Macroeconomic Modelling and Policy Implications: an Assessment for Italy using ITEM and QUEST

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Abstract

In this paper we compare the dynamic properties of the Italian Treasury Econometric Model (ITEM) with those of the endogenous growth model developed by DG ECFIN for economic policy evaluation (QUEST III) and calibrated for Italy. We consider an array of shocks often examined in policy simulations and investigate their implications on macro variables. In doing so, we analyse the main transmission channels in the two models and provide a comparative assessment of the magnitude and the persistence of the effects, trying to ascertain whether the responses to shocks are consistent with the predictions of economic theory. We show that, despite substantial differences between the two models, the responses of the key variables are qualitatively similar when we consider competition enhancing policies and labour productivity improvements. On the other hand, we observe quantitative disparities between the two models, mainly due to the forward-looking behaviour and the endogenous growth mechanism incorporated into the QUEST model but not in ITEM. The simulation results show that Quest III is a powerful tool to capture the effects of structural economic reforms, like competition-enhancing policies or innovation-promoting policies. On the other hand, owing to the breakdown of fiscal variables in a large number of components, ITEM is arguably more suitable for the quantitative evaluation of fiscal policy and the study of the impact of reforms on the public sector balance sheet.

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CONTENTS

1 INTRODUCTION

Over the last few decades the field of macroeconomic modelling has witnessed a strong progress in the development of new models, recording deep changes both in methodological and theoretical aspects. One of the most successful implementations of these developments has been reached by the Dynamic New Keynesian (DNK) models that integrate typical New Keynesian elements (such as imperfect competition and frictions in price setting) into a general equilibrium framework (e.g. Galí and Gertler, 2007, Mankiw 2006, Christiano *et al.*, 2005 among others). Indeed, equilibrium conditions for the main aggregate variables are derived from the optimising behaviour of households and firms, and combined with the market clearing condition. In the basic Dynamic Stochastic General Equilibrium (DSGE) model, households are utility maximising forward-looking agents that decide how much to consume and invest, and supply differentiated types of labour allowing them to set wages. Firms are profit maximizing agents that use labour services, rent capital and set prices as monopolistic suppliers of differentiated goods.[1] Both households and firms face a variety of real and nominal frictions limiting their ability to reset prices or wages in the spirit of Calvo (1983) or Rotemberg (1982). In these models fiscal policy is usually restricted to Ricardian setting, while monetary policy is characterized as a feedback rule (e.g., Taylor rule, see Taylor, 1993), in which the policy interest rate is set in response to deviations of inflation from a target and some measure of economic activity (e.g., output gap).

There is no doubt that this approach to macroeconomics has important advantages compared to the previous macroeconomic modelling approaches. The main advantage consists in providing many results of a textbook IS-LM model, but in a fully dynamic, coherent microfounded setting. In this perspective, the economic effects and the transmission mechanisms of policy interventions can be better understood.

In addition, this approach allows to establish a direct relationship between the structural features of the economy and parameters in reduced form, something that was not always possible in large macroeconometric models. In DSGE models, the calibrated (or estimated) parameters represent deep structural parameters and these values are thus independent of the conduct of monetary and fiscal policy. From this point of view, DSGE models are not subject to the Lucas (1976) critique, contrary to the traditional macroeconometric models in which the estimated parameters are not invariant to policy shifts or to expected policy changes. This is an important reason as to why traditional models are not well suited for the analysis of structural reforms or to analyse the effects of different policy interventions.

[1] For a description of the basic DSGE models, see, for example, Walsh (2003) and Galí (2008) and the references therein. For a complete description of the microfoundations see Woodford (2003). See also Smets and Wouters (2003 and 2007).

Moreover, DSGE modelling is a quite flexible technique and owing to significant developments in computational techniques, basic DSGE models may be extended in many dimensions, introducing new frictions, shocks and market imperfections.

Finally, DSGE models also shed new light on the linkages among monetary and fiscal policy, inflation and the business cycle (e.g. Leith and Wren-Lewis, 2000, Galí *et al.* 2007, Schmitt-Grohé and Uribe, 2007, Forni *et al.*, 2009, Annicchiarico *et al*., 2006, 2009, Kirsanova *et al.* 2009), providing a powerful tool for macroeconomic evaluation and policy analysis. Their primary purpose is to assess the macroeconomic implications of different sources of fluctuations and structural changes and appraise the effect of fiscal and monetary policies as well as compare different scenarios of economic reforms. Recently, a relevant body of literature has dealt with DSGE modelling (e.g. Galí, 2008, Galí and Gertler, 2007, Goodfriend, 2007), approaching theoretical issues (like the modelling of nominal rigidities or the microfoundations of shocks) and enriching the channels of propagation of impulses (see Blanchard and Galí, 2007). Furthermore, several contributions have dealt with the estimation of these models (e.g. Smets and Wouters, 2003, 2007), and have employed them for forecasting (see Adolfson *et al.*, 2007a, 2007b).

At the beginning, these developments were relegated to academia, but in recent years DSGE models have been widely employed in the boardrooms of several governments and central banks. A number of central banks, ministries, multilateral and international institutions have already developed their own DSGE models for policy analysis or have planned to do it in the nearest future[2] (e.g. Castillo *et al.*, 2009; Laxton, 2008, Pesenti, 2008).

The US Federal Reserve' DSGE model, for example, is employed to analyse the effects of a full battery of shocks, such as those arising from fiscal and monetary policy (see Erceg *et al.*, 2005, 2006). The Sveriges Risksbank has instead applied its DSGE model to derive different scenarios related to alternative hypotheses for the future movements of some macro variables (see Adolfson *et al.*, 2007a, 2007b).

Despite the capabilities of DSGE models, some economists argued that there is a trade-off between theoretical coherence and the ability of fitting data (e.g. Sims, 2006). For instance, DSGE models are not fully able to account for persistence observed in inflation dynamics, without relying on arbitrary *ad hoc* assumptions and departing from the coherence of microfoundations. From this point of view, large scale econometric models represent a useful benchmark for evaluating DSGE models, since they provide reduced-form characterizations of the data-generating process.

The main aim of this paper is to provide a comparative assessment of the predictions of a macroeconometric model and a DSGE model with a focus on the Italian economy. In particular, we will compare the simulation results from the Italian Treasury Econometric Model (ITEM) with those obtained through the latest version of the European Commission'

[2] The main central Banks have developed DSGE models are: Bank of Canada (ToTEM), Bank of England (BEQM), European Central Bank (NAWM), Norges Bank (NEMO), Sveriges Riksbank (RAMSES) and the US Federal Reserve (SIGMA). Also the IMF has developed its own DSGE model (GEM). The European Commission has developed different versions of its own DSGE model (QUEST III), the one that is used in this paper.

DSGE model, QUEST III, calibrated for Italy (see Cicinelli *et al.*, 2008, 2010; Roeger *et al.*, 2008; D'Auria *et al.,* 2009). To this end we will run some simulations, analysing the response of the main macrovariables to an array of structural reforms and shocks that are often examined in policy simulations. These include labour productivity improvements, a reduction of the price and the wage mark-ups, an increase in public consumption and a shift in the tax structure from tax on labour to tax on consumption. In doing so, we try to emphasize the main transmission channels active in the two models.

For both models our simulation results turn out to be consistent with economic theory and show the beneficial effect on growth and employment of structural reforms, like enhancing competition in the final goods market, in the labour markets or tax reforms. However, our comparative assessment reveals some noticeable differences between the two models as to what pertains the dynamic responses to shocks.

We conclude that QUEST III is a more powerful tool to capture the effects of structural reforms like competition-enhancing policies or changes in the research and development system. QUEST III seems more suitable for analysing structural policies and assessing their macroeconomic impact in the medium and long run (see Roeger *et al.*, 2008, 2009; Varga and in 't Veld, 2009). From a methodological point of view, QUEST III is well suited for the analysis and comparison of alternative scenarios without being subject to the Lucas critique (see Lucas, 1976). On the other hand, ITEM is more flexible and precise to evaluate fiscal policy scenarios and reforms, since its public finance section is extensively developed, both on the expenditures and on the revenues side. In addition, ITEM features a complete modelling of financial assets and liabilities of institutional sectors such as the household sector, the non residents sector and the sector pertaining to public administration (see, Cicinelli *et al.*, 2008, 2010).

The remainder of the paper is organized as follows. Section 2 is devoted to a brief description of the QUEST model and of the DSGE methodology, while Section 3 presents ITEM describing its main mechanisms. Section 4 examines long-horizon simulations with both models to appraise the effects of permanent shocks. Section 5 concludes.

2 THE QUEST MODEL

By incorporating imperfect competition in goods and labour market, nominal and real rigidities and allowing for the existence of a variety of shocks, Dynamic New Keynesian (DNK) models provide a realistic representation of the economic system and of the dynamic responses to disturbances and policy interventions in a fully micro-founded, optimization-based environment.

The new QUEST III model we use in this paper belongs to this class of models and is an extension of the original DSGE model for quantitative policy analysis developed at the Directorate general for Economic and Financial Affairs at the European Commission (see Ratto *et al.*, 2008), augmented with endogenous growth (see Roeger *et al.*, 2008). The latter is modelled consistently with the framework proposed by Jones (1995, 2005) to adapt the

Romer's (1990) model with endogenous development of the R&D sector. In particular, in our simulation exercise we will use the version of the model calibrated for Italy, already employed by the Commission in several multi-country analyses of structural reforms (e.g. D'Auria *et al.* 2009).

The endogenous growth version of QUEST is particularly well-suited to analyse the impact of structural economic reforms enhancing growth in the context of the Lisbon Strategy. By including several nominal and real frictions and by modelling markets as imperfectly competitive, the model can be used to study the effects of competition-enhancing policy. On the other hand, the explicit consideration of an endogenous mechanism of growth allows the study of policies and reforms aimed at increasing the rate of knowledge creation, while the distinction of employment in three skill categories (low, medium, high) allows to analyse the effects of policy measures such as increasing the social benefits for low-skilled workers, changing the skill composition of the labour force, promoting high skilled immigration policies and subsiding employment of the high-skilled workers in the R&D sector.

STRUCTURE AND MAIN EQUATIONS

The QUEST III model is a large-scale DSGE model. It features eight types of agents: households-workers, trade unions, final goods firms, intermediate goods firms, R&D sector, foreign sector, monetary and fiscal authorities.

The economy is populated by two types of households. The first type, the non liquidity constrained households, supply medium and high skilled labour services, trade domestic and foreign assets, accumulate investment goods and physical capital which they rent out to the intermediate goods producers, buy the patents produced in the R&D sector and license them to the intermediate goods sector, make decisions about how much to consume in an intertemporal optimisation context, making use of all the available information and taking into account technological, institutional and budgetary constraints. The other set of households, the liquidity constrained households, are hand-to-mouth consumers who do not have access to financial markets and consume their after-tax disposable income, supplying low-skilled labour services (see Galí *et al.*, 2007).

This differentiation is a technical device to introduce non-Ricardian consumption behaviour in addition to distortionary taxes on labour income, consumption and wealth accumulation. The existence of liquidity constrained households play a key role in shaping the macroeconomic effects of fiscal policy interventions as well as of structural reforms. Their presence into DSGE models is necessary to reproduce empirically relevant Keynesian types of effect of fiscal policy (see e.g. Galí *et al.*, 2007 and Forni *et al.*, 2009).

For each skill group (high, medium and low) it is assumed that households supply differentiated labour services to unions which set wages in monopolistically competitive labour markets. Nominal wage rigidity is given by the existence of adjustment costs for changing wages. Each category of workers represents a constant fraction of the population.

Based on the detailed description of QUEST model by Roeger et al. (2008), the representative non liquidity constrained household i derives utility from an intertemporal utility function of the form:

$$V_0^i = E_0 \sum_{t=0}^{\infty} \beta^t \left\{ U\left(C_t^i, C_{t-1}\right) + \sum_{s}^{\infty} V\left(1 - L_t^{i,s}\right) \right\}, \qquad (1)$$

where E_0 is the conditional expectation operator, β is the discount factor, s denotes the skill level (medium M, high H), C_t^i is the consumption (with C_t being an aggregate of domestic and foreign varieties of final goods), C_{t-1} is the past level of aggregate consumption. Thus, U is the instantaneous utility function allowing for external habit persistence in consumption .$L_t^{i,s}$ is the typical labour service of households i belonging to the skill category s, is a function of consumption allowing for external habitand V is a constant elasticity of substitution CES instantaneous utility function defined over leisure. The typical non liquidity constrained household makes its decisions about consumption, labour supply, investments in financial assets (domestic and foreign assets), investments in physical capital and its renting, the purchase of new patents and their licensing and the degree of capacity utilization in order to maximize (1) subject to a sequence of flow budget constraints, the accumulation equations of physical capital and of the stock of existing patents (the so called intangible capital) and the standard transversality conditions. Households receive wage income, total profits from the final and the intermediate goods sector, transfer from the government and, in case of unemployment, benefits. They pay taxes on consumption and on labour and interest income. In solving their intertemporal problem, consumers face quadratic adjustment costs on investments in physical capital, on capacity utilization and on nominal wage changes (for more details, see Roeger et al., 2008).

From the maximisation we obtain a number of first order conditions. One of the most relevant among them is the Euler's equation which describes the optimal time path of consumption:

$$U_{C^i}\left(C_t^i, C_{t-1}\right) = \beta E_t \frac{1+i_t}{1+\pi_{t+1}} \frac{1+t_t^c}{1+t_{t+1}^c} U_{C^i}\left(C_{t+1}^i, C_t\right), \qquad (2)$$

where U_{C^i} i s the partial derivative of the utility function with respect to C^i, π_{t+1} is inflation, i_t denotes the nominal interest rate, t_t^c is the tax rate on consumption and C_{t-1} is the past level of consumption as a consequence of an external habit assumption. The Euler equation represents one of the key building blocks of the DSGE methodology. It is an equilibrium relationship which establishes that, along the optimal path of consumption, a reallocation at the margin of one unit of consumption from today into the future is still compatible with households' intertemporal optimization as it does not alter the maximized level of utility. From eq. (2) it is clear that forward looking expectations play a fundamental role in shaping current consumption. When making their consumption plans, households take into account expectations about the future standing ready to revise their plans in response to shocks, so that the economy returns to its equilibrium path (the so called "saddle path"). As already

mentioned, for liquidity constrained households optimal consumption is simply equal to the net wage income plus transfers from the public sector and they only supply low-skilled labour services (for details see Roeger *et al.*, 2008).[3]

Trade unions set wages in monopolistically competitive labour markets charging a wage mark-up over the reservation wage. In particular, for each category of skills s, a trade union maximises a joint utility function for each type of labour i. It follows that real wages are higher and employment is lower than in a standard RBC model. The wage set by unions will crucially depend on preferences, on the tax rate on labour, on the level of unemployment subsidies and on the degree of market power of unions, which in turn will depend on the elasticity of substitution between different types of labour services for each skill category of workers.

The final good sector is modelled *à la* Dixit and Stiglitz (1977). Final goods firms produce differentiated goods which are imperfect substitutes to each others. Each firm acts as a monopolistic competitor facing a demand function with price elasticity equal to σ_d, which in turn is equal to the elasticity of substitution among different varieties of the final good. The representative firm j produces output using a production technology characterized by the following inputs: a combination of labour services, $L_{y,t}^{j}$, A different varieties of intermediate goods, x^j and public capital, KG , subject to a fixed cost FC_y and overhead labour FC_L:

$$Y^j = \left[A^{exog}(L_{y,t}^{j} - FC_L)\right]^{\alpha} \left[\sum_{i=1}^{A_t} (x_{i,t}^{j})^{\theta}\right]^{\frac{1-\alpha}{\theta}} KG^{1-\alpha_G} - FC_L, \qquad (3)$$

where A^{exog} denotes labour productivity subject to shocks, $\alpha, \alpha_G \epsilon\ (0,1)$ measure, respectively, the contribution of labour inputs and of public capital to production, and ϑ is the elasticity of substitution between different varieties of the intermediate goods x. The labour input $L_{y,t}^{j}$ is defined by the following CES aggregator[4]:

$$L_{y,t}^{j} = \left\{ s_L^{\frac{1}{\sigma_L}} (ef_L\ L_t^L)^{\frac{\sigma_L - 1}{\sigma_L}} + s_M^{\frac{1}{\sigma_L}} (ef_M\ L_t^M)^{\frac{\sigma_L - 1}{\sigma_L}} + s_{H,Y}^{\frac{1}{\sigma_L}} (ef_H\ L_t^{HY})^{\frac{\sigma_L - 1}{\sigma_L}} \right\}^{\frac{\sigma_L - 1}{\sigma_L}}, \qquad (4)$$

where s_L s_M and s_{HY} denote the population shares of labour force for each category of skills, low, medium and high, respectively, while ef_L , ef_M and ef_H denote the corresponding efficiency level. Finally, the parameter σ_L is the elasticity of substitution between the three categories of skills (for further details see Roeger *et al.*, 2008).. The above production function incorporates the product variety framework proposed by Dixit and Stiglitz (1977)

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[3] For a version of QUEST extended to include also credit constraint households, see Roeger and in 't Veld (2009).

[4] As it is well known, constant elasticity of substitution (CES) is a feature of some production functions and utility functions. More precisely, it refers to a particular type of aggregator function which combines two or more types of consumption, or two or more types of production inputs into an aggregate quantity. This aggregator function exhibits constant elasticity of substitution.

applied to the literature of R&D diffusion (Grossman and Helpman, 1991; Aghion and Howitt, 1998).

Each firm of the final good sector sets the optimal price and makes choices about labour inputs and intermediate goods in order in order to maximise profits. Firms are subject to adjustment costs on price resetting (nominal frictions). On the other hand, hiring or firing of workers involves a convex adjustment cost (real frictions).

As explained in detail by Roeger et al. (2008), the intermediate goods sector is populated by monopolistically competitive firms facing a linear technology which allows to transform one unit of physical capital k_t, rented from households at a rental rate i_t^K, into one unit of intermediate good. In order to enter the market, intermediate goods producers must license a design from the households and make an initial administrative payment equal to FC_A.

The typical intermediate goods producer i (for $i = 1, \dots, A$) solves the following profit-maximisation problem:

$$PR_{i,t}^x = max_x\{p_{i,t}^x x_{i,t} - i_t^K P_t^C k_{i,t} - i^A P^A - FC_A\}, \tag{5}$$

where $x_{i,t} = k_{i,t}$, $p_{i,t}^x$ is the price of the intermediate good i, P_t^C is the price of capital and the term $i^A P^A$ denotes the licensing fee. Entry of new firms into the intermediate goods sector will take place as long as the expected discounted value of future profits is equal to the fixed entry cost FC_A plus the net value of patents P^A.

The innovation mechanism is represented by the creation of new ideas (patents) able to produce new variety of intermediate goods. In the R&D sector the production of new designs depends on the number of skilled workers employed and on the existing stock of ideas. In particular, we have the following knowledge production function:

$$\Delta A_t = v A_{t-1}^{*\omega} A_{t-1}^{\varphi} (L_t^{RD})^{\lambda}, \tag{6}$$

where A and A^* denote the domestic and the international aggregate stocks of knowledge, L_t^{RD} the high-skilled labour services employed in the R&D sector and v measures the total productivity of the R&D sector. Parameters ω and φ measure the international and the domestic spillover effects of knowledge and are assumed to be positive but less than one (the so called "standing on shoulders" effect of knowledge accumulation indicating that the productivity of researchers increases with the stock of ideas that have already been discovered). Parameter $\lambda\lambda$ is supposed to be such that $0 < \lambda < 1$, capturing the possibility of an externality associated with duplication of research activity (the so called "stepping on toes" effect, i.e. some ideas created by some researchers may not be new to the economy). Real frictions are also introduced in this sector in the form of quadratic adjustment costs on labour inputs.

Given (6) it can be easily shown that the rate of technological progress on balanced growth path (that is when all relevant economic variables grow at the same constant rate) is

$$g_A = \frac{\omega g_{A^*} + \delta n}{1 - \varphi}, \tag{7}$$

where g_{A^*} is the exogenous growth rate of the international stock of knowledge and n is the growth rate of skilled workers which is ultimately equal to the rate of population growth, since it assumed that the composition of the workforce stays unchanged over time. From (7) it is evident that long-run growth is not affected neither by saving decisions nor by the number of workers employed in the R&D[5]. In such circumstances, conventional policies, such as subsidies to the R&D sector, are not able to affect long-run growth, but they influence growth along the transition path, thus affecting the levels of income, consumption and welfare.

The foreign sector is exogenous (small open economy hypothesis). In particular it is assumed that economies trade both final and intermediate goods, given constant elasticities of substitution between bundles of domestic and foreign goods. In both areas exporters act as monopolistic competitors in their respective exports market and charge a mark-up over their respective domestic prices.

The conduct of monetary policy is described by a Taylor rule (see Taylor, 1993, Clarida *et al.*, 1999), allowing for a certain degree of inertia of the interest rate response to inflation and output gap:

$$i_t = \tau_{lag} i_{t-1} + \left(1 - \tau_{lag}\right)\left[r^{eq} + \pi_t^T + t_\pi(\pi_t - \pi_t^T) + \tau_{y,1} ygap_{t-1} + t_{y,2}(ygap_t - ygap_{t-1})\right], \tag{8}$$

where i_t denotes the nominal interest rate, r^{eq} is the long-run real interest rate, π_t the actual inflation, π_t^T the inflation target and $ygap_t$ the output gap defined as deviation of capital and labour utilization from their long-run trends, see Roeger *et al.*, (2008).

Finally, the behaviour of the fiscal authority is described by a set of equations according to which both expenditures and receipts are responsive to economic fluctuations. Government consumption, C^G and investments, I^G depend on the output gap and transfers, TR, act as automatic stabilisers. The government collects taxes on labour income, on consumption and on tangible and intangible capital. The dynamic budget constraint, governing the time path of public debt B , is standard:

$$B_t = (1 + i_t)B_{t-1} + P_t^C C_t^G + P_t^C I_t^G + TR_t + R_t^G - T_t^{L,s}, \tag{9}$$

where R_t^G denotes revenues from distortionary taxation on labour income, consumption and capital and $T_t^{L,s}$ lump-sum taxation. By assumption $T_t^{L,s}$ evolves as a function of the debt-

[5] It should be noted that in Jones framework technological change is fully endogenous, so that the growth mechanism can be labeled as "endogenous". However, since long-run growth only depends on exogenous factors, models such as this one are sometimes referred to as "semi-endogenous" growth models.

GDP ratio in order to ensure fiscal solvency and rule out any explosive behaviour of public debt (for more details see Roeger *et al.*, 2008).

3 THE ITEM MODEL

ITEM is a medium-size linear macroeconometric model (36 behavioral equations and 211 identities) allowing to track and explain the time path of a considerable number of macroeconomic variables.

The approach underlying ITEM in not that of a DSGE model like QUEST III. In fact, the relationships between variables are not obtained within an intertemporal optimization framework nor with forward-looking expectations. Differently from a DSGE approach, which achieves structural identification through a fully theory-dependent framework, ITEM relies on statistical identification that is obtained through the appropriate selection of a well-defined model as reduced form (see Spanos, 1990 and Favero, 2001).

Whilst the DSGE approach is rooted on appropriate microfoundations, on the other hand it shows some limitations compared to a data-driven dynamic model like ITEM, which is able, for example, to evaluate a variety of fiscal policy issues in great detail, as a result of a full breakdown of fiscal variables in a large number of components. At the same time, in ITEM we explicitly consider the borrowing and the lending activities of the institutional sectors, enriching the entire propagation mechanism of each policy reform and making the model more informative (see Cicinelli *et al.*, 2008).

STRUCTURE AND MAIN EQUATIONS

ITEM has a quarterly frequency and includes 371 variables. The economy is articulated in four sectors: households, firms, government and the foreign sector.

A key feature of ITEM is that real GDP is determined on the supply side, contrary to the standard macroeconometric modeling approach according to which models are “closed” on the demand side. ITEM is characterized by a finer disaggregation of value added through the following accounting identity:

$$GDP = VAM + VANM + TXNT, \tag{10}$$

where VAM is the market value added, $VANM$ is non-market value added and $TXNT$ denotes net indirect taxes. Then, the model is closed on the supply side through inventory changes (INVCH) obtained as a buffer. That is, from the fundamental national accounting identity it is inventory changes to be obtained as a residual:

$$INVCH = GDP - (C + I + G + X - M), \tag{11}$$

where C is private consumption, I investment, G public expenditure and X and M, respectively, export and import. All variables in the right-hand side are modeled through a behavioral equation. In particular, output of market sector (value added of the private sector, VAM) is described by a standard production function with constant returns to scale:

$$VAM = TFP \times L^{\alpha} \times K^{1-\alpha}, \tag{12}$$

where L and K are labour and capital and Total Factor Productivity (TFP) captures changes in technology and in organization of production activity (Solow, 1957). In this setup the TFP works as a bridge from the short to the long-run and is modeled in such a way that for determining output the demand side prevails in the short run, while the supply side does so in the long run. In particular, measured TFP can be decomposed into two components: an exogenous structural component capturing the technical and organizational innovation (TFP_TP) and a component, reflecting the cyclical variation in factor utilization (IFU). The latter component stems from the mismeasurement in the available statistics of inputs that fall short of measuring the variable degree of intensity of factor utilization along the business cycle. This causes measured productivity to be procyclical. Therefore, measured TFP changes can be expressed as

$$Dlog(TFP) = dlog(TFP_{TP}) - dlog(IFU), \tag{13}$$

and

$$VAM = TFP\_P \times (IFU \times L)^{\alpha} \times (IFU \times K)^{1-\alpha}, \tag{14}$$

The second component, IFU, is modeled through the following statistical equation:

$$DIFU = \alpha + \beta * DDEM + \mu * INVCH(-1), \tag{15}$$

where D denotes the difference operator, hence $DIFU = IFU - IFU(-1)$, DEM represents aggregate demand and $INVCH(-1)$ is the ratio between lagged aggregate supply and lagged aggregate demand.

Prices and wages equations are modeled as in standard econometric models, with prices depending on unit labour costs and a measurement of capacity utilization, and wages depending on labour productivity, the unemployment rate and the tax wedge on labour. Contrary to the DSGE modeling approach, in ITEM real and nominal frictions are not derived from a microfounded theoretical set-up, but are the results of the dynamic specification of equations allowing to replicate the main empirical effects of those frictions.

However, the long-run demand for labour and capital services is modeled consistently with the prediction of firms' maximisation problem (see Cicinelli *et al.* 2008).

The demand side is formulated in a standard fashion. In the long run, private consumption (C) depends upon real labour disposable income (YLD), real household net financial assets ($HNFA$) as well as the real interest rate on short-term borrowing (R):

$$C = \alpha \times YLD + (1 - \alpha) \times HNFA - \gamma \times R, \tag{16}$$

Household net financial assets (HNFA) accumulation is characterized by the following equations:

$$\begin{aligned} HNFA &= HFA - HFL, \\ HFA &= (1 + app) \times HFA(-1) + ACC, \\ HFL &= \alpha - \beta \times SGDP, \end{aligned} \tag{17}$$

where app, the rate of appreciation of financial assets (HFA), is modeled as a function of the US stock prices (the Dow Jones), the structural components of TFP growth and a measure of foreign inflation.

Over time the value of financial assets (HFA) is adjusted by means of both its appreciation (or depreciation) and the flows of households' savings (ACC). By contrast, household financial liabilities (HFL) move in accordance with the structural components of real GDP ($SGDP$).

The foreign sector is represented by real export (X) and import (M) equations. The long-run part of the equation for real export (X) is:

$$X = \alpha \times WD + \beta \times REER, \tag{18}$$

where WD denotes world demand (exogenous in the model) and $REER$ the real exchange rate.

Real imports (M) depend on the absorption (AB) and the relative price of non-oil imports (PMP):

$$M = AB + \delta \times (PMP), \tag{19}$$

The difference between exports and imports, representing the trade balance, contributes to explain the amount of financial liabilities held by non residents ($NRFL$), whose equation is:

$$NRFL = (1 + rev) \times NFRL(-1) + CA, \tag{20}$$

where rev is the degree of appreciation of $NFRL$ and *CA* is the current account balance.

The properties and main characteristics of ITEM have been documented in previous contributions (see Cicinelli *et al.* 2008, 2010 and Favero *et al.*, 2000). The short-run level of

real output is determined by demand conditions, while in the long run output depends on developments on the supply side. In ITEM the shocks generating permanent effects on output are associated with a) shifts affecting the tax wedge on labour and the user cost of capital, b) shifts to labour supply and c) variation in the (exogenous) structural component of TFP. On the contrary, changes in the demand conditions only give rise to transitory effects and the real GDP long-term level basically stays unchanged.
In the section below we focus on results from simulating different policy interventions with ITEM and QUEST.

4 SIMULATIONS

Our comparative analysis is based on the results of some different scenarios of policy reforms such as product and labour market reforms, tax shift and changes in tax structure and policy reforms that affect public expenditure. We also analyse the implications of a permanent increase in labour productivity.
For each reform scenario we will evaluate the simulation results of the two models under consideration (QUEST III and ITEM) trying to compare the main transmission channels and identify the key sources of differences.

More specifically, we will consider the following scenarios:

1. TFP: Exogenous improvement of labour productivity
2. FINMARKUP: Reduction of price mark-up
3. WMKP: Reduction of wage mark-up
4. PC: An increase in public consumption
5. TAXSHIFT: A tax shift from labour to consumption

Figures 1-5 provide a graphical comparison of the main aggregate variables responses (GDP, real private consumption, fixed Investment, real wages, term of trade, employment) under the 5 scenarios. For each variable we plot percentage deviations from the initial steady state for a 40-quarter time horizon.
In QUEST we use the parameters' calibration for Italy devised by D'Auria *et al.* (2009). The ITEM estimations are those of Cicinelli *et al.* (2008).

4.1 AN EXOGENOUS IMPROVEMENT OF LABOUR PRODUCTIVITY

In this scenario, an exogenous 1% productivity improvement has been implemented. This shock is obtained in QUEST III by varying the exogenous factor A^{exog} in the production

function of final output (see equation 3) and it gives rise to permanent positive effects on output, consumption and investment.

In ITEM, the same shock is imparted to the structural component of TFP. Figure 1 presents the dynamic response of some variables to the shock. The effect on output is amplified in QUEST with respect to ITEM because of the endogenous R&D response to a productive shock (see equation 3). In QUEST, the channel through which a shock transmits to output is the intermediate sector: the entry of new firms in this sector induces a higher demand of intermediate output and, as a consequence, a higher supply of patents.

Consumption and investment dynamics depend on the balance between substitution and income effects. In fact, on the one hand consumers are willing to reduce saving and investment because more output can now be obtained with the same level of capital; on the other hand, the higher return of capital may induce consumers to save more. Eventually, the deterioration in the terms of trade, triggered by the increase in the TFP, negatively affects consumption and employment.

In ITEM the transmission mechanism is very different and can be explained by recalling the short- and long-run properties of the model. In the short run, the productivity increase gives rise to a reduction of unit labour cost, which, in turn, determines a price decrease. This latter effect is also driven by a lower degree of capacity utilization, approximated in the model by the wedge between measured (and procyclical) TFP and its structural component reflecting innovation. The reduction of prices fosters competitiveness of domestic products in the international markets, inducing an increase in exports. Higher real wages drive up disposable income. Turning to the long-run response of the economy, the percentage increase in real wages matches the increase of both structural TFP and labour productivity; real GDP is 0.80 percentage points above its base level, while employment stays unchanged and the capital stock stabilises at 0.66 percentage points above its initial level.

From this analysis we can draw two main policy implications. First, policy actions addressed to an R&D improvement will produce a larger long-run effect on output, the more able an economy is to turn productivity into endogenous innovative activities. By contrast, in an economy similar to that described in ITEM, R&D spillovers will fade away in the long run. In both cases, the effect on employment of those policies will be negligible and slightly negative in QUEST. Second, we observe a striking difference in terms of quantitative impact on consumption and real wage and, consequently, on households' welfare. In particular, in QUEST the long-run effect on consumption (fostered by the wage increase) is twice as large as in ITEM. In the QUEST case, in fact, the effect on consumption is also amplified by the presence of liquidity constrained households.

We conclude that the effect on welfare of productivity-enhancing policies turns out to be considerably weak if the economy under consideration is not able to use the endogenous "push" driven by the R&D sector.

4.2 A REDUCTION OF THE PRICE MARK-UP

In this scenario we reduce the final goods mark-up by 1%. Such a shock reflects policies enhancing competition among firms, because it reduces the rents related to the existence of non-competitive markets.

In QUEST, this shock directly affects the demand of labour for each kind of skill (low, medium and high). In ITEM, the shock is imparted to the value added deflator of the market sector in such a way that yields an ex-ante 1% permanent decrease of prices.

In QUEST, a higher degree of competition in final goods sector transmits its effects on the intermediate sector and, consequently, on the R&D sector.

In the long run, we observe a higher level of output, consumption, capital and wages with respect to the baseline scenario, combined with a deterioration of the terms of trade (see Figure 2).

In ITEM, the product price reduction fosters competitiveness increasing exports. Moreover, prices go down by more than nominal wages and the resulting rise of real wages drives up disposable income, bringing about a permanent decline of the equilibrium unemployment rate. The associated increase of employment is such that, in the long run, employment levels are about half percentage point above their base level. In the long run real GDP is also higher than the base level (by 0.60 percentage points).

Also in this second scenario we observe that the dynamic response of the main macro aggregates differ considerably across the two models. In QUEST, the long-run effect on output and wages is driven by endogenous growth. From Table 1 we note that the increase of ideas/patents, representing the endogenous growth's mechanism of QUEST, explains half of output increase. Furthermore, without this endogenous channel output growth in QUEST would be quantitatively similar to that of ITEM.

The expansionary effect on consumption, induced by the enhanced competition between firms, is stronger in QUEST than in ITEM; this is explained by the different framework for consumption decisions in the two models (forward-looking consumers in QUEST), but also by the presence of liquidity constrained consumers (absent in ITEM). As a matter of fact, because liquidity constrained households may only consume their current income, they benefit only partially from the price decrease, and this reduces the size of consumption increase.

Of a particular interest is the long-run effect on employment in the two models. We observe that the enhanced competition scenario have a permanent positive impact on employment in ITEM and a null impact in QUEST. The different effect hinges on the way in which the two models characterize the labour market. In QUEST, unions, by imposing real wages, make them exceed marginal productivity inducing a reduction in the employment level. In ITEM, this mechanism is absent and wages are set at their marginal productivity, generating a permanent effect on employment.

We can then conclude that the effectiveness of policies aimed at promoting competition in the product market crucially depends on the degree of competition in the labour market.

4.3 A REDUCTION OF THE WAGE MARK-UP

This shock seeks to simulate a reduction in the monopoly power of workers and an increase in substitutability between different types of labour services. Figure 3 illustrates the response of the economy to a permanent one percent reduction of the wage mark-up in the two models.

In QUEST the reduction of the wage mark-up affects the labour market through a reduction of real wages and an increase of employment.In ITEM, this shock is designed as a reduction of nominal wages that brings about an ex-ante one per cent increase of employment.

In QUEST, in the short run, both the real wage reduction and the terms of trade deterioration lower consumptions. In the long run, this effect is offset by a positive variation of consumption of the non liquidity constrained households due to a higher expected permanent income.

In ITEM, in the short run, there is a price decline that contributes positively to competitiveness, but also a real wage decline, implying an initial consumption reduction. Within the price and wage equations block, the downward shift of wages yields a permanent reduction of the equilibrium unemployment rate. Indeed, in the long run, both employment and real GDP are 1% above their initial level. We also observe a permanent increase of consumption and investment.

From a qualitative point of view, the results of this simulation resemble those from simulating the final good markup reduction; the main difference lies in the real wages and employment reaction.

In QUEST, the negative response of wages is negligible, whereas employment increases by more, albeit still much less than in ITEM. The reduction of wages should drive down consumption of liquidity constrained household, but the expected increase of permanent income of non liquidity constrained households with forward-looking behaviour, offsets the effect on liquidity constrained households.

These results provide some more insights for the ITEM-QUEST comparison. In particular, since in QUEST unions set the optimal wage level, a reduction in the wage mark-up will automatically reduce the wage claims and thereby the unions power. As a result, firms will find it convenient to substitute capital with labour. In ITEM, conversely, the optimal wage level is set by firms and this will make the effect on employment more extensive than in QUEST.

4.4 AN INCREASE IN PUBLIC CONSUMPTION

In this scenario we consider a permanent increase in government consumption equal to 1% of GDP for each year. The results are quite similar in ITEM and QUEST showing a slowdown of private consumption and a weak increase of investment and employment.

As elucidated above, because in ITEM the short-run level of real output is determined by demand conditions, while in the long-run output depends on supply side conditions, an increase in public spending will produce a different effect on output in the short and in the long-run.

In fact, from Figure 4 we note that government spending induces an immediate expansion of output in ITEM as well as in QUEST. In the former the government spending multiplier does not exceed unity reflecting a weak rise of consumption and household net wealth. The sharp fall of aggregate consumption and investment in the medium long-run period reflects the crowding out effect connected with the decline of household financial wealth and higher tax burden connected to higher government spending.

In QUEST the effects are quite different in the short run, but results are similar in the long run.

Output displays a permanent increase and private consumption a permanent fall, reflecting a rise of labour supply due to the the negative wealth effect. The households anticipate future increase in taxes (Ricardian equivalence) and then reduce their consumption because saving more is now the optimal choice.

The crowding out effect on private consumption in response to an increase of public consumption is a standard feature of many DSGE models (i.e. Coenen and Straub, 2005) and its size depends on the fraction of liquidity constrained consumers (Galí *et al.*, 2007) and on the calibrated value of labour adjustment cost parameters.[6] In fact, the inclusion of non-Ricardian agents and adjustment cost parameters in the labour market provide an effective channel for increasing the reliability of DSGE models to account for responses which are similar to those obtained in existing macroeconometric models and consistent with the empirical evidence (Blanchard and Perotti, 2002).

4.5 A TAX SHIFT FROM LABOUR TO CONSUMPTION

In this scenario we consider a tax shift from labour to consumption. In QUEST this shock is implemented by reducing labour taxes for each kind of workers and increasing consumption taxes for the two categories of households by 1%.

In ITEM the same effect is implemented in an indirect way. The social security contributions rate paid by the employers is reduced so as to obtain an ex-ante decrease of tax revenues equal to 1% of nominal GDP of the baselines simulation. At the same time, an increase of the consumption tax rate is introduced in order to give rise to an ex-ante increase of fiscal revenues equal to 1% of nominal GDP of the baseline simulation.

[6] The consumption response to a positive government spending becomes positive if these two parameters tend to zero (see Ratto *et al.,* 2009).

The simulations results of the two models, reported in Figure 5, look very similar for some key variables showing a positive effect on GDP, consumption and employment, but quantitative differences remain. In this case, endogenous growth plays an important role in explaining the GDP variation, but the major contribution is given by employment (in QUEST as well as in ITEM, see Table 1).

In QUEST the dynamic adjustment mechanism is complex because of the mixed impact of the tax reform on households' budgetary positions.

We observe a positive (direct) effect related to the rise of labour supply with a consequent slowdown of wages and increase of employment. The increase in employment is followed by an increase in investment until the optimal capital-labour ratio is re-established.

The negative (indirect) effect is, instead, due to consumption and wages behavior. The higher tax on consumption should negatively affect consumption; however the presence of non-Ricardian households coupled with the 'consumption smoothing' feature associated to the behavior of Ricardian households outweighs the negative effect induced by the shifting in the burden of taxation. On the other hand, the real wages decline because the increased supply of labour negatively affects the household income.

In ITEM there is a permanent reduction of production costs that drives down producer prices. Hence, real wages go up. By contrast, consumer prices raise on impact, because of the higher tax rates on consumption. Notwithstanding the rise of real wage, we observe a permanent reduction of unemployment in the medium and in the long run. This expansionary effect on employment of the tax shift is due to the decline of the tax wedge on labour. Indeed, in the calculation of the tax wedge on labour a change in the consumption tax has a lower importance than an equal change of the labour tax and this implies that the tax shift designed in this simulation exercise implies a lower tax wedge on labour. In the long run, we experience a rise of GDP that is 0.38 percentage point above its base level. Employment and the capital stock are also above their base levels by roughly the same percentage amount.

In this simulation there are not salient differences which are attributable to specific aspects of our framework, except the quantitative divergences driven by endogenous growth in QUEST. A note of caution associated with this exercise is that ITEM is not a suitable framework for analyzing redistributive policies. The reason is that heterogeneity across agents is not explicitly modeled. Since the structure of labour tax rates is progressive and the structure of consumption tax rates is not, then a tax shift such as those devised here have redistributive effects that, admittedly, are not fully captured by the ITEM model.

5. CONCLUSIONS

In this paper we provide a comparative assessment of the macroeconomic effects of policy reforms using QUEST III, the DSGE model developed by DG ECFIN for policy

evaluation, and ITEM, the large scale econometric model used for policy analysis at the Italian Ministry of Economy and Finance.

Our comparisons involve examining the dynamic responses of macro aggregates to some shocks and structural reforms often analysed in policy work.

The comparison shows that the short-run responses of QUEST are qualitatively similar to those of ITEM for some key macroeconomic variables, including output, consumption, investment and employment. On the other hand, the simulation results also show some quantitative differences in policy responses, highlighting some areas of the models where divergences in the response size have relevant consequences for policy design, although in some cicumstances they may be source of uncertainty around the best policy to adopt.

Arguably, a relevant portion of the simulation differences across the two models is associated to the forward looking agents' behaviour and the endogenous growth mechanism characterizing QUEST.

From this comparison we can draw the following conclusions.

First, we note the in QUEST the major contribution to GDP growth is driven by the R&D sector. If we shut down this channel of GDP expansion, we will almost obtain the same results as in ITEM (in terms of GDP growth). Then we can conclude that in spite of the great methodological differences , the two models exhibit quite similar patterns in the long run.

Second, we observe a different use of input factors (capital and labour) across the two models. It depends on the differences in modelling the labour market and the capital accumulation process. As emphasized above, in QUEST trade unions set wages in monopolistically competitive labour markets, while in ITEM firms set wages in a competitive environment. As a consequence, QUEST is more reliable than ITEM to assess structural labour market reforms in contexts where trade union power is policy relevant.

The third point concerns the QUEST assumption of rational expectations that has important implications for agents' decisions that are largely influenced by expected future developments.

REFERENCES

Adolfson, M., Andersson, M., Lindé, J., Villani, M., & Vredin, A. (2007a). Modern Forecasting Models in Action: Improving Macroeconomic Analyses at Central Banks. *International Journal of Central Banking,* 3(4), 111-144.

Adolfson, M., Laséen, S., Lindé, J., & Villani, M. (2007b). RAMSES – A New General Equilibrium Model for Monetary Policy Analysis. *Economics Review 2/2007, Sveriges Riksbank.*

Aghion, P. & Howitt, P., (1998). Capital Accumulation and Innovation as Complementary Factors in Long-Run Growth. *Journal of Economic Growth*, 3(2), 111-30.

Annichiarico, B., Marini, G., & Piergallini, A. (2008). Monetary Policy and Fiscal Rules. *The B.E. Journal of Macroeconomics (Contributions)*, 8(1), 4.

Annichiarico, B., Giammarioli, N., & Piergallini, A. (2006). Fiscal Policy in a Monetary Economy with Capital and Finite Lifetime. ECB Working Paper no. 661.

Blanchard, O. J., & Galí, J. (2007). Real Wage Rigidities and the New Keynesian Model. *Journal of Money, Credit, and Banking*, 39(s1), 35-65.

Blanchard, O. J., & Perotti, R. (2002). An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output. *Quarterly Journal of Economics* 117 (4), 1329–68.

Calvo, G. A. (1983). Staggered Prices in a Utility Maximizing Framework. *Journal of Monetary Economics*, 12(3), 383-398.

Castillo, P., Montoro, C., & Tuesta, V. (2009). A Dynamic Stochastic General Equilibrium Model with Dollarization for the Peruvian Economy. Working Paper no. 2009-003, Banco Central de Reserva del Perú.

Christiano, L. J., Eichenbaum, M., & Evans, C.L. (2005). Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy. *Journal of Political Economy*, 113(1), 1-45.

Cicinelli, C., Cossio, A., Nucci, F., Ricchi, O., & Tegami, C. (2008), The Italian Treasury Econometric Model (ITEM). Government of the Italian Republic (Italy), Ministry of Economy and Finance, Department of the Treasury, Working Paper no. 1.

Cicinelli, C., Cossio, A., Nucci, F., Ricchi, O., & Tegami, C. (2010), The Italian Treasury Econometric Model (ITEM). *Economic Modelling, 27(1),* 125-133.

Clarida, R. H., Galí, J., & Gertler M., (1999). The Science of Monetary Policy: A New Keynesian Perspective. *Journal of Economic Literature*, 37(4), 1661-1707.

Coenen, G., & Straub, R. (2005). Does Government Spending Crowd in Private Consumption? Theory and Empirical Evidence for the Euro Area," ECB Working Paper no. 513.

D'Auria, F., Pagano, A., Ratto, M., & Varga,J. (2009). A Comparison of Structural Reform Scenarios across the EU Member States: Simulation-Based Analysis Using the QUEST Model with Endogenous Growth. European Economy – Economic Paper no. 392.

Dixit, A. K., & Stiglitz, J.E. (1977). Monopolistic Competition and Optimum Product Diversity. *American Economic Review*, 67(3), 297-308.

Erceg, C. J., Guerrieri, L., & Gust, C. (2005). Expansionary fiscal shocks and the trade deficit. International Finance Discussion Papers no. 825, Board of Governors of the Federal Reserve System (U.S.).

Erceg, C. J., Guerrieri, L. & Gust, C. (2006). SIGMA: A New Open Economy Model for Policy Analysis. *International Journal of Central Banking*, 2(1).

Favero, C.A. (2001). *Applied Macroeconometrics.* Oxford: Oxford University Press.

Favero, C.A., Fiorito, R., Nucci, F., Padrini, F. & Ricchi, O. (2000). “The Italian Treasury Econometric Model (ITEM): an Overview”, Ministry of Treasury, Rome, mimeograph.

Forni, L. , Monteforte, L. & Sessa, L. (2009). The General Equilibrium Effects of Fiscal Policy: Estimates for the Euro Area. *Journal of Public Economics*, 93(3-4), 559-585.

Galí, J. (2008). *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework*. Princeton and Oxford: Princeton University Press.

Galí, J. & Gertler M. (2007). Macroeconomic Modeling for Monetary Policy Evaluation. *Journal of Economics Perspectives*, 21(4), 25-46.

Galí, J., López-Salido, J. D., & Vallés, J. (2007). Understanding the Effects of Government Spending on Consumption. *Journal of the European Economic Association*, 5(1), 227-270.

Goodfriend, M. (2007). How the World Achieved Consensus on Monetary Policy. *Journal of Economics Perspectives*, 21(4), 47-68.

Grossman, G. M. & Helpman, E. (1991). Trade, Knowledge Spillovers, and Growth. *European Economic Review*, 35(2-3), 517-526.

Jones, C. I. (1995). R&D-Based Models of Economic Growth. *Journal of Political Economy*, 103(4), 759-784.

Jones, C. I. (2005). Growth and Ideas. In P. Aghion & S. Durlauf (Eds.), *Handbook of Economic Growth* (Vol. 1, pp. 1063-1111). Elsevier – North Holland.

Kirsanova, T., Leith, C. & Wren-Lewis, S. (2009). Monetary and Fiscal Policy Interaction: The Current Consensus Assignment in the Light of Recent Developments. *Economic Journal*, 119(541), F482-F496.

Laxton, D. (2008). Getting to Know the Global Economy Model and its Philosophy. IMF Staff Papers, 55(2), 213-242.

Leith, C., & Wren-Lewis, S. (2000). Interactions between Monetary and Fiscal Policy Rules. *The Economic Journal*, 110(462), C93-C108.

Lucas, R. (1976). Econometric Policy Evaluation: A Critique. *Carnegie-Rochester Conference Series on Public Policy*, 1(1), 19-46.

Mankiw, G. (2006). The Macroeconomist as Scientist and Engineer. *Journal of Economic Perspectives,* 20(4), 29-46.

Pesenti, P. (2008). The Global Economy Model: Theoretical Framework. IMF Staff Papers, 55(2), 243-284.

Ratto, M., Roeger, W., & in 't Veld, J. (2009). QUEST III: An Estimated Open-Economy DSGE Model of the Euro Area with Fiscal and Monetary Policy. *Economic Modelling*, 26(1), 222-233.

Roeger, W., Varga, J., & in 't Veld, J. (2008). Structural Reforms in the EU: A Simulation-Based Analysis Using the QUEST Model with Endogenous Growth. European Economy – Economic Paper no. 351.

Roeger, W., & in 't Veld, J. (2009). Fiscal Policy with Credit Constraint Households. European Economy – Economic Paper no. 357.

Romer, P. (1990). Endogenous Technological Change. *Journal of Political Economy*, 98(5), 71-102.

Rotemberg, J. J. (1982). Sticky prices in the United States. *Journal of Political Economy*, 90(6), 1187-1211.

Schmitt-Grohé, S., & Uribe, M. (2007). Optimal Simple and Implementable Monetary and Fiscal Rules. *Journal of Monetary Economics*, 54(6), 1702-1725.

Sims, C. A. (2006). Comment on Del Negro, Schorfheide, Smets and Wouters, from: http://sims.princeton.edu/yftp/DSSW806/DSseattleComment.pdf

Smets, F., & Wouters, R. (2003). An Estimated Stochastic Dynamic General Equilibrium Model of the Euro Area. *Journal of the European Economic Association*, 1(5), 1123-1175.

Smets, F., & Wouters, R. (2007). Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach. *American Economic Review*, 97(3), 586-606.

Solow, R. (1957). Technical Change and the Aggregate Production Function. *Review of Economics and Statistics*, 39(3), 312-320.

Spanos, A.. (1990). The Simultaneous-Equations Model Revisited: Statistical Adequacy and Identification. *Journal of Econometrics*, 44(1-2), 87-105.

Taylor, J. B. (1993). Discretion Versus Policy Rules in Practice. *Carnegie-Rochester Conference Series on Public Policy*, 39(1), 195-214.

Varga, J., & in 't Veld, J. (2009). A Model-Based Analysis of the Impact of Cohesion Policy Expenditure 2000-2006: Simulations with QUEST III Endogenous R&D Model. European Economy – Economic Paper no. 387.

Walsh, C. E., (2003). *Monetary Theory and Policy*. Cambridge (MA): The MIT Press.

Woodford, M. (2003). *Interest and Prices*. Princeton and Oxford: Princeton University Press.

Table 1: Factors contributing to GDP

ITEM

			Shock		
	TFP	**FINMARKUP**	**TAXSHIFT**	**WMKP**	**PC**
GDP	0.80	0.65	0.38	0.91	-0.06
Capital	0.20	0.11	0.06	0.23	0.00
Employment	0.00	0.40	0.17	0.73	0.01
TFP	0.60	0.14	0.14	-0.06	-0.07

QUEST

			Shock		
	TFP	**FINMARKUP**	**TAXSHIFT**	**WMKP**	**PC**
GDP (A)	0.88	0.92	1.09	0.76	0.11
Capital	0.14	0.39	-0.03	-0.02	0.00
Employment	-0.04	-0.01	0.62	0.45	0.13
TFP	0.24	0.53	0.49	0.74	0.09
Ideas/Patents (B)	0.17	0.47	0.41	0.30	0.08
GDP*(A-B)	0.71	0.45	0.68	0.46	0.03

Notes: TFP: Exogenous improvement of labour productivity; FINMARKUP: Reduction of price mark-up; TAXSHIFT: Reduction of wage mark-up; PC: Increase of public consumption; WMKP: A shift from tax on labour to tax on consumption. In QUEST the effect on GDP is net of fixed costs and GDP* denotes the effect on GDP net of the effect of the variation in the stock of ideas/patents.

Figure 1. A one percent improvement of labour productivity

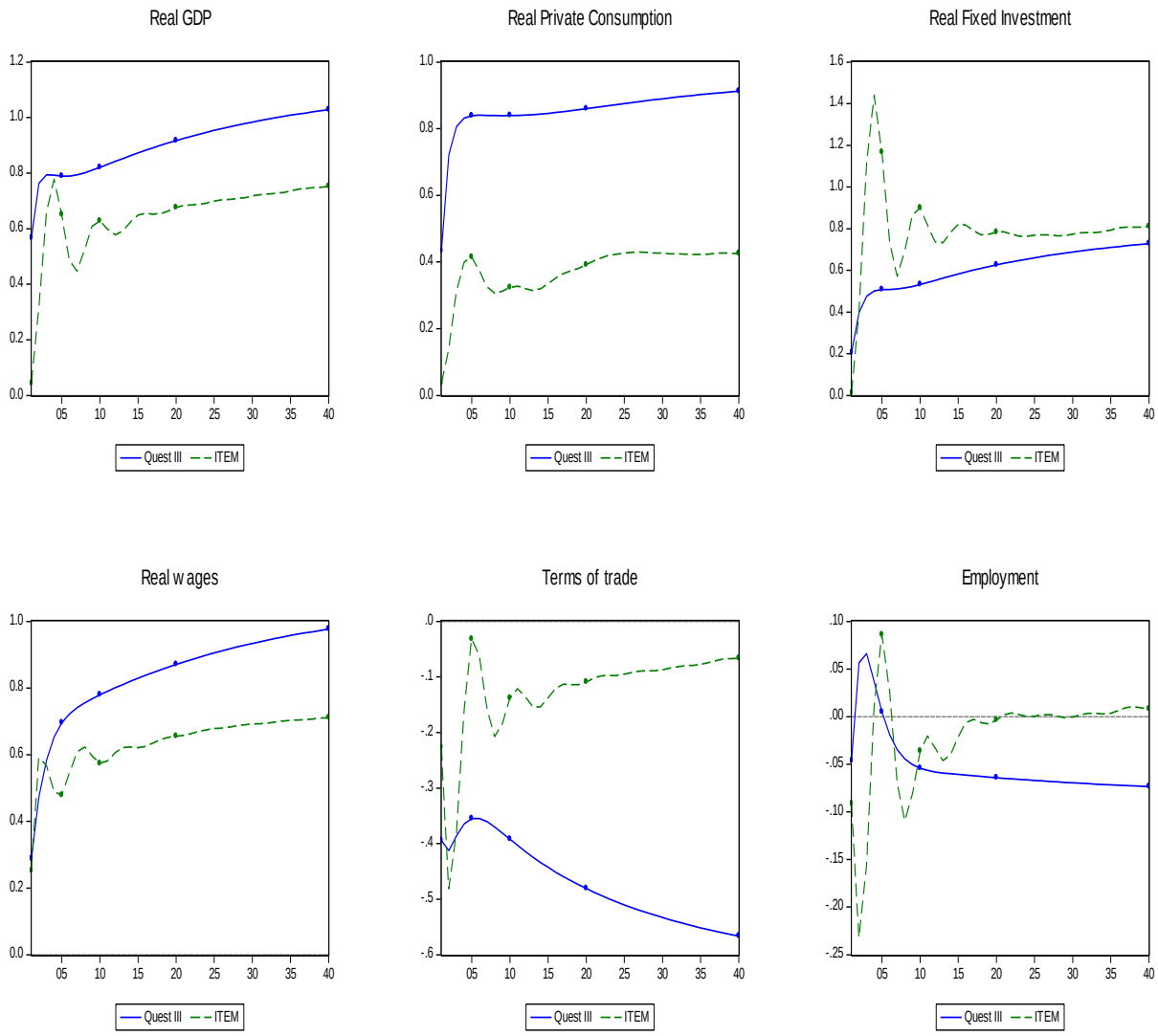

Figure 2. A one percent point reduction of the final goods mark-up

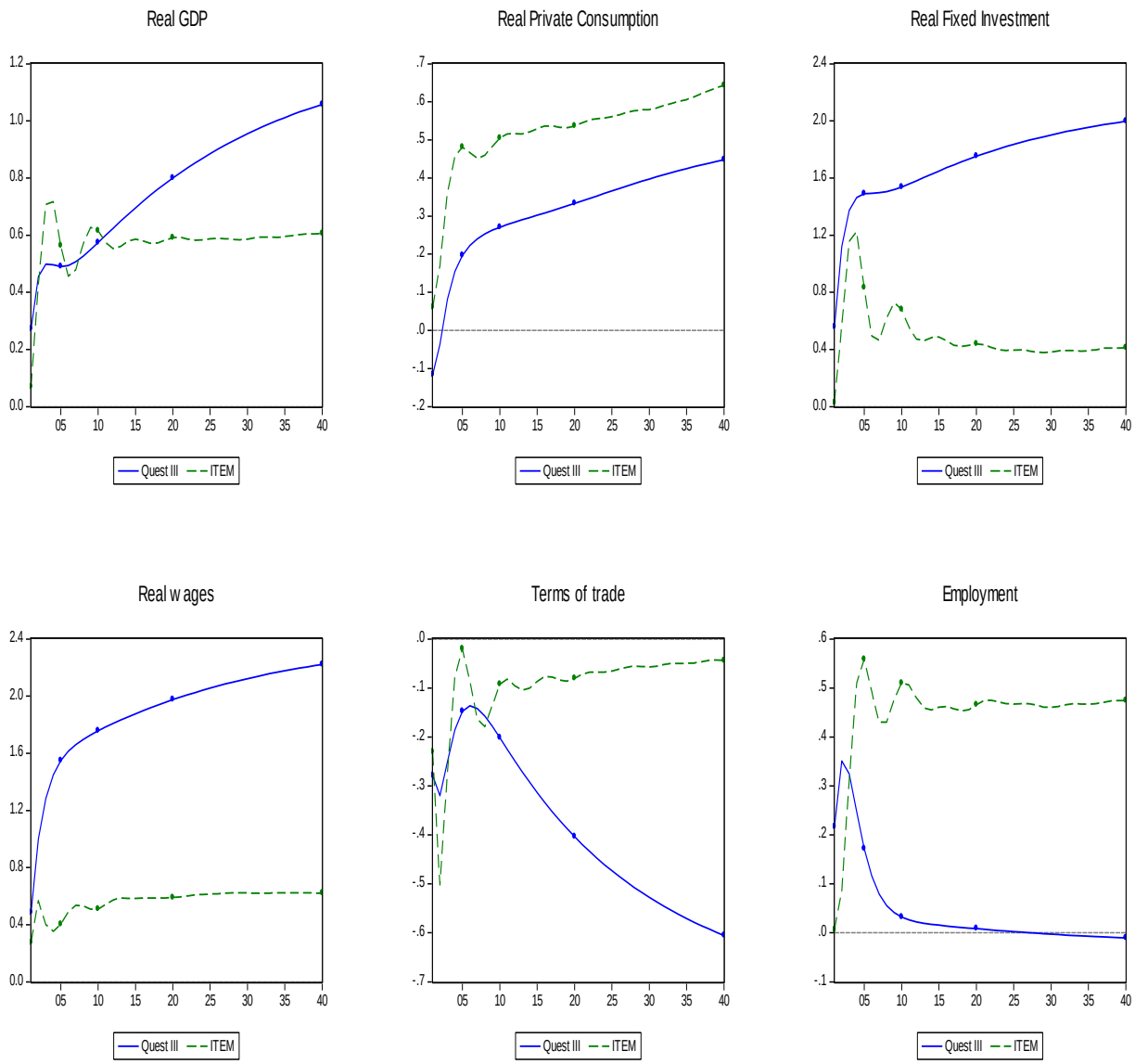

Figure 3. A one percent point reduction of the wage mark-up

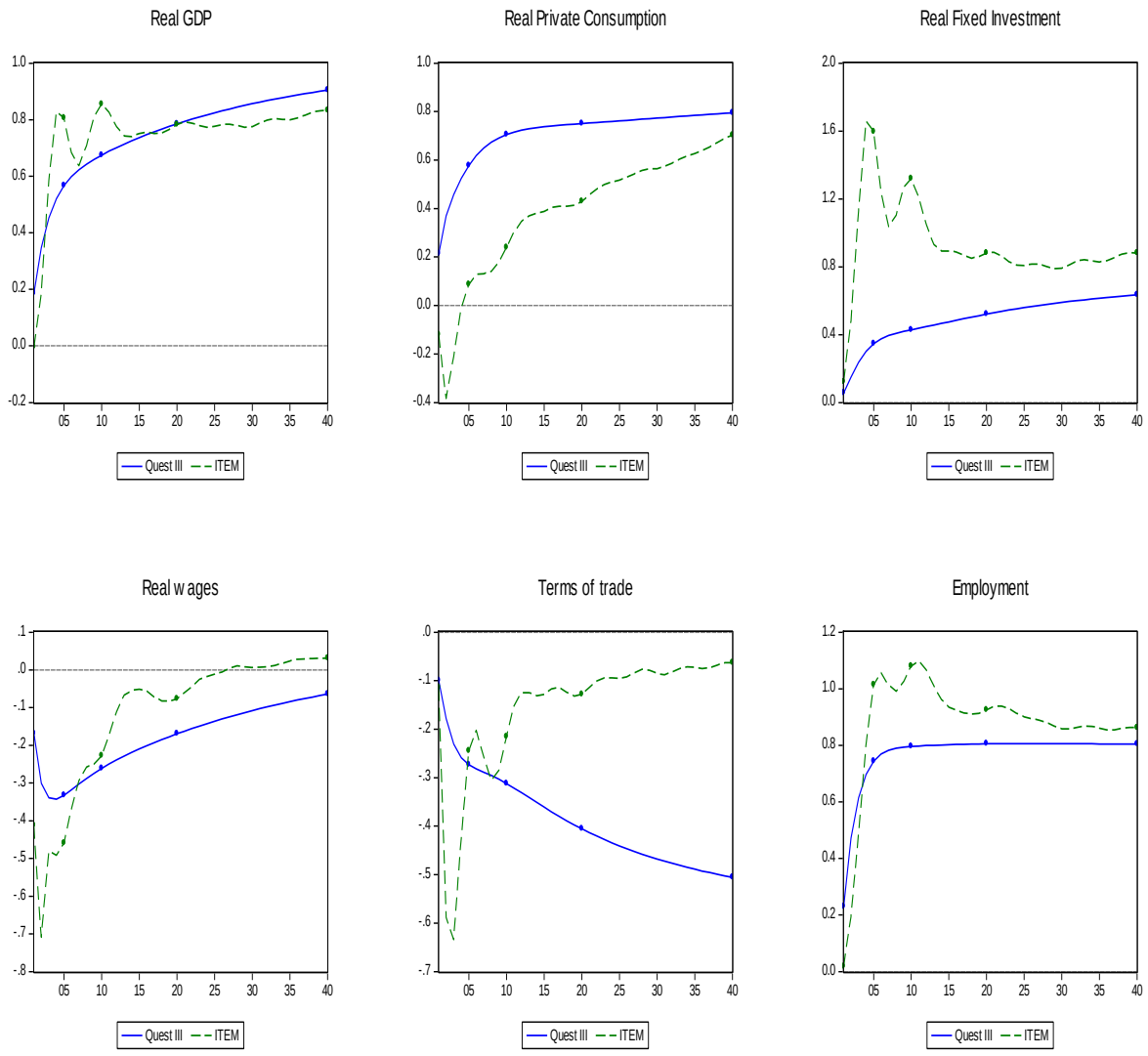

Figure 4. A one percent of GDP increase in public consumption

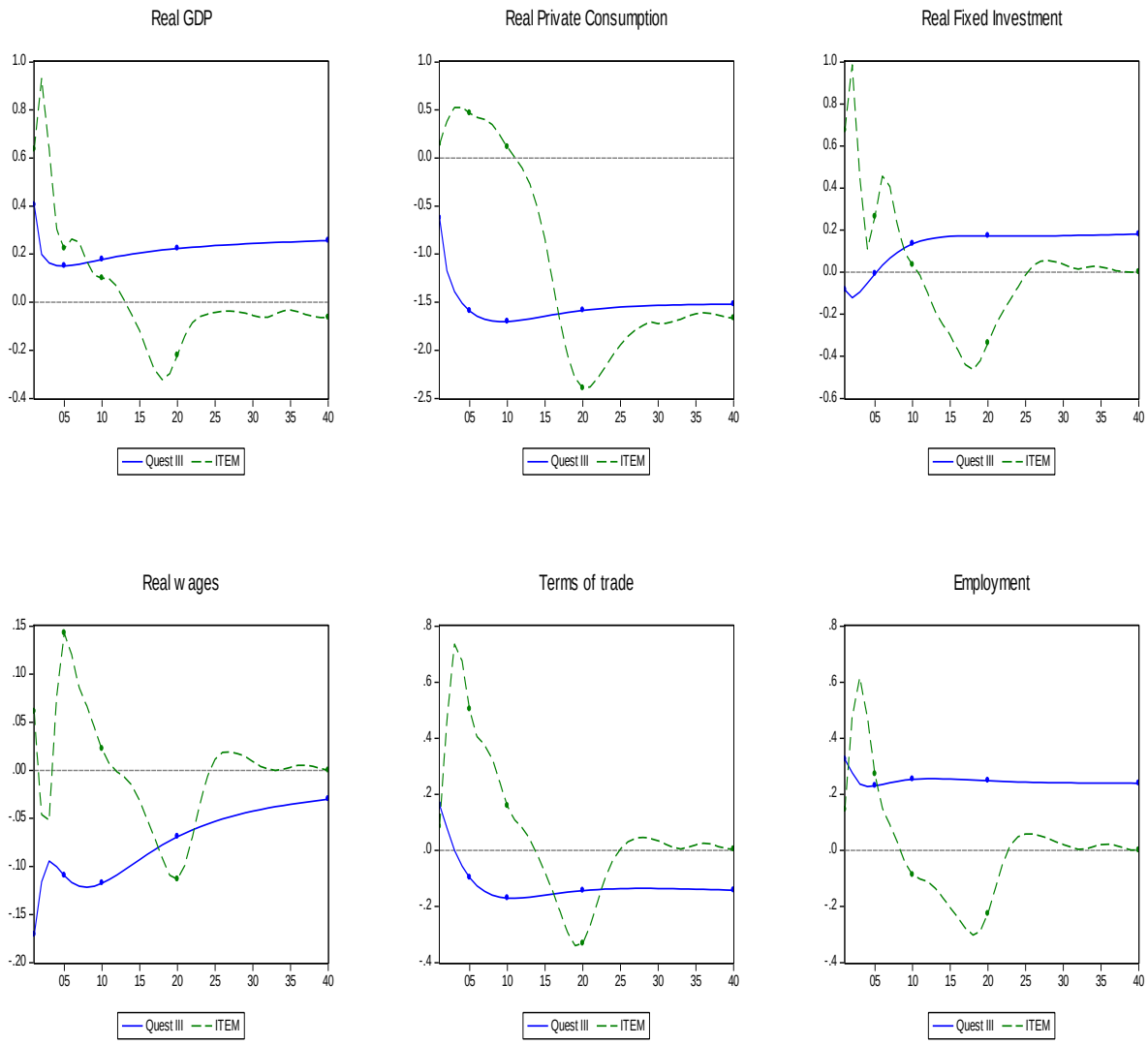

Figure 5. A one percent of GDP tax shift from labour to consumption