



IMF Working Paper

Some Simulation Properties of the Major Euro Area Economies in MULTIMOD

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Abstract

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This paper was prepared as part of a euro area macroeconomic model comparisons project. Four standard macroeconomic experiments are considered to illustrate the differences in dynamic adjustment properties of two versions of MULTIMOD, the IMF's multicountry macroeconomic model. One version of MULTIMOD that is examined contains separate country blocks for the three major economies in the euro area, Germany, France, and Italy. The second, more recent version, contains a single block describing the behavior of the whole euro area.

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I. INTRODUCTION

With the advent of European monetary union, developing an in-depth understanding of how economic disturbances may affect the union's major economies differently is an important challenge for policymakers. Policymakers will need to be cognizant of the potential disparities that could arise across the major European economies when evaluating the cost and benefits associated with the menu of policy options that they must choose from. The simulation analysis presented in this paper uses MULTIMOD, the IMF's multicountry macroeconomic model, to help further policymakers' understanding of how economic disturbance may be transmitted differently in the euro area's major economies.

As part of a model evaluation project organized by the Centre for Economic Policy Research (CEPR) and the Centre for European Integration Studies (ZEI), the analysis incorporates a set of standardized simulation experiments that are being conducted on a suite of macroeconomic models of the euro area.¹ Variants of four standard macroeconomic experiments are considered: a fiscal expenditure impulse; a monetary policy impulse; a productivity impulse; and a change in the non-accelerating inflation rate of unemployment (NAIRU). In this paper we present the set of standard simulation experiments that are common across all models as well as some variants that have been designed to illustrate some important caveats that policymakers should bear in mind when using this type of analysis.

Simulation results are presented from two versions of MULTIMOD. The first is a slightly modified version of MULTIMOD Mark III² that incorporates separate blocks for the three major economies in the European monetary union: Germany, France, and Italy. The remaining countries in the union are aggregated into a separate block and euro area results represent the aggregate results from these four blocks. Monetary policy is set at the euro area level based on weighted inflation and output indices for the area as a whole. Inter-euro-area exchange rates are held fixed, while the euro area exchange rate varies relative to the currencies of the area's trading partners. This version of the model also incorporates individual blocks for the United Kingdom, the United States, Japan, and Canada. The remaining industrial countries are aggregated into a single block and there are two additional blocks representing developing countries. The second version of MULTIMOD is an updated MARK IIIB version that incorporates a single block representing the euro area.³

¹ The results from all of the macroeconomic models in the study will be forthcoming in *Economic Modelling*.

² See Laxton and others (1998) for a detailed description of the Mark III version of MULTIMOD.

³ In addition to the incorporation of a euro area block, Mark IIIB incorporates new base-case specifications of the behavior of monetary and fiscal policy, a slightly different characterization of the inflation process, a recoding of the model that more easily permits solutions when countries choose different steady-state rates of inflation, and updated parameter estimates.

The shock experiments conducted highlight two areas in which differences in the characteristics of euro area countries could result in important differences in their responses to economic disturbances. The first is the extent to which households in different countries are constrained to consume only out of their current disposable income, rather than having unlimited access to capital markets and thus being able to smooth consumption by borrowing against future labor income. The second is the level of public debt. The higher is the level of public debt, the more deleterious are the effects of shocks that result in increases in real interest rates. On the other hand, economies with a higher level of public debt appear to more quickly reap the benefits of favorable supply-side innovations, provided policymakers quickly recognize the source of the acceleration in real activity and adjust policy accordingly.

The remainder of the paper is structured as follows. In Section II a very brief overview of the structure of MULTIMOD is presented. The model's response to the two policy shocks are presented in Section III. Section IV contains the results from the supply-side shocks. Some conclusions are offered in Section V.

II. MULTIMOD – AN OVERVIEW

This section presents a very simple overview of MULTIMOD, the IMF's multicountry model of the world economy. The interested reader is directed to Laxton and others (1998) for a more complete description of the model's structure, estimation, and properties.

MULTIMOD has a two-tiered structure. The first tier is a static representation that describes the long-run equilibrium of the economy where countries can be characterized as either net debtors or net creditors. The steady-state model is derived in a manner that makes it exactly consistent with the behavioral structure that determines the dynamic adjustment towards this full stock-flow equilibrium. This steady-state representation can be used to conduct comparative static analysis of the impact of permanent shocks to the economy. It also provides the terminal conditions exploited by the solution algorithm for solving the complete model. MULTIMOD's second tier is a dynamic representation that describes the transition path that the economy takes to the long-run equilibrium.

For the simulations presented in this paper, we use a slightly modified version of MULTIMOD Mark III. It contains individual blocks for seven industrial countries: Germany, France, Italy, the United Kingdom, the United States, Japan, and Canada. There are also two aggregate industrial country blocks. The first consists of the EU countries other than Germany, France, and Italy. The second consists of all remaining industrial countries. Each industrial country/block has an identical structure, but the estimated parameter values may vary. Developing countries are aggregated into two blocks. The main developing country block is made up of net debtor countries. The remaining developing country block consists of net creditor countries that are primarily those that export large quantities of oil. Both the developing country blocks are very simple with the key distinguishing feature being that the net debtor countries face a borrowing constraint. Analysis can be done with either individual industrial country/blocks or the complete model of the world economy. As noted earlier, we

also present some results from the most recent Mark IIIB version of MULTIMOD, which contains a single block representing the euro area.

Each industrial country block models the behavior of five types of economic agents: households, firms, nonresidents, fiscal authorities, and monetary authorities. Each industrial country produces a single composite tradable good. Nonresidents perceive this composite tradable good to be an imperfect substitute for their own home-produced composite tradable good. The main developing country model as well as the international trade accounts distinguish among three types of tradable goods: the composite good, oil, and non-oil primary commodities. The main developing country model also includes a nontradable manufactured good.

A. Households

In MULTIMOD, households consume the traded goods, supply labor, and accumulate financial assets in the form of government bonds and claims on the capital used by firms. In the industrial country blocks, household behavior is based on an extended version of the Blanchard (1985) finite-planning-horizon model. Because current generations are disconnected from future generations, the model embodies non-Ricardian features where changes in government savings can affect national savings, interest rates, and asset accumulation.

The basic Blanchard framework for household behavior has been extended along several dimensions. First, households are split between those whose consumption in each period is equal to a fraction of their combined financial and human wealth and those that can consume only their disposable income each period. This latter group of households face liquidity constraints that prevent them from borrowing against their human wealth (the present value of their expected life-time labor income). Further, households' labor income profiles are age dependent. These extensions allow changes in taxes to have more short-term impact on economic activity and mean that population dynamics have important implications for consumption and saving. Households' supply of labor is assumed to be perfectly inelastic with respect to the real wage.

B. Firms

Firms in MULTIMOD combine labor and capital under Cobb-Douglas production technology with the objective of maximizing the net present value of their expected future stream of profits. Firms are assumed to be perfectly competitive. Capital accumulation is based on the q theory of Tobin (1969) with the addition of costly adjustment. Adjustment costs are quadratic around the steady-state level of investment. Differences between the market price of capital and its replacement cost lead firms to change their desired level of capital. Costly adjustment means that firms adjust investment flows gradually to achieve their new desired level for the capital stock.

C. Nonresidents and International Trade

Unlike the explicit optimization theory determining the behavior of households and firms, international trade is motivated by the assumption that nonresidents view a country's

composite good as being an imperfect substitute for their own home-produced composite good. This assumption leads to the modeling of trade volumes as functions of activity and relative prices. Activity variables are constructed from input/output tables allowing for different import propensities in consumption, investment, government expenditure, and exports. Domestic activity is the scale variable driving imports and nonresident activity is the scale variable driving exports. In addition to trading, nonresidents can also hold domestic financial assets or alternatively supply foreign financial assets to domestic residents depending on whether the country is a net debtor or net creditor. It is assumed that the financial assets held or supplied by nonresidents are government bonds. Global consistency ensures that worldwide trade flows balance and global net foreign asset positions sum to zero.

D. Fiscal Authorities

The fiscal authorities in MULTIMOD purchase goods and provide transfers that they finance through taxation or debt issue. The fiscal authorities have targets for the ratios of expenditures, transfers and debt to GDP. Cyclical variation in economic activity leads to deviations from target ratios. To restore government debt to its target relative to GDP, the fiscal authorities gradually adjust the tax rate on labor income. Because households supply labor inelastically, this labor income tax is effectively a lump-sum tax. Transfer and expenditure target ratios are automatically restored as economic activity stabilizes. The Mark IIIB version also incorporates endogenous fiscal transfers that respond to the degree of slack in the economy and thus act as automatic stabilizers.

E. Monetary Authorities

In MULTIMOD, the role of the monetary authority is to provide the nominal anchor. The Mark III version allows for several possible nominal anchors: the money supply; the nominal exchange rate; the price level; or the rate of inflation. For the simulations presented in this paper, the nominal anchor is assumed to be the rate of inflation in the non-oil GDP deflator and the monetary authorities adjust the short-term nominal interest rate according to a Taylor-type monetary policy reaction function. The short-term nominal rate is adjusted relative to a neutral nominal rate in response to the gap between current inflation and its target rate and the gap between current output and potential output. The response coefficient on the inflation gap is set at 1.0 and the response coefficient on the output gap has been set to 0.25.⁴ The Mark IIIB version of MULTIMOD, which incorporates a single block for the euro area, characterizes the default monetary policy as inflation targeting. The model user can choose whether the inflation and output gap terms in a Taylor-type policy rule are lagged, contemporaneous or one-period-ahead forecasts. This version of the model permits solutions with different countries/blocks choosing different long-run target rates of inflation.

⁴ For this exercise the organizers requested that monetary policy respond to contemporaneous inflation. However, there is a body of research that illustrates that in the face of nonlinearities in the inflation process and lags in the monetary transmission mechanism, adjusting the interest rate in response to model-consistent forecasts of future inflation can improve the stabilization properties of monetary policy.

F. Prices

MULTIMOD contains a complete description of relative prices. Industrial country prices can be functions of up to four key prices: the world price of oil, the world price of non-oil primary commodities, non-oil GDP deflators, and exchange rates. The world price of oil is exogenous and the world price of non-oil primary commodities adjusts instantaneously to clear the non-oil commodities market. The behavior of the non-oil GDP deflator (referred to as core inflation) is described by a reduced-form Phillips curve and uncovered interest parity determines exchange rate behavior. How these prices are combined to generate the full set of relative prices depends on the individual country's/block's trading relationship with the rest of the world.

MULTIMOD, like most macroeconomic policy models, relies on a reduced-form Phillips curve to characterize the behavior of core inflation in the industrial countries. Core inflation (the rate of inflation in the non-oil GDP deflator) is a function of lagged inflation, expected future inflation and a nonlinear transformation of labor market disequilibria. The natural-rate hypothesis is imposed in the estimation of parameter values. The nonlinearity is such that inflation is more responsive to excess demand in the labor market than it is to excess supply. Although the specification does not include explicit wage rates, the dynamics of inflation and inflation expectations are characterized in a manner that implicitly recognizes important features of wage-setting behavior (in particular, contracting lags and wage-push elements). The most recent version of MULTIMOD that contains a single block for the euro area nests both a linear and nonlinear Phillips curve and the output gap rather than the labor market gap drives inflation. Further, a real-wage catch-up term has been included in the Phillips curve to capture the effect of households resisting the erosions in the purchasing power of their real wage that can arise from changes in import prices.

The behavior of the nominal exchange rate is governed by uncovered interest parity. The exchange rate will deviate from the expected future exchange rate in proportion to the gap between the domestic short-term interest and the foreign short-term interest. All exchange rates are expressed in terms of the United States currency.

G. Expectations

The agents in MULTIMOD are required to form expectations of the future evolution of many variables. For example, households must form expectations about future labor income and firms must form expectations about future profit streams. In MULTIMOD, it is assumed that expectations of all future variables are perfectly rational (model-consistent) except expectations of non-oil GDP inflation. Here the model relies on a mixture of backward-looking and model-consistent expectations to generate the empirically observed persistence in inflation.

H. Estimation

The Mark III version of the model was estimated over the 1972 to 1996 period. The Mark IIIB version has been estimated over the 1980 to 2001 period. The major differences in the estimates in the more recent sample period are in the proportion of liquidity constrained

consumers and the degree of persistence in inflation expectations. The new estimates suggest fewer liquidity constrained consumers and less persistence in inflation expectations.

III. POLICY IMPULSES

In this section we consider two policy disturbances. The first is a one-year temporary reduction in the level of government expenditure equivalent to one percent of GDP.⁵ The second is a temporary, one hundred basis point increase in the nominal short-term interest rate. Several different variants of each experiment are presented. With the fiscal impulse we consider both a euro-wide impulse as well as country specific fiscal impulses. In the base-case versions of these impulses, the nominal short-term interest rate is held fixed at the baseline level as is the fiscal tax rate. The monetary impulse is done both world wide and for the euro area only. Again to more precisely isolate the pure impact of monetary policy we hold the fiscal tax rate fixed at the baseline in the first year.

A. Euro Area Decline in Government Expenditure

This simulation is a one-year decline in government expenditures equivalent to 1 percent of GDP. The nominal short-term interest rate is held fixed at the baseline in the first year, thereafter the monetary policy rule takes over and stabilizes inflation at target. A summary of the simulation results are presented below in Table 1.⁶

⁵ In MULTIMOD, government expenditures include expenditures on goods and services plus gross fixed capital formation.

⁶ More detailed simulation results are available from the authors.

Table 1. Euro Area Reduction in Government Expenditure
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Germany							
Real GDP	-1.54	0.21	0.21	0.14	0.09	0.01	0.0
Contributions of:							
Consumption	-0.65	0.23	0.21	0.18	0.12	0.00	0.0
Investment	-0.01	0.01	0.04	0.01	0.00	0.00	0.0
Government	-1.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	0.12	-0.03	-0.05	-0.04	-0.02	0.01	0.0
Core Inflation	-0.36	-0.33	-0.22	-0.12	-0.05	0.01	0.0
France							
Real GDP	-1.46	0.22	0.24	0.20	0.15	-0.01	0.0
Contributions of:							
Consumption	-0.58	0.19	0.19	0.18	0.14	0.00	0.0
Investment	-0.01	0.01	0.04	0.02	0.01	0.00	0.0
Government	-1.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	0.12	0.01	0.00	0.00	0.00	-0.01	0.0
Core Inflation	-0.46	-0.39	-0.26	-0.17	-0.09	0.01	0.0
Italy							
Real GDP	-1.52	0.16	0.17	0.11	0.08	0.04	0.0
Contributions of:							
Consumption	-0.60	0.12	0.11	0.08	0.06	0.04	0.0
Investment	-0.01	0.02	0.05	0.02	0.01	0.01	0.0
Government	-1.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	0.09	0.03	0.01	0.02	0.02	-0.01	0.0
Core Inflation	-0.46	-0.35	-0.21	-0.11	-0.03	0.03	0.0
Other Euro Area							
Real GDP	-1.41	0.32	0.32	0.22	0.12	-0.01	0.0
Contributions of:							
Consumption	-0.57	0.21	0.22	0.20	0.14	-0.01	0.0
Investment	0.00	0.04	0.08	0.03	0.01	0.00	0.0
Government	-1.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	0.16	0.07	0.02	-0.01	-0.03	0.00	0.0
Core Inflation	-0.61	-0.37	-0.12	0.01	0.05	-0.02	0.0
Total Euro Area							
Real GDP	-1.48	0.23	0.24	0.17	0.11	0.00	0.0
Contributions of:							
Consumption	-0.60	0.20	0.19	0.16	0.12	0.00	0.0
Investment	-0.01	0.02	0.05	0.02	0.01	0.00	0.0
Government	-1.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	0.13	0.02	-0.01	-0.01	-0.01	0.00	0.0
Core Inflation	-0.47	-0.36	-0.19	-0.07	-0.01	0.00	0.0
CPI Inflation	-0.23	-0.27	-0.24	-0.17	-0.09	0.01	0.0
Nominal Short-Term Interest Rate	0.00	-0.50	-0.22	-0.05	0.02	0.01	0.0
Real Short-Term Interest Rate	0.36	-0.31	-0.14	-0.04	0.01	0.01	0.0
Nominal Exchange Rate (U.S.\$)	0.45	0.40	0.85	1.04	1.09	1.01	1.01
Real Competitiveness Index	0.04	-0.14	-0.04	0.00	0.01	0.00	0.0

Table 1. Euro Area Reduction in Government Expenditure (continued)
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Aggregate Euro Model							
Real GDP	-1.14	0.11	0.10	0.08	0.05	0.00	0.0
Contributions of:							
Consumption	-0.19	0.10	0.09	0.08	0.06	0.00	0.0
Investment	-0.01	0.02	0.03	0.01	0.00	0.00	0.0
Government	-1.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	0.07	-0.02	-0.02	-0.02	-0.01	0.00	0.0
Core Inflation	-0.17	-0.14	-0.06	-0.03	-0.01	0.00	0.0
CPI Inflation	-0.11	-0.10	-0.08	-0.06	-0.03	0.00	0.0
Nominal Short-Term Interest Rate	0.00	-0.17	-0.07	-0.03	0.00	0.00	0.0
Real Short-Term Interest Rate	0.14	-0.11	-0.04	-0.02	0.00	0.00	0.0
Nominal Exchange Rate (U.S.\$)	0.31	0.25	0.34	0.39	0.40	0.37	0.38
Real Competitiveness Index	0.11	-0.02	0.00	0.01	0.00	0.00	0.0

For all countries and models, the multipliers on this decline in government expenditure are larger than 1. For the disaggregated model, the magnitudes range from 1.54 in Germany to 1.41 in the “other” euro area countries, with the average multiplier being 1.48. For the model that aggregates all the euro area countries into a single block, the multiplier is 1.14. There are two reasons that these multipliers exceed unity; the presence of liquidity constrained consumers and the increase in the real short-term interest rate that occurs when the nominal interest rate is held at baseline. Simulation results holding the real interest rate at control in the first year suggest that the increase in the real interest rate contributes less than a tenth of one percent of GDP. The most important reason for the multipliers exceeding unity is the presence of the liquidity constrained consumers. The decline in government expenditure immediately feeds into their disposable income which in turns directly reduces their consumption. The version of MULTIMOD that aggregates all the euro area countries into a single block incorporates a more recent estimate of the proportion of liquidity constrained consumers.⁷ This estimate implies that thirty percent fewer households face liquidity constraints than does the estimate incorporated into the disaggregated version. Consequently, the multiplier is smaller because consumption declines less.⁸

The significant effect of the proportion of liquidity constrained consumers raises an important point for policymakers in the euro area. The version of MULTIMOD that disaggregates the euro area countries incorporates the same estimate for the proportion of liquidity constrained consumers in each euro area country. This compromise arose because of

⁷ In the first year of the simulation, transfers and taxes are held fixed at their baseline levels to isolate the pure effect of the fiscal expenditure impulse.

⁸ If the proportion of liquidity constrained consumers in the Mark III version is set equal to the proportion of liquidity constrained consumers in the Mark IIIB version, the fiscal expenditure multiplier is 1.17 in the first year, virtually identical to the multiplier in the Mark IIIB version.

the difficulties associated with precisely estimating this key parameter.⁹ However, policymakers should bear in mind that if significant differences exist across euro Area countries in the extent to which households' current consumption is constrained by their current disposable income, much larger cross-country differences could exist in fiscal expenditure multipliers than those reported here.

There is also a notable difference in the response of monetary policy in the two version of the model. Even controlling for the smaller multiplier in the Mark IIIB version, policy eases considerably less in response to the decline in government expenditure. This reflects the fact that the more recent Phillips curve estimates contained in Mark IIIB suggest that on average there is less persistence in the inflation process in Europe than earlier estimates suggested. Given the longer period of low and stable inflation contained in the most recent data, this result is not surprising.

B. The Impact of Starting Point Demand Conditions

In MULTIMOD, the magnitude of the eventual response of the monetary authority to a change in fiscal expenditures depends on the demand conditions prevailing at the time of the fiscal initiative. This result arises because MULTIMOD incorporates a nonlinear relationship between demand conditions and inflation; inflation responds more to excess demand than it does to excess supply. Forward-looking consumers, firms and financial markets factor this into their current responses and, consequently, the magnitude of the government expenditure multiplier will depend on the conditions prevailing in the economy when the fiscal initiative is taken.

Table 2 presents the government expenditure multipliers under five alternative assumptions about the initial demand conditions in the labor market. The basic-case assumption is that the labor market conditions are those that prevailed in the World Economic Outlook. To consider the effects of more excess demand, simulations results are reported starting with the unemployment rate 3 percentage points and 1 percentage point below the initial baseline. Alternatively to illustrate the implications of more excess supply, simulations results are reported starting with unemployment rates 3 percentage points and 1 percentage point above the initial baseline. These simulations suggest that if there is a nonlinear relationship between demand conditions and inflation like that incorporated in MULTIMOD, fiscal expenditure multipliers are smaller when the economy is experiencing significant excess demand. Essentially, when government expenditures are reduced when the economy is overheating, future monetary policy can be easier. Forward-looking agents understand this and the initial impact on consumption and investment is mitigated. The same holds true under increases in fiscal expenditure. A positive fiscal spending impulse when the economy is experiencing significant excess demand will imply that future monetary policy

⁹ Given the difficulty in precisely estimating the proportion of liquidity constrained consumers and the very small difference across euro area countries in the estimates presented in Laxton and others (1998), all euro area countries were constrained to have the same proportion of liquidity constrained consumers.

will need to be proportionately tighter, reducing current consumption and investment demand and thus the magnitude of the fiscal expenditure multiplier.¹⁰

Table 2. The Impact of Starting Point Conditions on Fiscal Expenditure Multipliers
(percent deviation from baseline)

	Starting Point Unemployment Gap				
	-3	-1	0	+1	+3
Germany	-1.42	-1.52	-1.54	-1.54	-1.55
France	-1.36	-1.45	-1.46	-1.46	-1.46
Italy	-1.41	-1.51	-1.52	-1.52	-1.53
Other	-1.33	-1.41	-1.41	-1.42	-1.42
Euro Area	-1.38	-1.48	-1.48	-1.49	-1.49

C. Country Specific Declines in Government Expenditures

This simulation is also a one-year, 1 percent of GDP decline in government expenditure. However, rather than being euro area wide, the decline is in the government expenditure of the individual country or group of countries specified. To save space, the results presented in Table 3 are for the country or block which is experiencing the decline in expenditure and the euro area results are presented only for GDP and the nominal short-term interest rate.¹¹

The responses suggest that the fiscal expenditure multipliers are still broadly similar across the major euro area countries and that they still exceed unity. The magnitudes of the multipliers, however, do decline when the shock is restricted to a specific country or block of countries. The declines range from 2/10 of 1 percent in Germany to 3/10 of 1 percent in Italy. Because their European trading partners are not experiencing the same decline in government expenditures, exports do not decline as much in the country experiencing the shock. In addition to its direct effect on GDP, this stronger net export position helps support the

¹⁰ The results in the table also illustrate the nature of the nonlinearity in MULTIMOD's inflation process. When demand conditions are close to the economy's supply potential, the inflation process is close to linear. Once unemployment gaps become significantly large, the nonlinearity starts to become apparent. The nonlinearity is more significant when the economy is experiencing significant excess demand than it is when the economy is experiencing significant excess supply.

¹¹ More detailed results are available from the authors.

income of liquidity constrained consumers and consumption declines less, further reducing the magnitudes of the multipliers.

With aggregate demand falling less with the initial decline in fiscal expenditure, the impact on the government balance is more favorable in the country cutting expenditure as tax revenues are relatively stronger. This leads to a subsequently larger easing in tax rates than when all euro area countries cut expenditures. The larger easing in taxes allows the economy to expand much more rapidly following the consolidation and this effect works through expectations to significantly reduce the impact on core inflation of the first year decline in output. This effect is the most pronounced in Italy.

Table 3. Reduction in Government Expenditure in Individual Country or Block
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Germany							
Real GDP	-1.33	0.25	0.27	0.24	0.16	-0.03	0.0
Contributions of:							
Consumption	-0.58	0.25	0.26	0.25	0.19	-0.02	0.0
Investment	0.00	0.02	0.04	0.03	0.01	-0.01	0.0
Government	-1.00	0.0	0.00	0.00	0.00	0.00	0.0
Net Exports	0.25	-0.02	-0.03	-0.04	-0.04	0.00	0.0
Core Inflation	-0.22	-0.16	-0.05	0.02	0.05	-0.02	0.0
Euro Area							
Real GDP	-0.52	0.08	0.09	0.07	0.04	0.00	0.0
Nominal Short-Term Interest Rate	0.00	-0.17	-0.08	-0.03	0.01	0.00	0.0
France							
Real GDP	-1.26	0.25	0.29	0.26	0.19	-0.05	0.0
Contributions of:							
Consumption	-0.51	0.23	0.25	0.25	0.20	-0.03	0.0
Investment	0.00	0.02	0.04	0.03	0.02	-0.01	0.0
Government	-1.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	0.25	-0.01	-0.01	-0.03	-0.04	-0.01	0.0
Core Inflation	-0.28	-0.18	-0.02	0.08	0.12	-0.04	0.0
Euro Area							
Real GDP	-0.35	0.05	0.05	0.04	0.03	0.00	0.0
Nominal Short-Term Interest Rate	0.00	-0.14	-0.07	-0.02	0.01	0.00	0.0
Italy							
Real GDP	-1.32	0.27	0.30	0.26	0.18	-0.05	0.0
Contributions of:							
Consumption	-0.54	0.26	0.28	0.27	0.20	-0.04	0.0
Investment	0.00	0.02	0.04	0.03	0.01	0.00	0.0
Government	-1.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	0.22	-0.01	-0.03	-0.04	-0.03	0.01	0.0
Core Inflation	-0.21	-0.09	0.01	0.07	0.07	-0.02	0.0
Euro Area							
Real GDP	-0.27	0.04	0.04	0.04	0.02	0.00	0.0
Nominal Short-Term Interest Rate	0.00	-0.07	-0.03	-0.01	0.00	0.00	0.0
Other Euro Area							
Real GDP	-1.19	0.30	0.31	0.24	0.14	-0.04	0.0
Contributions of:							
Consumption	-0.50	0.23	0.25	0.18	0.13	-0.02	0.0
Investment	0.01	0.04	0.06	0.04	0.02	-0.01	0.0
Government	-1.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	0.31	0.03	0.00	-0.04	-0.06	-0.01	0.0
Core Inflation	-0.39	-0.17	0.04	0.13	0.12	-0.04	0.0
Euro Area							
Real GDP	-0.42	0.06	0.06	0.04	0.03	0.00	0.0
Nominal Short-Term Interest Rate	0.00	-0.16	-0.06	0.00	0.01	0.00	0.0

D. Worldwide Monetary Policy Impulse

This simulation considers a one-year, 1 percentage point increase in nominal short-term interest rates that occurs in all industrial countries. In the first year of the simulation, fiscal tax rates are held fixed at their baseline rates. The simulation results presented below in Table 4 are for the euro area countries only.

The results from the disaggregated model suggest that the monetary policy multiplier is very similar across the euro area countries in the first year. The multipliers are all in the neighborhood of 2/10 of 1 percent of GDP. However, in the second year of the simulation, output declines by a significantly larger amount in Italy than in the other euro area countries. Continued weakening in consumption in Italy is driving the result. This reflects the fact that once fiscal policy is allowed to respond in the second year, labor taxes must rise considerably more in Italy than in the other euro area countries to eventually restore the government's debt-to-GDP target. Because Italy has a significantly larger stock of public debt than do the other euro area countries, the increase in the service cost resulting from the increase in interest rates leads to a larger deviation in the debt-to-GDP ratio from target. Fiscal policy must therefore respond more aggressively and household disposable income and, consequently, the consumption of liquidity constrained households declines more in Italy than in the other euro area countries.

Even though the monetary policy stance is reversed in the second year, the shock has persistent effects on both consumption and investment. The persistence in consumption arises because of the response of fiscal policy in the second year that is noted above. The persistence in investment arises because of the estimated persistence in investment in response to changes in Tobin's Q.

The Mark IIIB version of the model, which aggregates all the euro area countries, suggests that the magnitude of the multiplier is roughly twice the size of the disaggregated model's multipliers in the first year.¹² In the second year and beyond, the multipliers appear to be quite similar. The difference in the first year largely reflects the different response of inflation between the two versions of the model. The Phillips curves in the aggregated model have been estimated on data that includes a more prolonged period of low and stable inflation. These updated estimates suggest that temporary changes in aggregate demand relative to supply have a smaller impact on core inflation. With less deflationary pressures arising from the initial increase in interest rates, the subsequent easing in real interest rates that follows is less than half of that which occurs in the disaggregated model. Because forward-looking households and firms care about both current real interest rates and their future path, the shock has a larger first year impact on consumption and investment.

¹² In the first year of the simulation, transfers as well as taxes rates are held fixed at their baseline level to isolate the pure effect of the monetary impulse.

Table 4. Worldwide Increase in the Nominal Short-Term Interest Rate
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Germany							
Real GDP	-0.19	-0.21	-0.02	-0.03	-0.04	0.03	0.0
Contributions of:							
Consumption	-0.12	-0.12	-0.04	-0.05	-0.04	0.02	0.0
Investment	-0.05	-0.04	0.05	0.03	0.02	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.02	-0.05	-0.04	-0.01	-0.01	0.01	0.0
Core Inflation	-0.18	-0.22	-0.20	-0.16	-0.13	0.01	0.0
France							
Real GDP	-0.15	-0.21	-0.03	-0.02	0.00	0.03	0.0
Contributions of:							
Consumption	-0.09	-0.16	-0.07	-0.06	-0.03	0.04	0.0
Investment	-0.03	-0.03	0.04	0.03	0.02	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.02	-0.02	0.00	0.02	0.01	-0.01	0.0
Core Inflation	-0.21	-0.26	-0.22	-0.16	-0.10	0.02	0.0
Italy							
Real GDP	-0.17	-0.31	-0.08	-0.06	-0.02	0.05	0.0
Contributions of:							
Consumption	-0.11	-0.29	-0.19	-0.17	-0.10	0.07	0.0
Investment	-0.05	-0.04	0.08	0.06	0.04	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.01	0.02	0.03	0.05	0.04	-0.01	0.0
Core Inflation	-0.26	-0.27	-0.22	-0.16	-0.10	0.02	0.0
Other Euro Area							
Real GDP	-0.16	-0.17	0.03	0.03	0.02	0.01	0.0
Contributions of:							
Consumption	-0.11	-0.13	-0.04	-0.04	-0.02	0.02	0.0
Investment	-0.04	-0.03	0.07	0.05	0.03	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.01	-0.01	0.01	0.02	0.01	-0.01	0.0
Core Inflation	-0.27	-0.27	-0.20	-0.13	-0.08	0.00	0.0
Total Euro Area							
Real GDP	-0.17	-0.22	-0.02	-0.02	-0.01	0.03	0.0
Contributions of:							
Consumption	-0.11	-0.16	-0.07	-0.07	-0.04	0.03	0.0
Investment	-0.04	-0.04	0.06	0.04	0.03	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.02	-0.02	0.00	0.01	0.01	0.00	0.0
Core Inflation	-0.23	-0.25	-0.21	-0.15	-0.10	0.01	0.0
CPI Inflation	-0.11	-0.18	-0.20	-0.18	-0.14	0.00	0.0
Nominal Short-Term Interest Rate	1.00	-0.46	-0.32	-0.21	-0.11	0.01	0.0
Real Short-Term Interest Rate	1.25	-0.25	-0.16	-0.11	-0.06	0.00	0.0
Nominal Exchange Rate (U.S.\$)	0.19	0.18	0.35	0.38	0.35	0.17	0.20
Real Competitiveness Index	0.01	-0.02	0.02	0.03	0.03	0.00	0.0

Table 4. Worldwide Increase in the Nominal Short-Term Interest Rate (continued)
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Aggregate Euro Model							
Real GDP	-0.35	-0.19	-0.03	0.00	0.02	0.02	0.0
Contributions of:							
Consumption	-0.18	-0.07	-0.05	-0.05	-0.03	0.01	0.0
Investment	-0.15	-0.08	0.05	0.04	0.03	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.02	-0.04	-0.02	0.01	0.00	0.00	0.0
Core Inflation	-0.09	-0.13	-0.12	-0.11	-0.09	0.00	0.0
CPI Inflation	-0.04	-0.09	-0.11	-0.11	-0.10	0.00	0.0
Nominal Short-Term Interest Rate	1.00	-0.21	-0.15	-0.11	-0.08	0.00	0.0
Real Short-Term Interest Rate	1.12	-0.08	-0.04	-0.02	0.00	0.00	0.0
Nominal Exchange Rate (U.S.\$)	-0.08	-0.05	-0.04	-0.04	-0.03	-0.01	-0.08
Real Competitiveness Index	-0.02	-0.01	0.01	0.00	0.00	0.00	0.0

E. Euro Area Monetary Policy Impulse

This impulse is a one-year, 1 percentage point increase in the euro area nominal short-term interest rate. Again fiscal tax rates are held fixed at baseline in the first year. The results for the euro area are presented in Table 5.

The results from the euro area shock differ only slightly from those of the worldwide impulse. Because only euro area interest rates increase, in the first year the Euro appreciates by roughly 1 percent and the multiplier increases slightly as net exports decline more. The price effect from that appreciation more than offsets the volume effect coming from stronger world demand (relative to the case of the worldwide increase in interest rates). In the second year, output recovers more quickly as the exchange rate depreciates generating an improvement in the net export position. Again, the second year impact in Italy is a further decline in output as labor income tax rates rise more there than in other euro area countries. The multiplier from the aggregated model is also larger because of the milder deflationary pressures generated by its inflation dynamics.

Table 5. Euro Area Increase in the Nominal Short-Term Interest Rate
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Germany							
Real GDP	-0.22	-0.12	-0.02	-0.05	-0.05	0.02	0.0
Contributions of:							
Consumption	-0.11	-0.09	-0.06	-0.07	-0.06	0.01	0.0
Investment	-0.05	-0.05	0.04	0.02	0.01	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.06	0.02	0.00	0.00	0.00	0.01	0.0
Core Inflation	-0.17	-0.20	-0.18	-0.15	-0.12	0.00	0.0
France							
Real GDP	-0.17	-0.13	-0.03	-0.04	-0.02	0.03	0.0
Contributions of:							
Consumption	-0.09	-0.13	-0.10	-0.09	-0.06	0.03	0.0
Investment	-0.04	-0.04	0.03	0.02	0.02	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.05	0.04	0.03	0.03	0.03	-0.01	0.0
Core Inflation	-0.20	-0.23	-0.21	-0.16	-0.10	0.02	0.0
Italy							
Real GDP	-0.19	-0.25	-0.08	-0.08	-0.03	0.05	0.0
Contributions of:							
Consumption	-0.10	-0.27	-0.21	-0.19	-0.11	0.06	0.0
Investment	-0.06	-0.05	0.06	0.05	0.04	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.04	0.08	0.07	0.06	0.05	-0.01	0.0
Core Inflation	-0.25	-0.25	-0.21	-0.15	-0.09	0.02	0.0
Other Euro Area							
Real GDP	-0.20	-0.08	0.03	0.00	0.00	0.01	0.0
Contributions of:							
Consumption	-0.09	-0.11	-0.07	-0.07	-0.04	0.02	0.0
Investment	-0.05	-0.04	0.06	0.04	0.02	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.07	0.07	0.05	0.04	0.02	-0.01	0.0
Core Inflation	-0.25	-0.24	-0.17	-0.12	-0.08	0.00	0.0
Total Euro Area							
Real GDP	-0.20	-0.14	-0.02	-0.04	-0.02	0.02	0.0
Contributions of:							
Consumption	-0.10	-0.14	-0.09	-0.10	-0.06	0.03	0.0
Investment	-0.05	-0.05	0.05	0.03	0.02	0.00	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.06	0.05	0.03	0.03	0.02	-0.01	0.0
Core Inflation	-0.21	-0.23	-0.19	-0.14	-0.10	0.01	0.0
CPI Inflation	-0.14	-0.12	-0.16	-0.16	-0.13	-0.01	0.0
Nominal Short-Term Interest Rate	1.00	-0.38	-0.28	-0.19	-0.10	0.01	0.0
Real Short-Term Interest Rate	1.23	-0.20	-0.13	-0.10	-0.05	0.00	0.0
Nominal Exchange Rate (U.S.\$)	0.92	-0.03	0.34	0.60	0.78	0.98	0.91
Real Competitiveness Index	0.30	-0.17	-0.10	-0.06	-0.03	0.01	0.0

Table 5. Euro Area Increase in the Nominal Short-Term Interest Rate (continued)
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Aggregate Euro Model							
Real GDP	-0.39	-0.16	-0.04	-0.04	-0.02	0.02	0.0
Contributions of:							
Consumption	-0.17	-0.06	-0.07	-0.07	-0.05	0.01	0.0
Investment	-0.16	-0.09	0.04	0.03	0.03	0.01	0.0
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Net Exports	-0.07	0.00	-0.01	0.00	0.00	0.00	0.0
Core Inflation	-0.12	-0.20	-0.09	-0.10	-0.09	0.00	0.0
CPI Inflation	-0.20	-0.06	-0.08	-0.09	-0.09	-0.01	0.0
Nominal Short-Term Interest Rate	1.00	-0.23	-0.11	-0.10	-0.07	0.00	0.0
Real Short-Term Interest Rate	1.19	-0.14	-0.01	-0.01	0.00	0.00	0.0
Nominal Exchange Rate (U.S.\$)	1.14	0.28	0.38	0.48	0.56	0.72	0.73
Real Competitiveness Index	0.66	-0.01	0.00	0.00	0.00	-0.01	0.0

IV. SUPPLY-SIDE IMPULSES

In this section we consider the impact of two improvements in the supply-side performance of the euro area economies. The first is a 1 percentage point permanent increase in total factor productivity. The second is a 1 percentage point permanent decline in the NAIRU. These shocks are implemented on a euro-wide basis. The results from the aggregate model of the euro area suggest that when these supply side-disturbances are well understood, there is little role for monetary policy in the adjustment process. To examine the implications of uncertainty, the experiments are also conducted with the monetary authority only slowly recognizing the source of the shock to the economy.

A. Permanent Increase in Total Factor Productivity

A summary of the simulation results from this increase in euro area total factor productivity is presented in Table 6. In the first year of the simulation, potential output in each of the euro area countries increases by 1 percent. Although both households and firms are forward looking and completely understand the implications of the shock for human wealth and the marginal product of capital, the existence of liquidity constrained households and adjustment cost in capital constrain the response of aggregate demand and actual output increases by less than the increase in potential output. In the disaggregated model, the opening of an excess supply gap reduces core inflation and monetary policy eases. This decline in the short-term interest rate coupled with the required long-run depreciation in the euro area currency lead to a depreciation of the euro against the U.S. dollar.¹³ Further, with expenditures held at baseline, the increase in government revenue resulting from the increase in real activity improves the ratio of public debt to GDP. Through the endogenous fiscal policy rule, this leads to a reduction in tax rates. The results from the disaggregated model suggest that, even with the easing in monetary and fiscal policy, the response of aggregate demand ranges from 0.64 percent in France to 0.92 percent in Italy with the average for the euro area being 0.76 percent.

¹³ This property of a long-run depreciation of the currency in the face of a positive productivity shock is a well-known property of single-good models such as MULTIMOD that impose a consistent long-run stock-flow equilibrium. With import demand driven by activity (derived using fixed import propensities) and relative prices, the country experiencing the increase in productivity needs to export more because not all the increase in domestic output is consumed domestically. To increase exports (and reduce the import share of domestic absorption), the terms of trade need to adjust and in a single-good model this is achieved through a real depreciation of the domestic currency brought about by a depreciation in the nominal exchange rate. Further, because MULTIMOD assumes that government debt is the only internationally traded financial instrument, the increase in the return on capital in the country experiencing the productivity shock (or expectations of its future path) does not affect the arbitrage condition in the exchange rate. If it existed, this channel could potentially generate a short-run appreciation of the currency as the expected future depreciation would then equalize international returns on a portfolio of bonds and equity.

Table 6. One Percentage Point Increase in Euro Area Total Factor Productivity
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Germany							
Real GDP	0.73	0.98	1.06	1.11	1.15	1.16	1.47
Contributions of:							
Consumption	0.51	0.65	0.72	0.75	0.76	0.77	1.10
Investment	0.07	0.17	0.16	0.16	0.15	0.16	0.22
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.15	0.16	0.18	0.20	0.23	0.24	0.16
Core Inflation	-0.09	-0.08	-0.05	-0.02	0.00	0.01	0.00
France							
Real GDP	0.64	0.88	1.02	1.12	1.19	1.18	1.46
Contributions of:							
Consumption	0.45	0.58	0.69	0.75	0.79	0.81	1.13
Investment	0.04	0.10	0.11	0.12	0.13	0.13	0.20
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.15	0.19	0.23	0.25	0.27	0.24	0.14
Core Inflation	-0.21	-0.21	-0.14	-0.05	0.02	0.04	0.00
Italy							
Real GDP	0.92	1.15	1.17	1.12	1.07	1.13	1.54
Contributions of:							
Consumption	0.78	0.92	0.95	0.88	0.80	0.71	1.23
Investment	0.08	0.19	0.16	0.13	0.12	0.16	0.21
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.05	0.05	0.07	0.11	0.15	0.26	0.11
Core Inflation	-0.02	-0.01	-0.01	-0.03	-0.06	-0.03	0.00
Other Euro Area							
Real GDP	0.78	1.03	1.12	1.15	1.16	1.16	1.48
Contributions of:							
Consumption	0.47	0.61	0.70	0.73	0.74	0.73	1.06
Investment	0.07	0.18	0.16	0.16	0.15	0.15	0.21
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.24	0.25	0.25	0.26	0.27	0.28	0.22
Core Inflation	-0.11	-0.07	-0.01	0.03	0.04	-0.01	0.00
Total Euro Area							
Real GDP	0.76	1.00	1.09	1.12	1.15	1.16	1.48
Contributions of:							
Consumption	0.53	0.67	0.75	0.76	0.77	0.76	1.11
Investment	0.07	0.16	0.15	0.14	0.14	0.15	0.21
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.16	0.17	0.19	0.21	0.24	0.25	0.16
Core Inflation	-0.11	-0.09	-0.05	-0.02	0.01	0.00	0.0
CPI Inflation	0.07	-0.02	-0.04	-0.04	-0.02	0.00	0.0
The Output Gap	-0.26	-0.04	0.03	0.04	0.05	-0.01	0.00
Nominal Short-Term Interest Rate	-0.34	-0.24	-0.15	-0.09	-0.06	-0.05	-0.03
Real Short-Term Interest Rate	-0.24	-0.18	-0.13	-0.09	-0.07	-0.06	-0.03
Nominal Exchange Rate (U.S.\$)	-2.25	-1.92	-1.67	-1.51	-1.41	-1.18	-0.74
Real Competitiveness Index	-0.91	-0.84	-0.79	-0.75	-0.73	-0.66	-0.54

Table 6. One Percentage Point Increase in Euro Area Total Factor Productivity (continued)
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Aggregate Euro Model							
Real GDP	0.76	0.88	0.94	0.98	1.02	1.16	1.47
Contributions of:							
Consumption	0.63	0.66	0.69	0.69	0.70	0.73	1.03
Investment	0.10	0.17	0.17	0.18	0.19	0.22	0.23
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.03	0.05	0.08	0.10	0.13	0.21	0.21
Core Inflation	0.00	0.08	0.06	0.04	0.03	0.00	0.00
CPI Inflation	0.14	0.12	0.10	0.07	0.06	0.01	0.00
The Output Gap	-0.25	-0.15	-0.11	-0.09	-0.07	-0.02	0.00
Nominal Short-Term Interest Rate	0.03	0.12	0.10	0.08	0.06	0.01	-0.01
Real Short-Term Interest Rate	-0.05	0.06	0.05	0.04	0.04	0.01	-0.01
Nominal Exchange Rate (U.S.\$)	-1.09	-1.21	-1.30	-1.37	-1.42	-1.55	-1.22
Real Competitiveness Index	-0.69	-0.74	-0.79	-0.83	-0.86	-1.01	-0.98

In the second year of the simulation, aggregate demand increases sufficiently to almost close the output gap. Beyond that horizon, the euro area economies experience a mild period of excess demand as inflation is re-anchored at the target. Output continues to gradually increase to its long-run equilibrium of roughly 1.5 percent above baseline. This long-run increase in output exceeds the 1 percent increase in productivity because of capital deepening. The increase in the marginal product of capital arising from the increase in productivity induces firms to increase the capital stock until its marginal product is once again equilibrated with its cost.

There are some interesting cross country differences that arise in the short-term response of aggregate demand. In France, the initial response is weaker than the euro area average whereas it is much stronger than the average in Italy. In France, the excess supply gap generates more of a decline in inflation, consequently real interest rates don't fall as much and the initial response of consumption and investment is below average. In Italy, the long-run improvement in government revenue because of the higher productivity level and the reduction in debt service cost from the decline in real interest rates allow for a significantly stronger easing in fiscal policy than average. This leads to the consumption of liquidity constrained households increasing much more than the average. Once again, the larger stock of public debt in Italy results in significantly different short-run adjustment dynamics relative to other euro area countries.

In the aggregate model, fiscal policy eases by roughly the same amount as the disaggregated model, but there is only a very mild easing in monetary policy. This reflects two factors. First, with fewer liquidity constrained households, the immediate response of consumption is stronger resulting in a smaller initial excess supply gap. Second the differences in the inflation process mean that even with a small excess supply gap, core

inflation does not decline.¹⁴ Beyond that, the dynamic adjustment in the aggregate model is quite similar to the Euro Area average from the disaggregated model. The long-run impact on output in the aggregate model is identical. The required long-run real depreciation in the terms of trade, however, is larger reflecting a lower estimated long-run price elasticity of export demand in the rest of the world in the aggregated model.

B. Decline in the NAIRU

In this experiment, the nonaccelerating inflation rate of unemployment (NAIRU) declines by 1 percentage point in all countries in the euro area. Aside from minor scale differences that arise related to the magnitude of the shock's initial impact on potential output, the summary results presented in Table 7 illustrate that the dynamic adjustment in both the aggregate and disaggregated models is qualitatively the same as that under the increase in total factor productivity. The scale differences arise because the decline in the NAIRU of 1 percentage point, in and of itself, increases potential output by roughly 3/4 of 1 percent. The further adjustment of the capital stock to its new long-run level results in a long run impact on output of roughly 1.1 percent.

¹⁴ This reflects the lower sensitivity of inflation to demand conditions and the inclusion of a real-wage catch-up channel in the Phillips curve that allows workers to try to maintain their real consumption wage. Households' real consumption wage initially declines in the shock because of the increase in import prices owing to the depreciation in the nominal exchange rate.

Table 7. One Percentage Point Decline in Euro Area NAIRU
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Germany							
Real GDP	0.54	0.72	0.79	0.82	0.85	0.86	1.08
Contributions of:							
Consumption	0.37	0.48	0.53	0.55	0.56	0.57	0.81
Investment	0.05	0.13	0.12	0.12	0.11	0.12	0.16
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.11	0.12	0.14	0.16	0.17	0.18	0.12
Core Inflation	-0.07	-0.07	-0.04	-0.02	0.00	0.01	0.00
France							
Real GDP	0.47	0.64	0.76	0.84	0.89	0.88	1.09
Contributions of:							
Consumption	0.33	0.43	0.50	0.55	0.58	0.60	0.84
Investment	0.03	0.08	0.08	0.09	0.10	0.09	0.14
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.11	0.15	0.18	0.20	0.21	0.18	0.15
Core Inflation	-0.16	-0.17	-0.11	-0.04	0.02	0.03	0.00
Italy							
Real GDP	0.68	0.85	0.86	0.82	0.78	0.83	1.12
Contributions of:							
Consumption	0.58	0.68	0.70	0.65	0.59	0.52	0.90
Investment	0.06	0.14	0.11	0.10	0.09	0.12	0.15
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.04	0.03	0.05	0.08	0.11	0.19	0.08
Core Inflation	-0.01	0.00	-0.01	-0.02	-0.04	-0.02	0.00
Other Euro Area							
Real GDP	0.58	0.76	0.81	0.83	0.83	0.84	1.08
Contributions of:							
Consumption	0.35	0.45	0.52	0.54	0.54	0.53	0.77
Investment	0.05	0.13	0.12	0.12	0.11	0.11	0.15
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.17	0.17	0.17	0.18	0.18	0.20	0.15
Core Inflation	-0.07	-0.04	0.00	0.02	0.03	-0.01	0.00
Total Euro Area							
Real GDP	0.56	0.74	0.80	0.83	0.84	0.85	1.09
Contributions of:							
Consumption	0.39	0.49	0.55	0.56	0.56	0.56	0.82
Investment	0.05	0.12	0.11	0.11	0.10	0.11	0.15
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.12	0.13	0.14	0.16	0.17	0.19	0.12
Core Inflation	-0.08	-0.07	-0.04	-0.01	0.01	0.00	0.00
CPI Inflation	0.05	-0.01	-0.03	-0.03	-0.02	0.00	0.00
Output Gap	-0.19	-0.03	0.02	0.03	0.04	0.00	0.00
Nominal Short-Term Interest Rate	-0.25	-0.18	-0.11	-0.06	-0.04	-0.04	-0.02
Real Short-Term Interest Rate	-0.18	-0.14	-0.10	-0.07	-0.06	-0.04	-0.02
Nominal Exchange Rate (U.S.\$)	-1.67	-1.42	-1.24	-1.12	-1.04	-0.87	-0.54
Real Competitiveness Index	-0.67	-0.62	-0.58	-0.56	-0.54	-0.49	-0.40

Table 7. One Percentage Point Decline in Euro Area NAIRU (continued)
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Aggregate Euro Model							
Real GDP	0.56	0.64	0.68	0.71	0.73	0.84	1.06
Contributions of:							
Consumption	0.46	0.48	0.50	0.50	0.51	0.53	0.74
Investment	0.08	0.13	0.13	0.13	0.14	0.16	0.17
Government	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Net Exports	0.02	0.04	0.06	0.07	0.09	0.15	0.15
Core Inflation	0.00	0.06	0.04	0.03	0.02	0.00	0.00
CPI Inflation	0.10	0.08	0.07	0.05	0.04	0.01	0.00
Output Gap	-0.18	-0.11	-0.08	-0.06	-0.05	-0.02	0.00
Nominal Short-Term Interest Rate	0.02	0.08	0.07	0.05	0.04	0.01	-0.01
Real Short-Term Interest Rate	-0.04	0.04	0.04	0.03	0.03	0.01	-0.01
Nominal Exchange Rate (U.S.\$)	-0.79	-0.88	-0.94	-0.99	-1.03	-1.12	-0.88
Real Competitiveness Index	-0.50	-0.54	-0.57	-0.60	-0.63	-0.73	-0.69

C. Misperceptions About the Supply-Side Impulses

The simulation responses to the two supply-side impulses presented above assume that the European Central Bank correctly perceives the increase in real activity to be an increase in the Euro Area's supply capacity. For a central bank with an inflation target, an important part of conducting monetary policy is being able to distinguish between accelerations in real activity that will not lead to increased inflationary pressures (supply shocks) and those that may (demand shocks). However, a precise decomposition of output into its demand and supply components, if ever available, is generally only available long after the policymaker must take a policy stance. Consequently, it is important to consider how the dynamic adjustment response of the economy to supply-side innovations might differ if the policymaker learns slowly about the true nature of the shock. This section considers exactly that.

Recall that in these simulations monetary policy for the euro area is set according to Taylor-type monetary policy rule. The adjustment in short-term nominal interest rate, relative to a neutral nominal interest rate, is proportional to deviations in current inflation from target (response coefficient of 1.0) and output from potential output (response coefficient of 0.25). If we assume that the policymaker can clearly observe current inflation, then there are two channels through which uncertainty about the level of an economy's productive capacity can influence the current policy stance: directly through the estimate of the current output gap; and indirectly through the policymaker's estimate of the neutral nominal interest rate.¹⁵ The simulations that follow consider the dynamic adjustment of the

¹⁵ The neutral nominal interest rate embodies a one-year-ahead forecast of inflation. Misperceiving the output gap also causes the policymaker to incorrectly forecast the one-
(continued...)

economy when misperceptions about the true level of potential output are allowed to influence the policy stance through these two channels. The simulations are run such that in the first year of the shock, the policymaker assumes that the acceleration in output is an increase in demand. In the second year, the policymaker believes the supply side to have shifted by roughly half of the true increase. In the third year and beyond, the policymaker correctly perceives the true level of potential output.¹⁶

In Table 8 we present the simulation results from the misperception of the 1 percentage point increase in total factor productivity using the aggregate euro area model. The numbers in parentheses represent the outcome when there is no misperception about the cause of the acceleration in real activity. In the first year the misperception about the level of the output gap and the estimate of the neutral nominal interest rate leads the monetary authority to set the short-term nominal interest rate 30 basis points above the level set when the innovation is well understood. Higher interest rates keep the exchange rate from depreciating as much, and these tighter monetary conditions slow the acceleration in real activity. With more excess supply in the economy, inflation declines more leading to a real interest rate differential that is even higher than the nominal one. In the second year the policymaker starts to become aware that a positive innovation to the supply side has occurred and the relative difference in the setting of the short-term interest is considerably reduced. However, the level of real activity is still below the well-understood case in the second year. Beyond the second year the levels of real activity are essentially identical in the two cases.

The main point to be drawn from this comparison is that the benefits from improvements in the supply-side of the economy may arrive more slowly when the monetary authority cannot quickly identify the source of the acceleration in economic activity. The small differences that arise in the inflation profiles under the two cases would not necessarily send strong warning signals that policy was being set too tightly. This suggests that the interest rate path presented above could be quite a plausible monetary policy reaction. The simulation results presented in Table 9 illustrate that the same qualitative result is obtained if the policymaker misperceives an improvement in supply-side performance resulting from a decline in the NAIRU. Another point worth mentioning is that if the policymaker was also using its estimate of the output gap to generate a forecast of inflation that it used in the policy rule rather than the outcome for inflation that is used in these simulations, the slowing in the arrival of the benefits could be even greater.

year-ahead inflation rate and, consequently, incorrectly forecast the neutral nominal interest rate.

¹⁶ It is worth noting that in these simulations the fiscal authorities are also behaving as if they perfectly understand the nature of the acceleration in output and they cut tax rates according. Simulations with the aggregate euro area model that has both fiscal authorities and the monetary authority learn slowly about the shock suggest that the additional marginal affect of fiscal policy is relatively minor. This result obtains because the additional relative tightness in fiscal policy is largely offset by easier monetary policy. However, this impact could be greater on specific countries, such as Italy, where the relative easing in fiscal policy is larger and aggregate euro area monetary policy would not adjust as strongly to offset it.

Table 8. Misperceived Increase in Total Factor Productivity*
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Aggregate Euro Model							
Real GDP	0.52 (0.76)	0.73 (0.88)	0.91 (0.94)	0.97 (0.98)	1.01 (1.02)	1.17 (1.16)	1.47 (1.47)
Contributions of:							
Consumption	0.49 (0.64)	0.58 (0.66)	0.65 (0.69)	0.67 (0.69)	0.68 (0.70)	0.74 (0.73)	1.03 (1.03)
Investment	0.02 (0.10)	0.10 (0.17)	0.18 (0.17)	0.21 (0.18)	0.21 (0.19)	0.22 (0.22)	0.23 (0.23)
Government	0.00 (0.00)						
Net Exports	0.00 (0.03)	0.04 (0.05)	0.07 (0.08)	0.10 (0.10)	0.12 (0.13)	0.21 (0.21)	0.21 (0.21)
Core Inflation	-0.08 (0.00)	-0.06 (0.08)	-0.03 (0.06)	-0.02 (0.04)	-0.02 (0.03)	0.00 (0.00)	0.0 (0.00)
CPI Inflation	0.03 (0.14)	0.04 (0.12)	0.04 (0.10)	0.01 (0.07)	0.00 (0.06)	0.00 (0.01)	0.0 (0.00)
Output Gap (actual)	-0.48 (-0.25)	-0.29 (-0.15)	-0.13 (-0.11)	-0.08 (-0.09)	-0.06 (-0.07)	-0.01 (-0.02)	0.00 (0.00)
Nominal Short-Term Interest Rate	0.33 (0.03)	0.18 (0.12)	-0.02 (0.10)	0.00 (0.08)	0.01 (0.06)	0.01 (0.01)	-0.01 (-0.01)
Real Short-Term Interest Rate	0.38 (-0.05)	0.21 (0.06)	0.00 (0.05)	0.03 (0.04)	0.03 (0.04)	0.01 (0.01)	-0.01 (-0.01)
Nominal Exchange Rate (U.S.\$)	-0.50 (-1.09)	-0.83 (-1.21)	-1.04 (-1.30)	-1.03 (-1.37)	-1.03 (-1.42)	-1.07 (-1.55)	-0.72 (-1.22)
Real Competitiveness Index	-0.36 (-0.69)	-0.63 (-0.74)	-0.80 (-0.79)	-0.83 (-0.83)	-0.87 (-0.86)	-1.03 (-1.01)	-0.96 (-0.96)

* The numbers in parentheses represent the outcome when the monetary authority correctly perceives that the acceleration in real activity is due to an improvement in the supply potential of the economy.

Table 9. Misperceived Reduction in the NAIRU*
(percent or percentage point deviation from baseline unless stated otherwise)

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 10	Steady State
Aggregate Euro Model							
Real GDP	0.38 (0.56)	0.53 (0.64)	0.66 (0.68)	0.71 (0.71)	0.73 (0.73)	0.85 (0.84)	1.06 (1.06)
Contributions of:							
Consumption	0.36 (0.46)	0.42 (0.48)	0.47 (0.50)	0.48 (0.50)	0.49 (0.51)	0.53 (0.53)	0.74 (0.74)
Investment	0.02 (0.08)	0.08 (0.13)	0.13 (0.13)	0.15 (0.13)	0.15 (0.14)	0.16 (0.16)	0.17 (0.17)
Government	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
Net Exports	0.00 (0.02)	0.03 (0.04)	0.05 (0.06)	0.07 (0.07)	0.09 (0.09)	0.15 (0.15)	0.15 (0.15)
Core Inflation	-0.06 (0.00)	-0.04 (0.06)	-0.02 (0.04)	-0.01 (0.03)	-0.02 (0.02)	0.00 (0.00)	0.00 (0.00)
CPI Inflation	0.02 (0.10)	0.03 (0.08)	0.03 (0.07)	0.01 (0.05)	0.00 (0.04)	0.00 (0.01)	0.00 (0.00)
Output Gap (actual)	-0.35 (-0.18)	-0.21 (-0.11)	-0.09 (-0.08)	-0.06 (-0.06)	-0.05 (-0.05)	-0.01 (-0.02)	0.00 (0.00)
Nominal Short-Term Interest Rate	0.23 (0.02)	0.13 (0.08)	-0.01 (0.07)	0.00 (0.05)	0.01 (0.04)	0.01 (0.01)	-0.01 (-0.01)
Real Short-Term Interest Rate	0.27 (-0.04)	0.15 (0.04)	0.00 (0.04)	0.02 (0.03)	0.02 (0.03)	0.01 (0.01)	-0.01 (-0.01)
Nominal Exchange Rate (U.S.\$)	-0.37 (-0.79)	-0.61 (-0.88)	-0.75 (-0.94)	-0.75 (-0.99)	-0.75 (-1.03)	-0.78 (-1.126)	-0.52 (-0.88)
Real Competitiveness Index	-0.27 (-0.50)	-0.46 (-0.54)	-0.58 (-0.57)	-0.60 (-0.60)	-0.63 (-0.63)	-0.74 (-0.73)	-0.69 (-0.69)

* The numbers in parentheses represent the outcome when the monetary authority correctly perceives that the acceleration in real activity is due to an improvement in the supply potential of the economy.

Although the simulation results from the misperceptions experiments are from the aggregate model, the responses from the disaggregated model to the monetary policy innovation suggests that the impact of this misperception could fall disproportionately across the individual countries in the euro area. The results presented earlier suggest that positive interest rate shocks have a more deleterious impact on Italy than the other large European economies because of Italy's large stock of government debt. Consequently, if policy is set too tightly because policymakers must learn about the true source of the shock, those countries with large stocks of government debt could be the ones most adversely affected.

V. CONCLUSIONS

MULTIMOD's responses to the four shock experiments considered suggest two possible sources of dynamic adjustment differences in euro area countries that policymakers should bear in mind. The first important source of difference is the extent to which households have access to capital markets to smooth consumption by borrowing against future labor income. This will influence the response of the different euro area economies to shocks that affect disposable income. The second important source of difference appears to be the level of public debt. The impact of shocks that affect the level of real interest rates have larger effects on economies with higher levels of public debt. Partly because of this real interest rate effect, countries with high levels of public debt appear to more quickly reap the benefits of improvements to the supply-side of the economy. However, this latter result may depend on policymakers correctly perceiving the change in real activity to be driven by the supply-side of the economy. If policymakers are slow to recognize the source of the innovation, the impact of these shocks in countries with higher levels of public debt may not be as favorable.

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