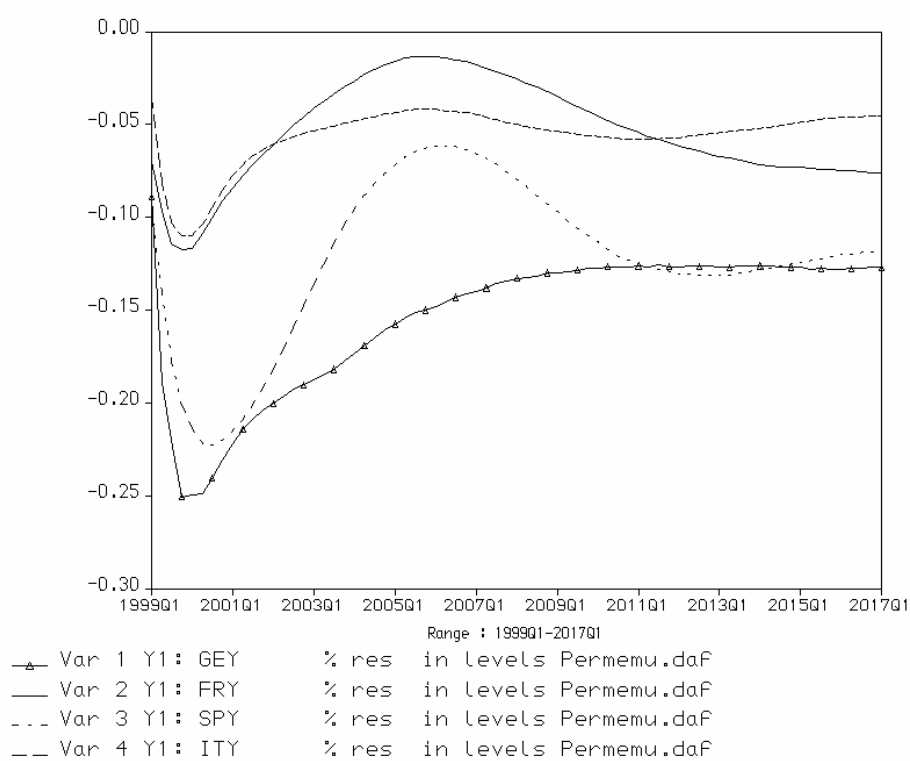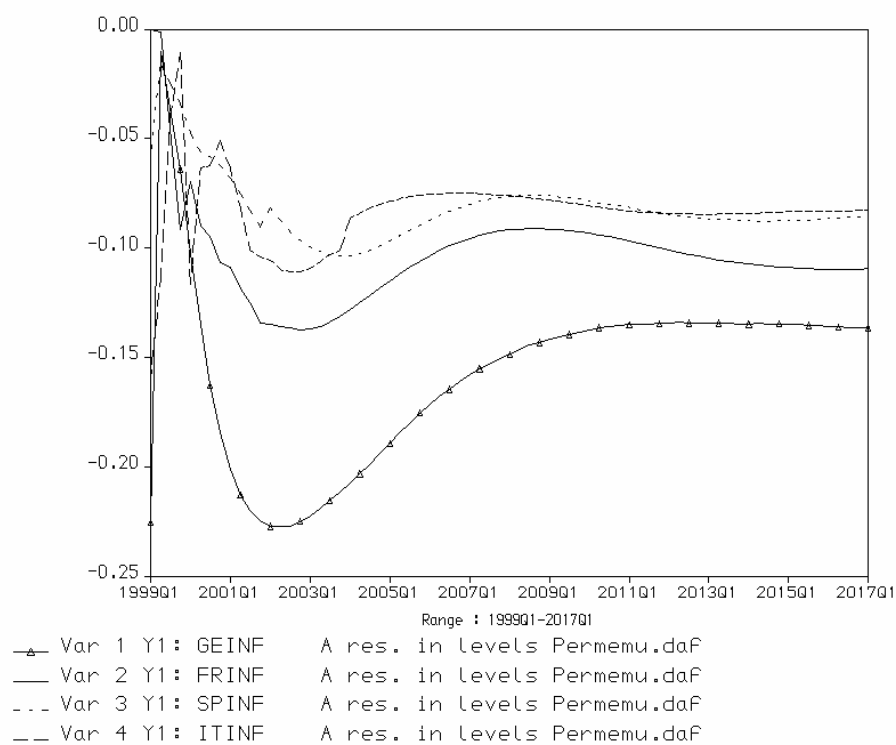Range : 1999Q1-2017Q1

—△— Var 1 Y1: GER3M   A res. in levels Permemu.daf
——— Var 2 Y2: EURO   % res in levels Permemu.daf

Range : 1999Q1-2017Q1

—△— Var 1 Y1: EMUGDP   % res in levels Permemu.daf
——— Var 2 Y1: EMUINFF A res. in levels Permemu.daf

FIGURE 2. PERMANENT MONETARY SHOCK (COUNTRIES)

Range : 1999Q1-2017Q1

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_△_ Var 1 Y1: GEINF    A res. in levels Permemu.daf
___ Var 2 Y1: FRINF    A res. in levels Permemu.daf
_.. Var 3 Y1: SPINF    A res. in levels Permemu.daf
__ Var 4 Y1: ITINF     A res. in levels Permemu.daf
```


Range : 1999Q1-2017Q1

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_△_ Var 1 Y1: GEY     % res  in levels Permemu.daf
___ Var 2 Y1: FRY     % res  in levels Permemu.daf
_.. Var 3 Y1: SPY     % res  in levels Permemu.daf
__ Var 4 Y1: ITY      % res  in levels Permemu.daf
```

IV.2. NON-MONETARY SHOCKS

Three types of non-monetary shocks are analysed more briefly below: the effects of a permanent increase in the oil price (a permanent supply shock), and a temporary fall in global stock markets (a temporary demand shock), which can be considered common shocks, and one idiosyncratic shock: a temporary increase in consumption in Germany. The latter shock enables the common effects of asymmetric shocks in the European case to be seen, highlighting the importance of the common monetary policy rule in the transmission of asymmetric shocks.

IV.2.1. Permanent supply shock (oil-price increase)

Impact

The first effect to note is on prices. A 20% rise in the price of oil entails a quarter-percentage-point increase in the euro-area inflation rate in year 1. Moreover, the euro area's greater external dependence on oil products compared to its main trading partners[48] is reflected in a deterioration of the euro area's terms of trade. This generates expectations of currency depreciation in the long term, reflected in a fall in the value of the euro on impact of more than 1.5% (see the upper chart of Figure 3). The resulting real depreciation of the euro explains why demand increases slightly on impact.

It should be noted that, despite the increase in inflation, the reaction of the monetary instrument is very timid[49]. One reason for this is to be found in the behaviour of nominal output (the result of multiplying real GDP by the GDP deflator), which falls significantly. Unlike consumer prices, the GDP deflator falls substantially, owing to the fall in export prices and the rise in import prices on impact as a result of the exchange-rate depreciation.[50]

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[48] Although Japan is another major or oil importer, Great Britain exports oil and the United States is the largest producer in the world.

[49] Given that the inflation parameter in the monetary policy rule is ½, ceteris paribus, one would expect a twenty-basis-point rise in interest rates on impact. However the nominal short-term interest rate increases by only seven basis points.

[50] The consumption deflator (the change in which determines the measure of inflation) does not include export prices, while the rise in import prices on impact, which does increase the CPI, reduces the level of the GDP deflator.

Table IV.3. Permanent supply-side shock
20% increase in the price of oil

	EURO AREA	GERMANY	FRANCE	SPAIN	ITALY
GDP					
Year 1	*0,03*	-0,03	0	0,07	0,01
Year 2	*0,08*	0,1	-0,01	0,05	0,01
End period	*0**	0,06*	-0,07*	-0,05*	0,01*
INFLATION					
Year 1	*0,11*	0,14	0,08	0,04	0,24
Year 2	*0,04*	-0,03	0,17	0,01	0,04
End period	*0,00**	0,00*	0,03*	0,01*	0,00*
Asterisks (*) denote residual deviations, caused by the cutting short of the series					
Average annual deviations from the baseline as percentages (GDP) and as levels (inflation)					

Adjustment

Following the big initial jump, inflation moderates, although it holds at positive rates during the adjustment process. Activity is favoured in the short term by the initial depreciation and the slowness with which the increase in prices is passed through to wage costs. This situation should mean that monetary policy remains restrictive. Although this is generally the case, in the quarters following the shock the interest rate falls below its equilibrium level, owing to the negative behaviour of the nominal GDP deflator. When the effects of the shock are eventually passed through to all prices, the stance of monetary policy becomes restrictive and activity falls, but this only occurs from year 3. The economy gradually adjusts to its new equilibrium level. Compared to the baseline, or equilibrium level prior to the shock, the euro exchange rate is lower in nominal and real terms, prices stabilise at a high level and the other variables return to their previous level.

Comments

The different economic and commercial structure of the euro area with respect to the rest of the world explains the depreciation of the euro. This depreciation on impact has an unexpected expansionary effect on activity, which continues for several years. This means that the negative supply shock has positive effects on demand or, in other words, that the slope of the demand curve is positive in the short term, which is difficult to justify.

The sustained high inflation rates in the area are explained by the nominal inertia, the exchange rate depreciation and the initial expansion. Finally, the monetary restraint induced by the initial deterioration of prices and the nominal rigidities explain the duration of the subsequent recession.

In this case too, the limited reaction of the monetary instrument is notable. Reasons have been given, relating to the deflators used, but once again the low level of monetary policy activism implicit in the rules adopted by NiGEM must be stressed.

- ***Countries***

Again, the lower charts of Figure 3 depict the change in inflation and the percentage deviation by real GDP from the baseline for Germany (punctuated lines), France (solid lines), Spain (dotted lines) and Italy (broken lines).

The jump in the inflation rate of the area observed on impact is due to the immediate reaction of prices in Germany and Italy which, as we have seen in the previous simulations have much less inertia than in Spain and France where inflation reacts more slowly. The slower transmission of expected inflation to costs in the latter two countries results in a relative decline in real wages, enabling activity to be sustained and even to increase in Spain in year 1. In the case of Spain, moreover, activity receives a considerable further boost from the increase in external demand as a result of the initial depreciation.

Subsequently all of the real costs are corrected, incorporating the increase in prices. At the same time, monetary policy reacts by raising interest rates to correct the persistent inflation. All this leads to a fall inactivity, which is especially pronounced in the medium term (five to six years). In Spain and France the fall is greater than on average in the euro area. By contrast, in Germany and Italy the rise in the price of oil feeds rapidly through to all prices and costs, so that the adjustments are more rapid and there is scarcely any recession.

The role played by the wealth effect in Germany should be highlighted once again. The strong increase on impact in German prices reduces real wealth and makes activity fall considerably on impact, unlike in the case of the euro-area aggregate. However, the positive effect of the depreciation on activity and also on nominal wealth means that activity recovers quickly and moves into an expansionary phase.

FIGURE 3. PERMANENT SUPPLY SHOCK: PERMANENT 20% RISE IN
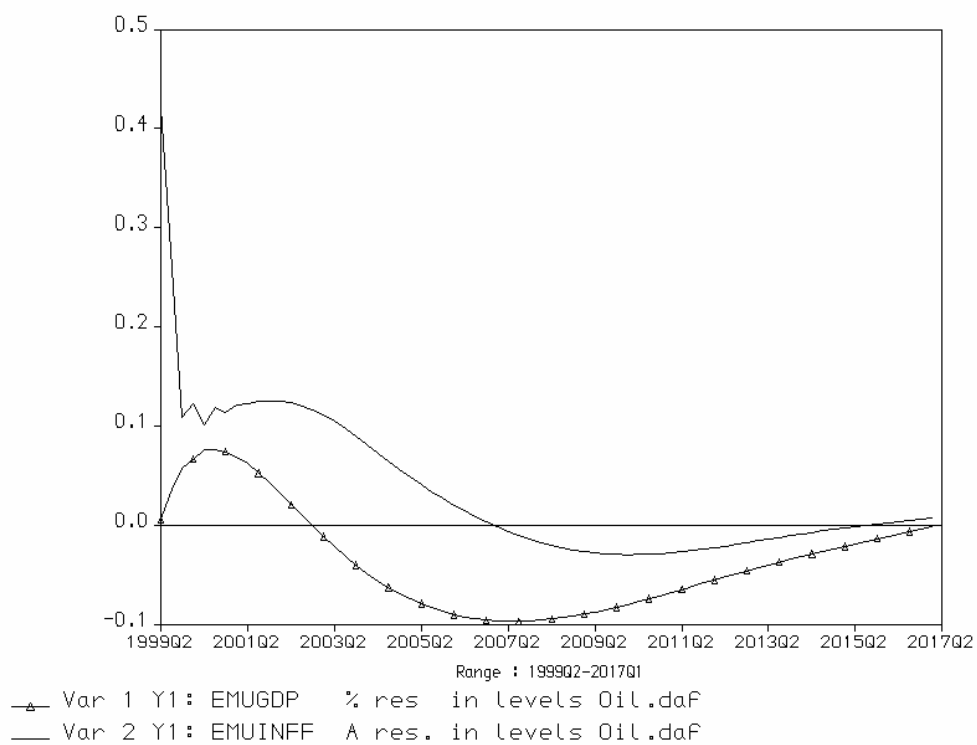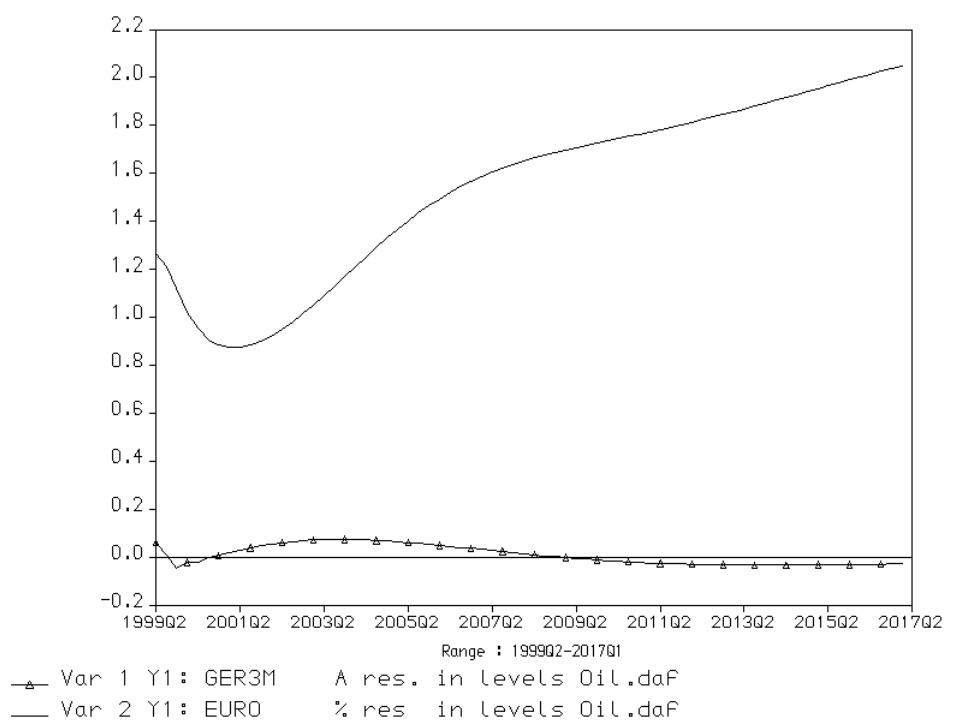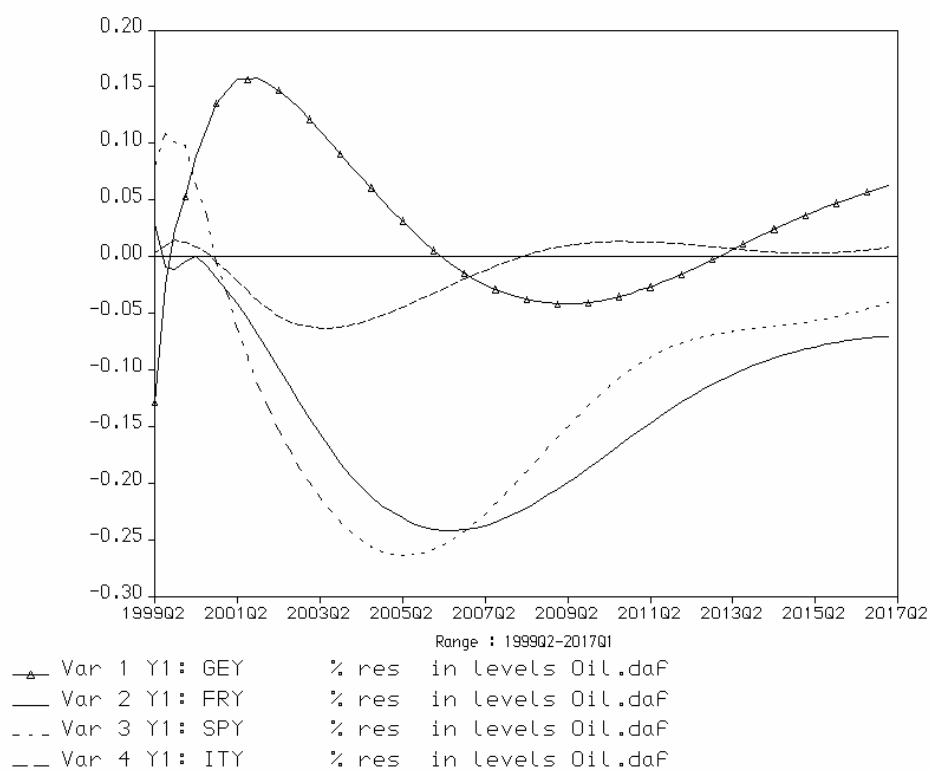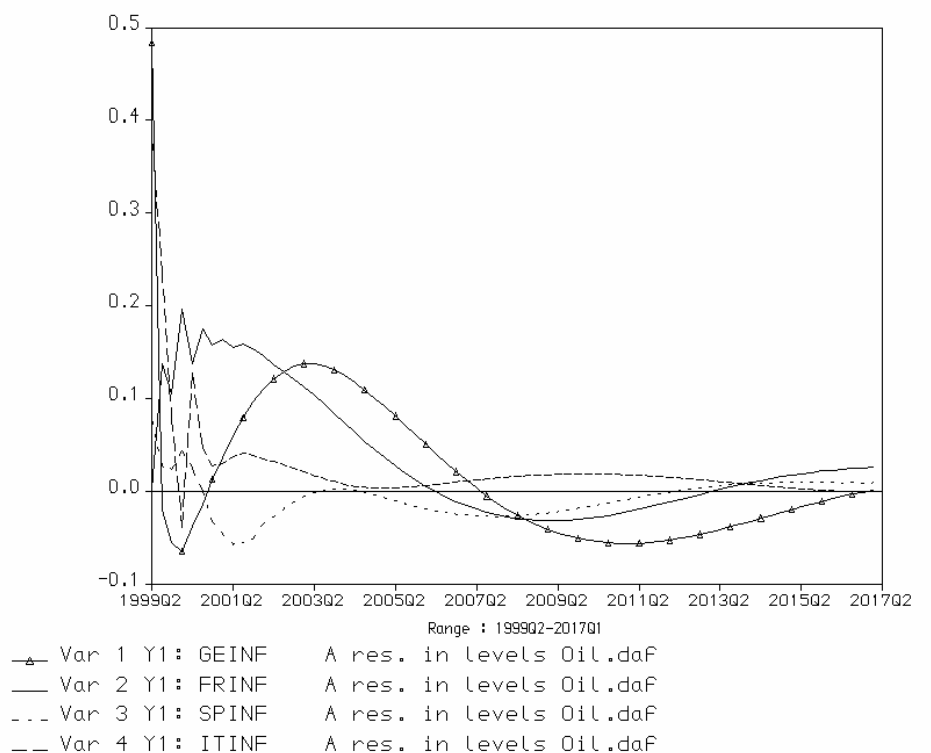THE OIL PRICE (EURO AREA)

FIGURE 3. PERMANENT SUPPLY SHOCK: PERMANENT 20% RISE IN THE OIL
PRICE (COUNTRIES)

IV.2.2. Common temporary demand shock (fall in stock markets)

This exercise is inspired by fears of a major stock market correction in the US. Nonetheless, the shock considered is a 20% plunge in the stock markets of all the countries lasting one quarter, after which they gradually return to their baseline levels. This is because the simulation model[51] does not capture the evident interconnections between stock markets in different countries, which mean that a fall on Wall Street can be expected to have a greater or lesser knock-on effect on impact on stock markets all around the world.

Impact

The fall in the stock market has an instantaneous effect on the financial wealth of households and, therefore, on consumption in all the countries. However, the greater capitalisation of the US market means that the fall in demand is much greater on impact in the US (70 basis points) than in the rest of the countries and in particular, as seen in Figure 4, than in the euro area (a 20-basis-point fall in GDP in the first quarter). The fall in activity exerts a contractionary effect on prices, so that inflation also falls although, as expected, it does so less sharply than in the US.

The greater effects of the stock market fall in the US will entail a stronger (downward) reaction by interest rates in that country than in the euro area, generating expectations of a euro depreciation, due to the positive interest rate differentials expected. On impact, therefore, the euro exchange rate appreciates strongly, as seen in the upper left-hand chart, to enable the subsequent depreciation to take place. This real appreciation of the euro is an obstacle to the recovery of external demand in Europe, but it facilitates recovery in the United States (the US dollar appreciates on impact by more than 2.5% in real terms).

Adjustment

The different effects of the financial shock are reflected particularly strongly in the behaviour of the nominal exchange rate. The larger fall in activity in the US means that European external demand contracts to a greater extent than that of the US. The result is a larger trade imbalance in the euro area than in the US, which generates a permanent depreciation of the euro in real terms. During the adjustment process the euro overshoots its initial nominal level to end up depreciating by around 1%.

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[51] When NiGEM is used to make forecasts, all the stock market indices follow the US market. In the simulation model, however, behavioural equations estimated for each country are introduced. And although they are estimated jointly and with restrictions that make them similar, a change in the stock market of one country is not fully and immediately transmitted to the rest.

As regards the reaction of monetary policy, the fall in short-term nominal interest rates facilitates the recovery of the stock market and also increases the value of bonds, counteracting the negative wealth effect of the shock and enabling activity to recover[52]. As a consequence of this the recession is severe but short.

Table IV.4. Temporary demand shock
20% fall in the stock markets of all countries lasting one quarter

	EURO AREA	GERMANY	FRANCE	SPAIN	ITALY
GDP					
Year 1	*-0,29*	-0,38	-0,23	-0,17	-0,18
Year 2	*-0,69*	-0,91	-0,61	-0,4	-0,69
End period	*0,09**	0,07*	-0,04*	0,11*	0,2*
INFLATION					
Year 1	*-0,10*	-0,13	-0,07	-0,05	-0,18
Year 2	*-0,22*	-0,34	-0,15	-0,09	-0,26
End period	*0,03**	0,08*	-0,03*	0,02*	-0,02*
Asterisks (*) denote residual deviations, caused by the cutting short of the series					
Average annual deviations from the baseline as percentages (GDP) and as levels (inflation).					

Comments

A temporary stock market correction has significant effects on demand through the induced effects on wealth and consumption. However, the differences in the assignment of wealth across the various countries mean that the monetary policy action to stabilise the economy varies in the degree of its aggressiveness. In particular, the monetary reaction in the US is greater owing to the larger fall in its activity. As a result, a nominal appreciation of the euro is generated which, in this case, enables the costs of the shock to be redistributed more uniformly.

- *Countries*

In the case of this shock, the differing intensity of the wealth effect across the euro-area economies is evident once more. The German economy is the most sensitive to changes in wealth, and suffers a greater recession in the first and second years, followed by Italy, where wealth effects are also significant, although a little less, and France. Consumption in Spain (dotted line) has the lowest elasticity of wealth. The order of the countries is practically the same as regards the speed of the fall in inflation induced by the recession.

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[52] As the shock only lasts one quarter, stock market prices would be expected to return rapidly to their initial level or even to a slightly higher level, due to the fall in interest rates. However, a significant degree of inertia is observed in the equations, especially in that of the US.

In Germany and Italy prices react relatively more quickly to changes in activity, so that we once again the inflation rates of these two countries show more erratic behaviour to start with, as well as a quicker correction of the initial fall. The inertia in the price-formation process in Spain and France is clearly visible in the smoother and slower changes in their inflation rates.

The greater sensitivity of the Spanish economy to changes in international competitiveness is once again evident. As soon as the nominal euro exchange rate reverses its initial appreciation activity recovers in Spain more rapidly than in the other economies.

FIGURE 4. COMMON TEMPORARY DEMAND SHOCK: 20% FALL IN THE STOCK MARKET (EURO AREA)
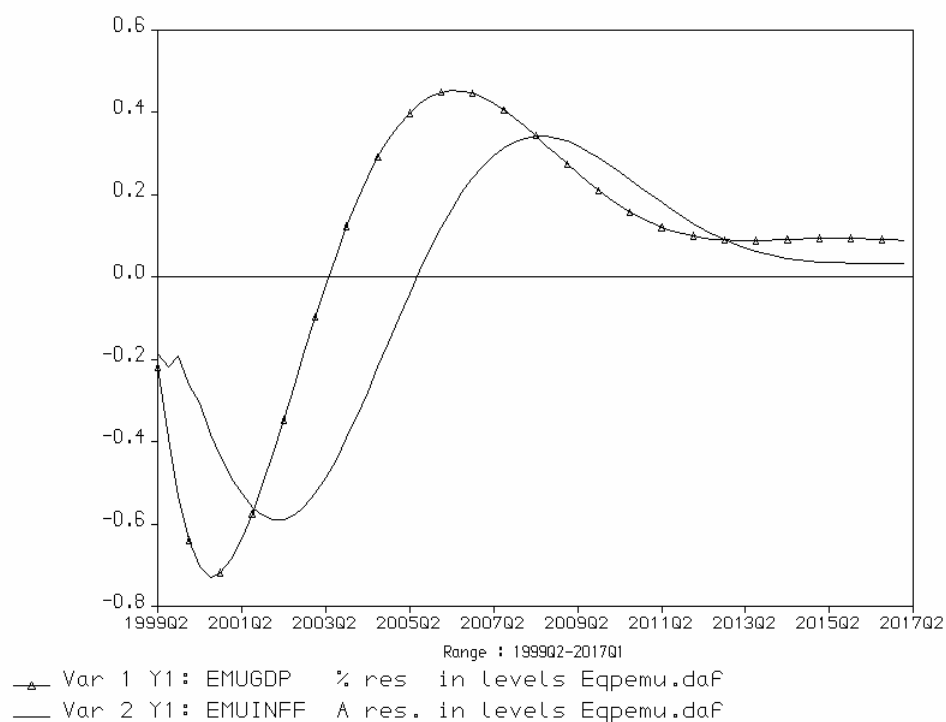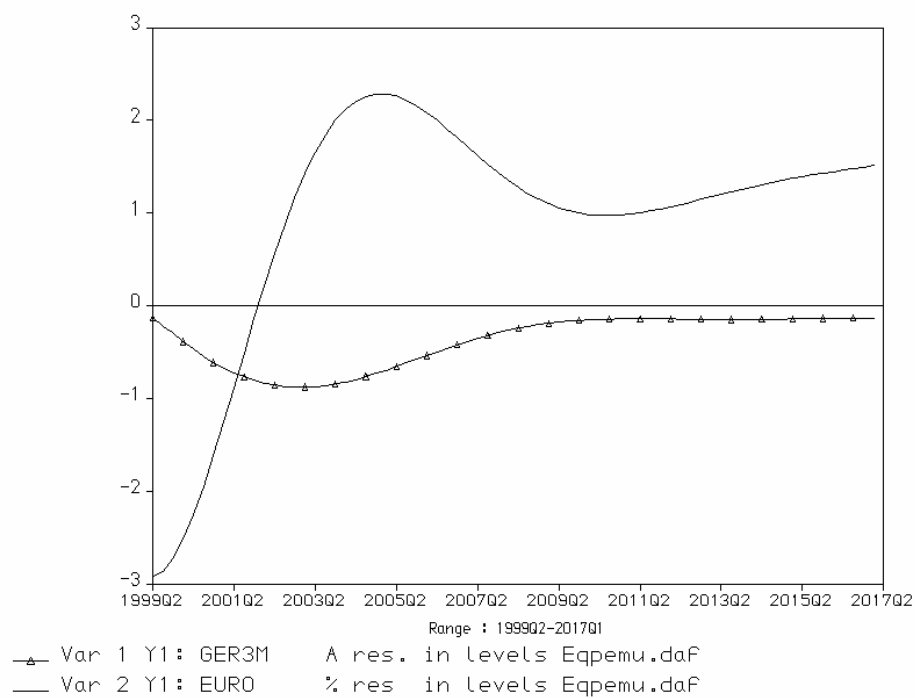
FIGURE 4. COMMON TEMPORARY DEMAND SHOCK: 20% FALL IN THE
STOCK MARKET (COUNTRIES)

Range : 1999Q2-2017Q1

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—△— Var 1 Y1: GEINF    A res. in levels Eqpemu.daf
——— Var 2 Y1: FRINF    A res. in levels Eqpemu.daf
-..- Var 3 Y1: SPINF    A res. in levels Eqpemu.daf
——— Var 4 Y1: ITINF    A res. in levels Eqpemu.daf
```


Range : 1999Q2-2017Q1

```
—△— Var 1 Y1: GEY     % res  in levels Eqpemu.daf
——— Var 2 Y1: FRY     % res  in levels Eqpemu.daf
-..- Var 3 Y1: SPY     % res  in levels Eqpemu.daf
——— Var 4 Y1: ITY     % res  in levels Eqpemu.daf
```
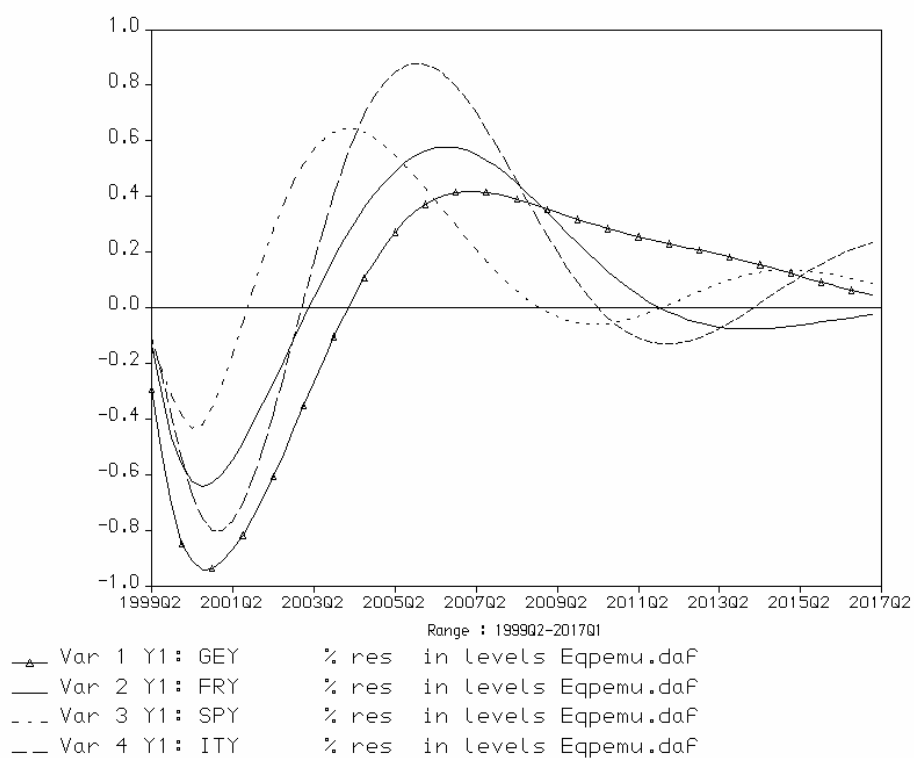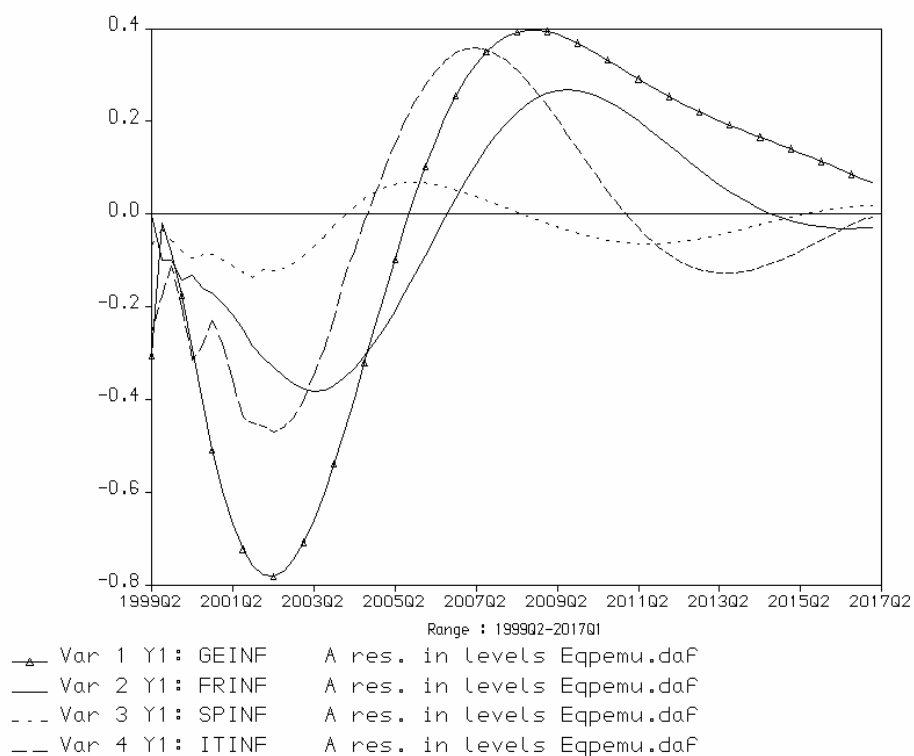
IV.2.3. Idiosyncratic demand shock (temporary 1% fall in consumption in Germany) and its comparison with a common shock.

Finally, an idiosyncratic temporary demand shock is considered (a 1% fall in German consumption lasting two years) and a comparison is made with the effects that the same shock at the euro-area level would have had.

Shock in Germany

In this case, it is convenient to begin with the effects of the shock in its country of origin. In the lower charts of Figure 5 it is striking that the shock is only partially reflected in German output (which falls by only 40 basis points on average in year 1 and by 37 basis points in year 2), while inflation also falls by up to one quarter of a percentage point in year 2. The main reason for this moderate behaviour on the part of activity is to be found in the effects on euro-area monetary policy induced by the fall in German consumption. Germany's importance in the euro area (it accounts for about 35% of the euro-area GDP) is reflected in the downward reaction of interest rates, which fall by 10 basis points on impact. This fall in interest rates entails, first, a depreciation of the euro on impact to enable the appreciation induced by the negative interest-rate differential to take place and, second, a fall in long-term interest rates. These two factors entail an increase in financial wealth in Germany where, as insisted above, wealth effects are very important. The result is that the initial fall in consumption is moderated by the positive wealth effect which, together with the direct stimulus to demand induced by the monetary loosening and currency depreciation, generates a relatively small fall in income on impact.

In the rest of the countries, the expansionary effect of the monetary and exchange rate policy predominates over the fall in German consumption from year 2, generating a moderate expansion in activity and an increase in inflation. This reaction by the other countries explains the moderation of the expansionary monetary stimulus in subsequent periods. Overall, the business cycle of the country that suffered the idiosyncratic shock is seen to be out of synchrony with those of the rest of the countries as a result of the reaction of euro-area monetary policy.

Comparison with a common shock

As is to be expected, when the fall in consumption is common to all the countries the asynchrony disappears, although the adjustment processes may give rise to certain divergences in the cycle, as seen in Figure 6. However, the importance of Germany is confirmed by the great similarity between the euro-area variables in the upper charts of Figures 5 and 6.

Comments

It can be seen from this example how idiosyncratic shocks affect the euro-area monetary policy (naturally, the larger the weight of the country concerned the greater the effect). In the case discussed, the reaction of the euro-area monetary policy, although enabling the fall in German GDP to be moderated, introduces a significant degree of asynchrony into the cycle. If monetary policy did not respond, the reduction in external demand in Germany would have had knock-on effects in the other countries. However, the fall in interest rates and the related exchange-rate depreciation introduces an expansionary bias into the other economies.

Table IV.5. Idiosyncratic temporary demand shock
1% fall in German consumption lasting two years

	EURO AREA	GERMANY	FRANCE	SPAIN	ITALY
GDP					
Year 1	-0,12	*-0,4*	-0,01	0,02	-0,01
Year 2	-0,09	*-0,37*	0,02	0,07	0,03
End period	0*	*0**	-0,01*	0,01*	0,03*
INFLATION					
Year 1	-0,01	*-0,04*	0,01	0,01	0,01
Year 2	-0,09	*-0,25*	0,00	0,01	-0,01
End period	0,00*	*-0,03**	0,00*	0,01*	0,02*
Asterisks (*) denote residual deviations, caused by the cutting short of the series					
Annual average deviations from the baseline as percentages (GDP) and as levels (inflation).					

Table IV.6. Common temporary demand shock
1% fall in euro-area consumption lasting two years

	EURO AREA	GERMANY	FRANCE	SPAIN	ITALY
GDP					
Year 1	*-0,12*	-0,40	-0,01	0,02	-0,01
Year 2	*-0,09*	-0,37	0,02	0,03	0,07
End period	*0,00**	-0,03*	-0,01*	0,01*	0,03*
INFLACION					
Year 1	*-0,03*	-0,04	0,01	-0,05	-0,07
Year 2	*-0,16*	-0,30	-0,03	-0,06	-0,20
End period	*0,00**	-0,02*	-0,02*	0,01*	0,02*
Asterisks (*) denote residual deviations, caused by the cutting short of the series					
Annual average deviations from the baseline as percentages (GDP) and as levels (inflation).					

FIGURE 5. IDIOSYNCRATIC DEMAND SHOCK: TEMPORARY 1% FALL IN GERMAN PRIVATE CONSUMPTION (EURO AREA)
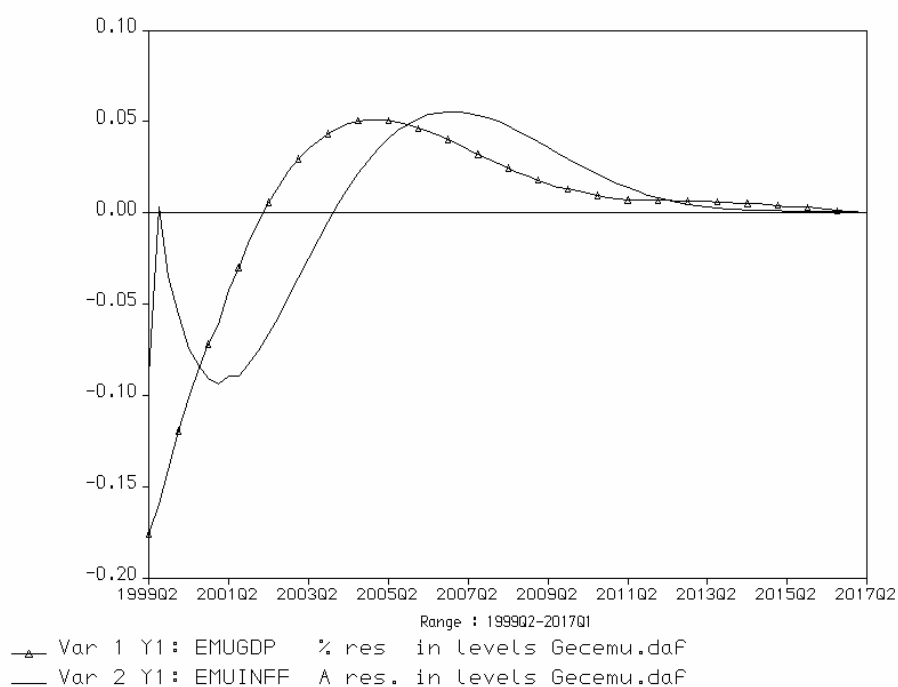
FIGURE 5. IDIOSYNCRATIC DEMAND SHOCK: TEMPORARY 1% FALL IN GERMAN PRIVATE CONSUMPTION (COUNTRIES)


```
 _▲_ Var 1 Y1: GEINF    A res. in levels Gecemu.daf
 ___ Var 2 Y1: FRINF    A res. in levels Gecemu.daf
 ... Var 3 Y1: SPINF    A res. in levels Gecemu.daf
 __ Var 4 Y1: ITINF     A res. in levels Gecemu.daf
```



```
 _▲_ Var 1 Y1: GEY      % res  in levels Gecemu.daf
 ___ Var 2 Y1: FRY      % res  in levels Gecemu.daf
 ... Var 3 Y1: SPY      % res  in levels Gecemu.daf
 __ Var 4 Y1: ITY       % res  in levels Gecemu.daf
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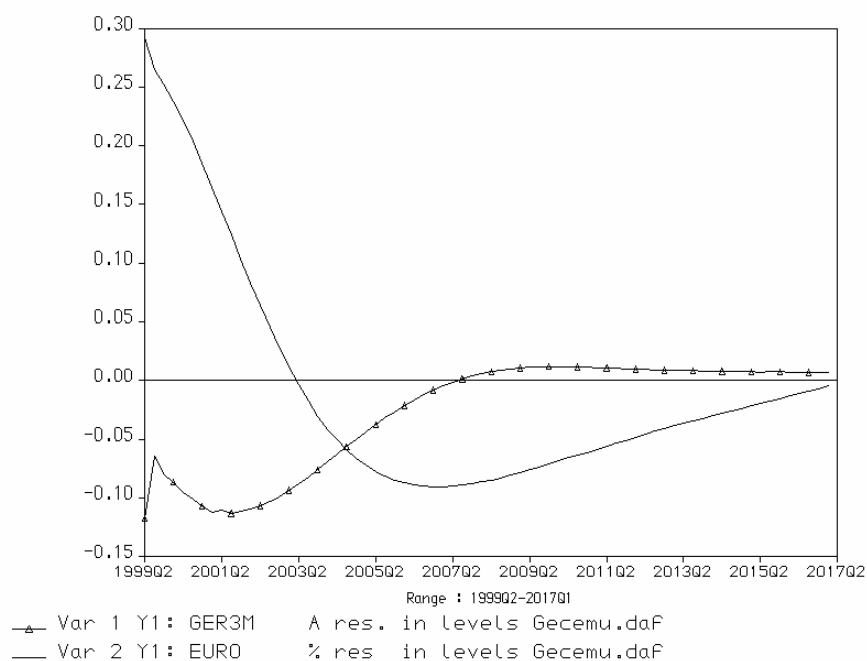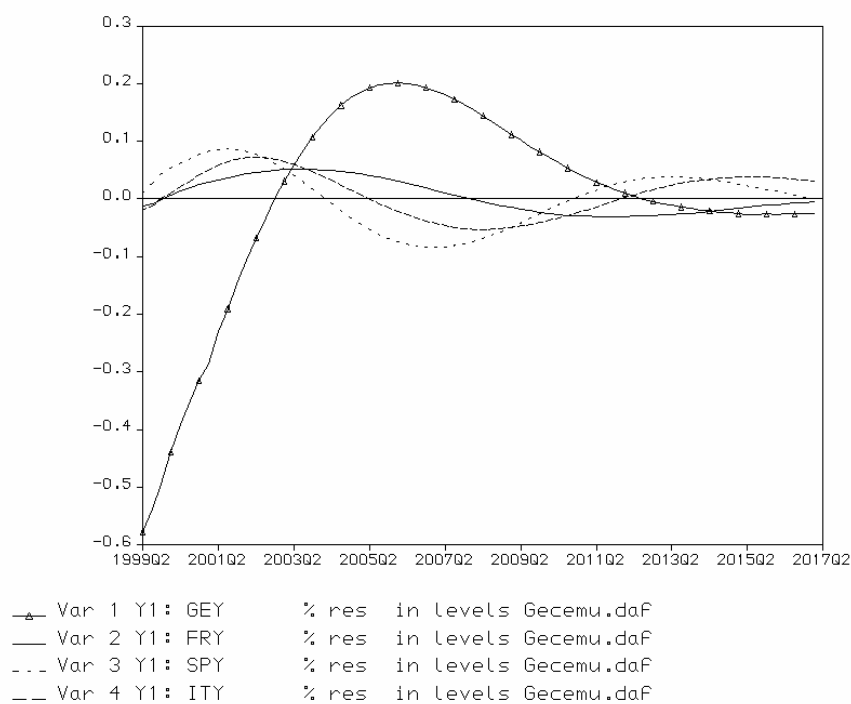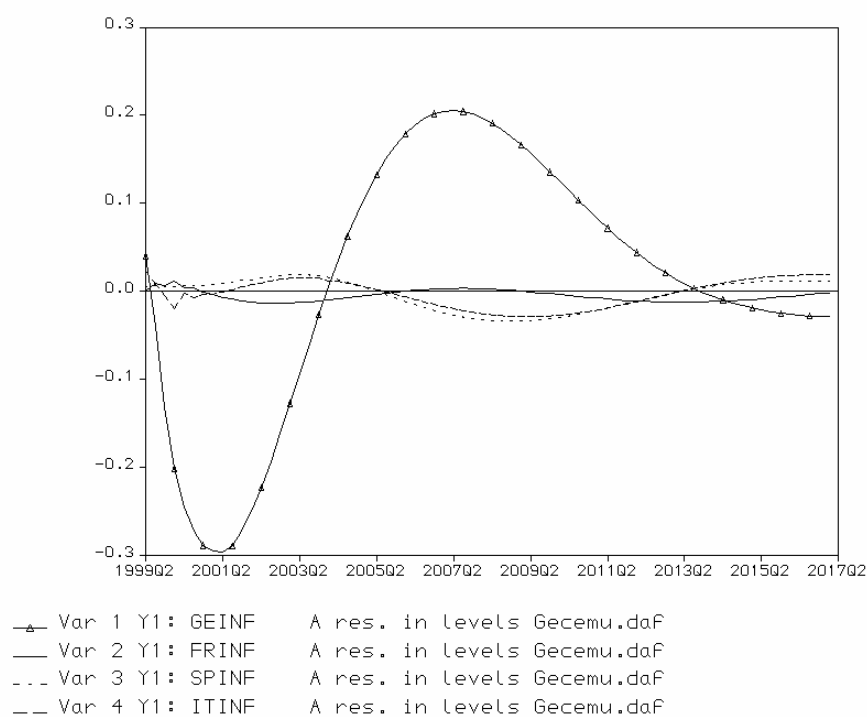
FIGURE 6. COMMON DEMAND SHOCK: TEMPORARY 1% FALL IN EURO-AREA
PRIVATE CONSUMPTION (EURO AREA)

FIGURE 6. COMMON DEMAND SHOCK: TEMPORARY 1% FALL IN EURO-AREA PRIVATE CONSUMPTION (COUNTRIES)


```
 ⌐▵ Var 1 Y1: GEINF    A res. in levels Emucemu.daf
 ── Var 2 Y1: FRINF    A res. in levels Emucemu.daf
 ... Var 3 Y1: SPINF   A res. in levels Emucemu.daf
 ── Var 4 Y1: ITINF    A res. in levels Emucemu.daf
```



```
 ⌐▵ Var 1 Y1: GEY     % res  in levels Emucemu.daf
 ── Var 2 Y1: FRY     % res  in levels Emucemu.daf
 ... Var 3 Y1: SPY    % res  in levels Emucemu.daf
 ── Var 4 Y1: ITY     % res  in levels Emucemu.daf
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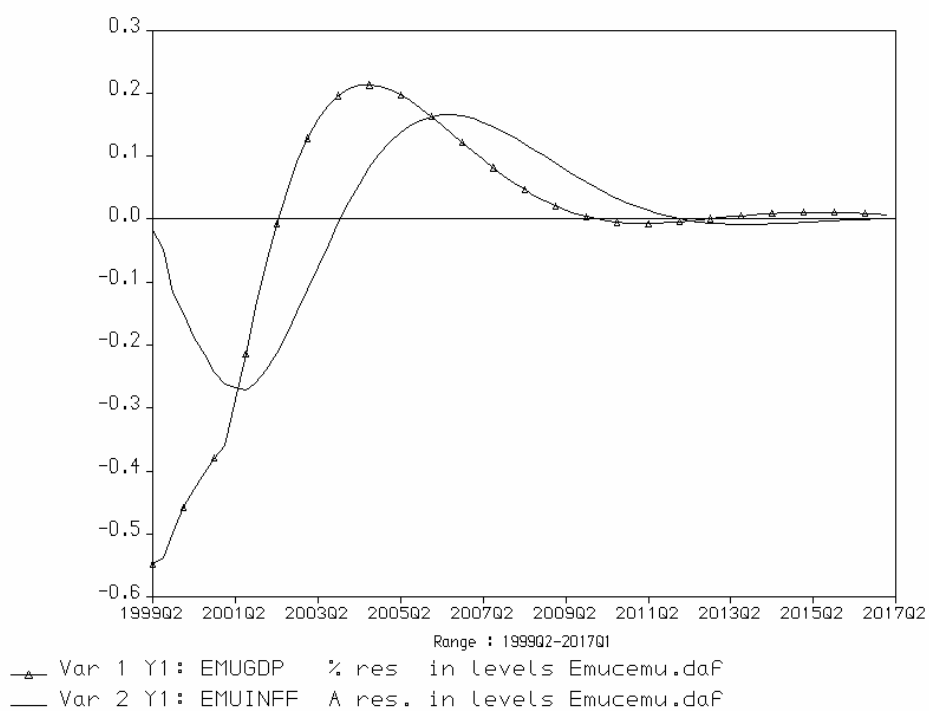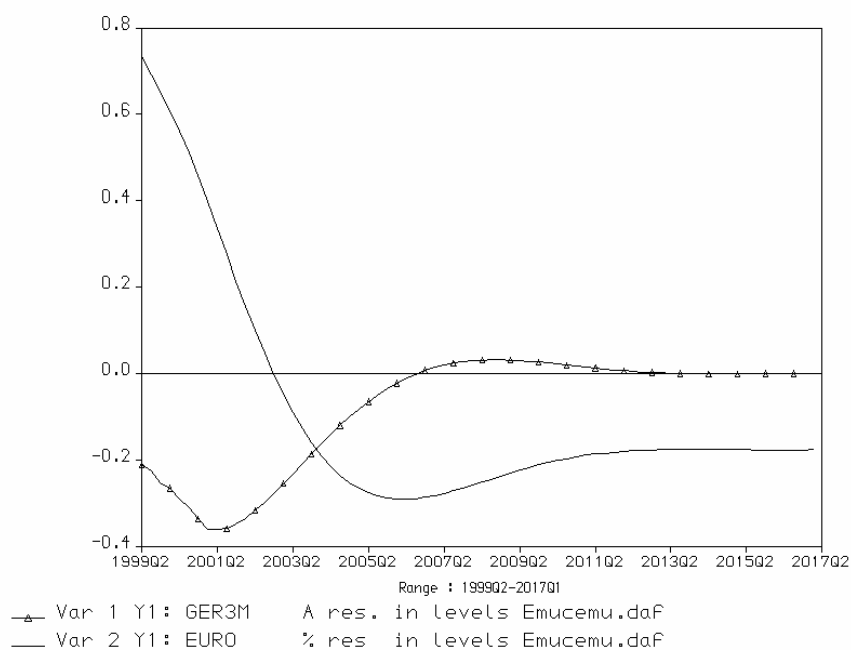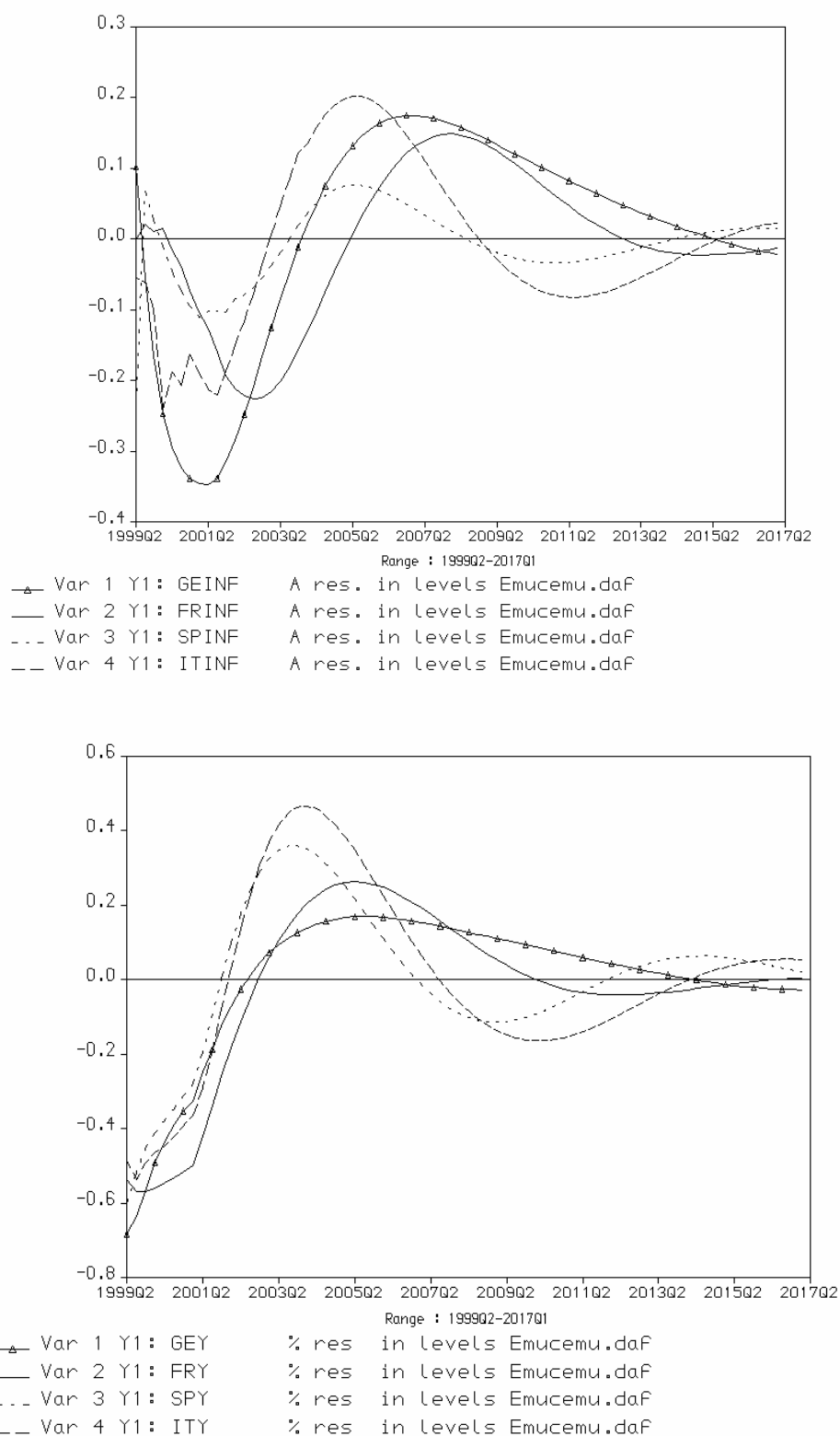
IV.3. EVALUATION OF THE SIMULATION EXERCISES

It has been possible to establish, on the basis of the various simulations performed, the most important characteristics of NiGEM's shock transmission mechanisms. These characteristics have been discussed above, but it is worth considering them taken together in order to obtain an overall view of the most important aspects of the model.

IV.3.1. The most distinctive features of the model

Probably the most striking result of the simulations is the centrality of the exchange rate in the shock transmission mechanism. Its forward-looking design, the existence of perfect foresight in the economy, the model's multi-country nature and the requirement to respect overall equilibrium in the economy period by period explain why the exchange rate's nominal adjustment on impact is the main channel through which the model adjusts to its long-term equilibrium.

This result contrasts with the very limited role of the monetary-policy reaction in the model and the scant direct effects exerted by changes in interest rates on real variables. For example, in year 1, a rise in interest rates has very scant effects on activity and inflation (the fall hardly reaches 30 basis points when at its greatest), despite the fact that the appreciation of the exchange rate should help to magnify these effects. At the same time, in all these simulations interest rate movements are small, despite the significant effects that some of the shocks have on inflation (such as the increase in the oil price in the third simulation). It is true that the perfect credibility implicit in the model will mean, as seen in the case of the permanent monetary shock, that a smaller monetary-policy reaction is needed to contain inflationary pressures. Even so, the model allows little room for an active monetary policy and generates few real effects, making it unsuitable for simulations of monetary policy.

The results of other simulations are also striking. The increase in the oil price proves to have real positive effects in the first few years, which are hard to reconcile with a negative supply shock. It is probably the lack of sophistication in the modelling of the supply side in NiGEM that is responsible for this, as it means that the expansionary effects on demand induced by the shock (exchange-rate depreciation on impact) dominate the result. By contrast, the fall in the stock market has more significant real effects than might be expected, probably owing to the prominent role of wealth effects in the model[53].

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[53] This importance given to wealth effects, which are traditionally underestimated in traditional monetary policy models, makes the scant effect of monetary policy more striking.

These comments suggest that, despite the attractiveness of conducting simulations with a macroeconometric model such as NiGEM, the results must be evaluated with care and interpreted taking into account the particular structure of the model. This underestimates certain transmission mechanisms (such as interest rates and monetary policy) and gives too much importance to others that do not traditionally enjoy such prominence (such as wealth effects and the role of the exchange rate).

IV.3.2. Analysis by country

In the simulations the different effects of the shocks on individual euro-area countries have been addressed. Although all the shocks, except the last one, can be considered as common to the area, the different economic structures and, in particular, the different importance of the transmission mechanisms across countries implicit in the model explain the asynchronies that arise in terms of inflation and activity, as observed in the various exercises. These asynchronies may generate, as in the case of the oil shock for Germany, negative correlations between the responses of the euro-area countries.

Some of the distinctive features have been highlighted in the analysis. Thus, Spain shows extreme sensitivity to changes in the exchange rate, owing to the high elasticity of its external sector with respect to relative prices, while wealth effects play a fundamental role in Germany. The different degrees of price and wage rigidity also explain the differing persistence of shocks across countries.

To obtain an overall view of the extent of the divergence of each country's behaviour, Figure 7 below shows, very roughly, for each shock considered, its different effects on activity and inflation in each country with respect to the euro area as a whole. Each radial line represents the difference, in basis points, between the response by euro-area GDP and inflation to a specific shock and the response by the same variables in the individual countries considered. The responses are measured as average deviations from the base scenario during the two years following the commencement of the simulated shocks. A positive deviation implies a larger increase in GDP than in the area as a whole, and vice-versa[54].

Figure 7 illustrates various relevant facts: Germany, both in terms of inflation and, principally GDP, is the country that generally displays the most divergent responses; by contrast, France and Italy show very similar responses in terms of GDP, while France and Spain are alike in their response to inflation.

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[54] In the case of the oil-price shock, the effects have been multiplied by a factor of four so that they can be seen more clearly in the diagram.

FIGURA 7. Respuesta diferencial respecto a la UEM en puntos básicos

PIB

INFLACION

Alemania — Francia — España — Italia — Euro-11
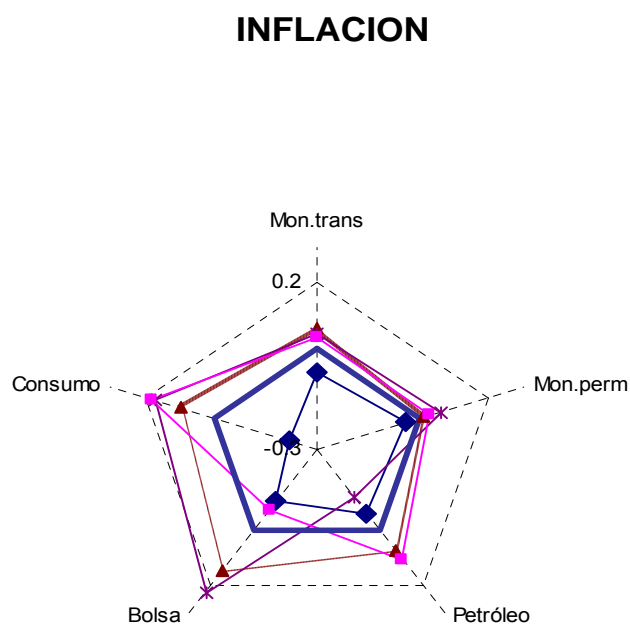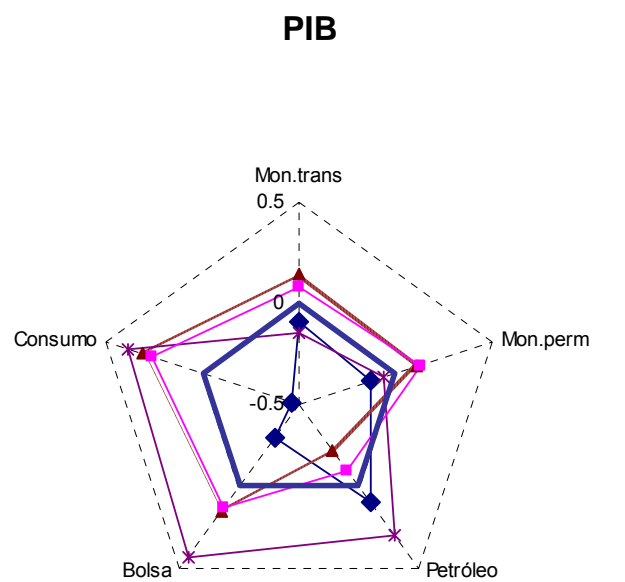
V.   CONCLUSIONS

Global macroeconometric models can be a powerful tool for economic analysis and forecasting under different scenarios. This paper analyses the NiGEM model and its application to the euro area, with the twofold objective of studying how it works and drawing, as far as possible and with the due qualifications, relevant conclusions on the situation of the European economies following the formation of the euro area.

A fundamental characteristic of NiGEM is that the model adopts a forward-looking approach, which enables the financial variables to react immediately and to anticipate their paths to equilibrium, as might be expected to occur in reality. Notable also is the degree of detail in the modelling of certain aspects as well as the ongoing drive by NIESR to update and improve the model.   All this makes NiGEM a very attractive tool for conducting simulations that enable the effects of different shocks or economic-policy measures on the world economy to be quantified.

That said, our experience as users suggests that, before making intensive use of the program, its main characteristics and limitations should be taken into account:

- NiGEM is a global macroeconometric program. The importance of the interdependencies and of global balance-of-payments consistency make the exchange rate and external financial flows key adjustment variables. This may mean that their true role is overestimated, to the detriment of other types of internal adjustment. A practical implication of this is that it may not be advisable to use NiGEM to analyse shocks in a particular single country.

- The terminal conditions imply stable paths for the financial variables, these being the fundamental variables in the generation of the adjustment process. As a result, exogenous shocks to the financial variables, especially if they are permanent, may disrupt the solving of the model, so that it is not advisable to simulate such shocks.

- The characterisation of the long-term equilibrium or baseline on which the model converges following a shock is not absolutely clear, except as regards the terminal conditions of the forward-looking variables and the fulfilment of global balance-of-payments consistency. Because the simulation horizon is cut short arbitrarily, or because the relationships contained in the baseline seek to reflect imbalances that are seen in the long run in the various economies, or for other reasons that we are unaware of, it is not clear which of the long-term relationships included in NiGEM's behavioural equations are fulfilled at the end of the simulation horizon. This point is clearly illustrated

when, for example, a permanent monetary shock is simulated, as in the second simulation of section IV.

- The target variables correspond to the model's baseline or initial equilibrium. As mentioned, this has implications for the analysis of the monetary policy, but also in the case of the fiscal policy. For practical purposes, on certain occasions this limitation requires an additional effort in the design of the shocks (estimating the paths of the target variables).

- The monetary policy rules included in NiGEM play a fundamental role in providing the model with a nominal anchor and in the convergence on the long-term monetary equilibrium. Their specification differs from the usual description of a reaction function of the monetary authority. These characteristics make comparison with standard monetary rules difficult and also, in practice and as shown by the simulation exercises conducted, they limit the active role attributed to the monetary authority in the stabilisation of prices.

- The updating of the program means that with each new version any of the basic relationships may change, significantly altering the results in some cases. As a result, users must make a considerable effort, requiring an ongoing commitment of resources, to monitor the program rigorously.

In our view, proper use of the program requires a thorough understanding of the model, which involves a heavy initial investment in terms of time and effort. Moreover, extreme care must be taken in the design of shocks, the results need to be tested for consistency and continuous monitoring is required.

The simulation exercises presented in this paper are the product of this effort. The results are revealing and interesting both at the general euro-area level and at the country level. Focusing on monetary shocks, the importance of the exchange rate channel in the transmission of shocks and the limited effects of monetary policy on activity and inflation are notable. The conclusion of the second exercise is also interesting, i.e. that a permanent reduction in inflation, contrary to what one might presuppose, does not require an initial increase in the rate of interest owing to the anticipation of the foreign exchange markets and to the way in which NiGEM specifies the monetary policy rules. This exercise also reveals the unsatisfactory characterisation of the relationships between the real variables at the end of the simulation period. In addition, it shows the importance of the wealth effect in NiGEM, and how the calculation of sacrifice ratios with NiGEM is immediate.

The next shock analysed, an increase in the oil price, produces results that are difficult to accept, including, for example, that the initial effect on demand is positive. This

kind of result, together with the difficulty of interpreting the long-term equilibrium in cases such as this one and the limited power of the variables and monetary rules to stabilise the economy, means that the results of simulations using NiGEM should be interpreted with extreme care and prudence.

In any event, the shocks analysed are good examples of how a common shock has different effects across countries owing to their different transmission mechanisms and their different economic structures. Thus, the different responses to a permanent increase in oil prices reveal the different speeds of adjustment of the price and wage systems, while the responses to a fall in stock markets illustrate the different strength of the wealth effect in the various countries. Finally, it can be seen that the common and idiosyncratic shocks to private consumption in the euro area have qualitatively similar effects across countries. It may be concluded from an overall assessment of the simulations, that common shocks may have different effects across countries, and it is notable that Germany is the country that, according to NiGEM, displays the most divergent behaviour in the euro area.
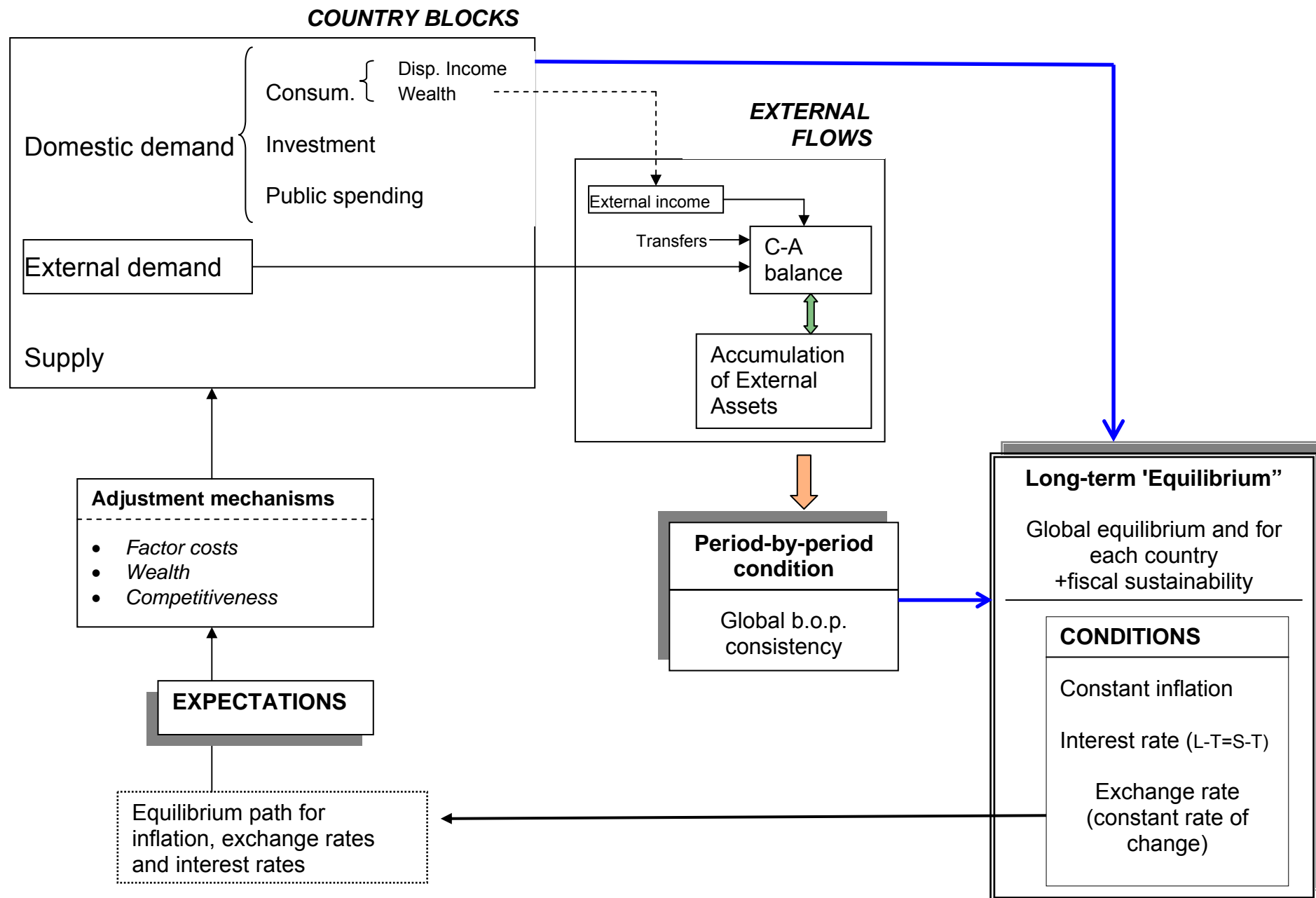
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Scheme 1: STRUCTURE AND ADJUSTMENT MECHANISMS OF NIGEM

COUNTRY BLOCKS

Domestic demand
- Consum. { Disp. Income / Wealth
- Investment
- Public spending

External demand

Supply

EXTERNAL FLOWS

External income

Transfers → C-A balance

Accumulation of External Assets

Adjustment mechanisms
- *Factor costs*
- *Wealth*
- *Competitiveness*

EXPECTATIONS

Equilibrium path for inflation, exchange rates and interest rates

Period-by-period condition

Global b.o.p. consistency

Long-term 'Equilibrium"

Global equilibrium and for each country +fiscal sustainability

CONDITIONS

Constant inflation

Interest rate (L-T=S-T)

Exchange rate (constant rate of change)

Scheme 2: THE MONETARY TRANSMISSION MECHANISM IN NIGEM

Short-term interest rate

RULES

- Monetary
- Inflation-GDP
- Inflation
- Taylor
- Cons. nom. interest rate
- Cons. real interest rate

EXPECTATIONS

Inflation

L-T rates

Fin. Assets

External assets

Exchange rate

ADJUSTMENT MECHANISMS

Factor costs

Wealth

Competitiveness

SUPPLY

Investment

DOMESTIC DEMAND

EXTERNAL DEMAND

Import prices

INFLATION