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Macroeconomic Modelling and the Effects of Policy Reforms: an Assessment for Italy using ITEM and QUEST

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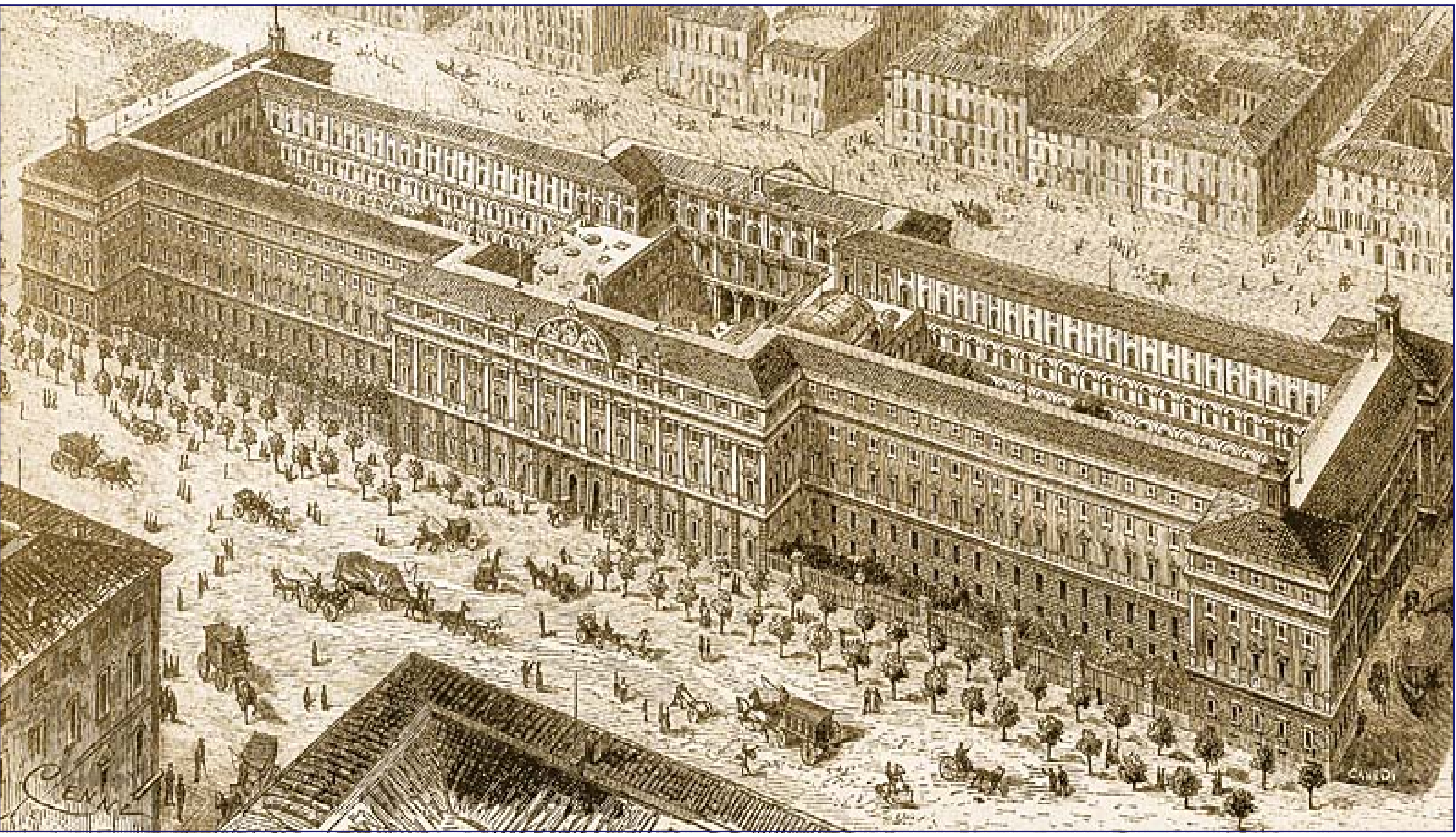

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Macroeconomic Modelling and the Effects of Policy Reforms: an Assessment for Italy using ITEM and QUEST

Barbara Annicchiarico (*), Fabio Di Dio (**), Francesco Felici (***) e Francesco Nucci (****)

Abstract

In this paper we compare the dynamic properties of the Italian Treasury Econometric Model (ITEM) with those of QUEST III, the endogenous growth model of the European Commission (DG ECFIN) in the version 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.

JEL Classification: E10, C50, E60
Keywords: Economic Modelling, DSGE, Structural Reforms, Italy.

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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., the 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., the 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 approach 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 so in the nearest future (e.g. Castillo *et al.*, 2009; Laxton, 2008, Pesenti, 2008).[2]

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

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[2] The main central Banks that 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 and QUEST III is the one that is used in this paper.

Model (ITEM) with those obtained through the latest version of the European Commission's 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 expenditure and on the revenue side. In addition, ITEM features a complete modelling of financial assets and liabilities of the 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 compares the results from long-horizon simulations conducted with both models in order to appraise differences in the macroeconomic effects of a number 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 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 among consumers 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 plays 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:

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

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 consumption (with C_t^i being an aggregate of domestic and foreign varieties of final goods), C_{t-1} is the past level of economy's average 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, and 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, transfers 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 maximization 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:

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

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 the economy-wide consumption. 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_t different varieties of intermediate goods, x^j and public capital, KG_t :

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

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, ϑ is the elasticity of substitution between different varieties of the intermediate goods x, FC_y denotes fixed costs and FC_L. overhead labour. The labour input $L_{y,t}^j$ is defined by the following CES aggregator[4]:

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

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

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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.

function incorporates the product variety framework proposed by Dixit and Stiglitz (1977) 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 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:

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

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 ${i_t}^A {P_t}^A$ 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 ${P_t}^A$.

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:

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

where A_t and ${A_t}^*$ 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 υ 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 λ 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

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

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. Under such circumstances, conventional policies, such as subsidies to the R&D sector, are not able to affect long-run growth, but they do influence growth along the transition path, thus affecting the levels of income, consumption and welfare. It should be noted that QUEST explicitly applies the Jones (1995) framework in order to model the technological change as semi-endogenous, so that the growth mechanism can be labeled as "endogenous" in the short-medium run, while in the long-run growth only depends on exogenous factors. The models exhibiting these characteristics are sometimes referred to as "semi-endogenous" growth models, with the transition process featuring the same implications as those in Romer (1990) and Jones (1995, 2005).
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 sectors 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 and Clarida *et al.*, 1999), allowing for a certain degree of inertia of the interest rate response to inflation and output gap:

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

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 $ygap_t$ is the output gap defined as deviation of capital and labour utilization from their long-run trends (see Roeger *et al.*, 2008 for details).
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:

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

where R_t^G denotes revenues from distortionary taxation on labour income, consumption and capital and $T_t^{L,s}$ is lump-sum taxation. By assumption $T_t^{L,s}$ evolves as a function of the debt-GDP ratio in order to ensure fiscal solvency and rule out any explosive path of public debt (for more details see Roeger *et al.*, 2008).

3 THE ITEM MODEL

ITEM is a medium-size linear macroeconometric model (36 behavioural 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 in 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:

$$GDP = VAM + VANM + TXNT, \quad (10)$$

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:

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

While private consumption, C, investment, I, export, public expenditure X and import, M, are modeled through a behavioral equation and public expenditure, G is assumed to be exogenous. In particular, output (value added) of market 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 between the short and the long run and is modeled in such a way that, in determining output, the demand side prevails in the short run, while the supply side conditions are predominant 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 measurement problem in the available statistics of inputs, that fall short of gauging the 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:

$$dIFU = \alpha + \beta \times dlog(DEM) + \mu \times INVCH(-1), \tag{15}$$

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 that arguably allow to replicate the main empirical implications of those frictions.

The long-run demand for labour and capital services is modeled consistently with the prediction of firms' maximization 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 gross interest rate on short-term borrowing (R):

$$c = \alpha \times yld + (1 - \alpha) \times hnfa - \gamma \times r, \tag{16}$$

where variables in lower-case letters are expressed in logarithms. 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 index), 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) is negatively related with the structural component 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:

$$NRFL = (1 + rev) \times NFRL(-1) + CA, \qquad (20)$$

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 a comparative assessment of results from simulating different policy interventions with both 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 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 in the dynamic response of macroeconomic variables.

More specifically, we consider the following scenarios:

1. LP: 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 response of the main aggregate variables responses (GDP, real private consumption, fixed investment, real wages, term of trade, employment) in each of the five scenarios. For each variable we plot percentage deviations from the initial steady state for a 40-quarter time horizon. For each scenario Table 1 reports the factors contributing to GDP long-run percentage variations allowing us to quantify how much of the observed long-run effects are due to changes in employment, capital and

productivity. This allows us to pin down the contribution of the R&D sector in the QUEST model.
In QUEST we use the parameters' calibration for Italy devised by D'Auria *et al.* (2009) and reported in Appendix A. The ITEM estimations are those documented in Cicinelli *et al.* (2008).
In QUEST, in order to render all variables stationary we express the non-stationary variables in efficiency units to remove the trend in total factor productivity and population. In the econometric specification of all equations in ITEM there is an error correction model (ECM) representation, so that variables enter the equations in first-difference (to achieve stationarity) and a long-run relationship between variables expressed in levels is featured.

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). This shock gives rise to a permanent positive effects on output, consumption and investment.
In ITEM, the same shock is imparted to the structural component of TFP to mimic an exogenous 1% increase in labour productivity. Figure 1 presents the dynamic response of some macroeconomic 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 productivity 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. As shown in Table 1, in the long-run real GDP is 0.88% above its initial level and the accumulation of knowledge triggered by the increase in labour productivity accounts for 0.17% of the GDP observed variation. Indeed, during the adjustment towards the new equilibrium the endogenous growth mechanism ensures higher growth rates than those observed in a neoclassical model, thus positively affecting the new steady state level of income.
The behaviour of employment is instead more complex. In the very short run technical progress has a negative impact on employment. Intuitively, this is due to the fact, because of price rigidities, firms do not fully adjust their prices downward to the new lower level of marginal costs.[5] In the medium run the effect is positive, in light of the increase in the supply capacity. In the long run, the effect becomes slightly negative as a consequence of the deterioration of the terms of trade (see Roeger *et al.*, 2008).
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

[5] The negative response of employment to a productivity shock is a typical feature of New Keynesian model. See Galí (2008).

deterioration in the terms of trade, triggered by the increase in the TFP, negatively affects consumption. In the long run employment shows a permanent decline since more productive agents substitute working hours with leisure (i.e. the income effect prevails over the substitution effect).

In ITEM the transmission mechanism is 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 a level which is 0.66 percentage points above its initial level.

From this analysis we can draw two main policy implications. First, policy actions addressed to a R&D improvement will produce a larger long-run effect on output the more the economy is capable of turning productivity improvements 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 is negligible being 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 model the positive effect on consumption is amplified by the presence of liquidity constrained households.

We conclude that the effect on welfare of productivity-enhancing policies turns out to be rather 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, as they reduce 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 it yields an ex-ante 1% permanent decrease of prices.

In QUEST, a higher degree of competition in the final goods sector transmits its effects to the intermediate sector and, consequently, to 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 the level in the baseline scenario. In the long run real GDP is also higher than the level of the baseline scenario (by 0.60 percentage points).

Also in this second scenario we observe that the dynamic responses of the main macroeconomic 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 the long-run output increase. 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 ITEM than in QUEST; this is explained by the different theoretical framework for consumption decisions in the two models, but also by the presence in QUEST of liquidity constrained consumers. As a matter of fact, since liquidity constrained households may only consume their current income, they benefit only partially from the price decrease, and as a result of this, their consumption increases by less.

Of a particular interest is the long-run effect on employment in the two models. We observe that the enhanced competition scenario has 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, the skill composition of the labour force and the wage setting mechanism. In ITEM labour supply is quite elastic, workers have no skill differentiation and all wages are the same and are set in accordance with labour productivity. Under these circumstances, an increase in the demand for labour generates a permanent positive effect on employment and on real wages.

In QUEST the reduction of the price mark-up induces an increased demand for capital (tangible and intangible) as a consequence of the entry of new firms. Similarly, the reduction of price mark-up gives rise to an increase in the demand for labour which translates into higher employment for low skilled workers (whose labour supply is more elastic given their lower employment level) and to an increase in the skill premium of medium and high skilled workers. In the long run, at aggregate level, the latter effect dominates the former.

4.3 A REDUCTION OF THE WAGE MARK-UP

This shock seeks to mimic 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 1% 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 1% increase of employment.

In QUEST, in the short run, both the real wage reduction and the terms of trade deterioration lower consumption. 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 mark-up 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 further insights on the ITEM-QUEST comparison. In particular, since in QUEST unions set the optimal wage level, a reduction in the wage mark-up automatically reduce the wage claims and thereby the unions power. As a result, firms find it convenient to substitute capital with labour. In ITEM, conversely, the optimal wage level is set by firms and this makes the effect on employment larger than it is 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 the 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 output displays a slight permanent increase, contrary to ITEM that predicts zero long-run effects on GDP. Private consumption exhibits a permanent fall, reflecting a rise of labour supply due to the negative wealth effect. A higher employment level account for most of the observed increase in long-run output.

Non-liquidity constrained households (half of the population) anticipate future increases in taxes and then reduce their consumption because saving more is now the optimal choice (intertemporal substitution effect). Lower consumption implies a lower marginal rate of substitution between leisure and consumption affecting the wage equation, so that we observe larger hours worked and lower real wages.

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), on the persistence of the public spending process and on the calibrated value of labour adjustment cost parameters. The inclusion of non-Ricardian agents and adjustment cost parameters in the labour market provide an effective channel for increasing the capability of DSGE models to account for responses consistent with the empirical evidence and similar to those obtained in existing macroeconometric models (Blanchard and Perotti, 2002). Notably, the degree of consumption crowding out in response to higher public spending is lower the higher is the share of non-Ricardian agents, the lower the labour adjustment costs and the lower the persistence of the public consumption increase.[6] Despite the fact that in QUEST non-Ricardian consumers represent half of the population, the high adjustment costs characterizing the labour market coupled with a permanent increase in public consumption are sufficient to produce a lack of co-movement between private and public consumption.

4.5 TAX SHIFT FROM LABOUR TO CONSUMPTION

In this scenario we consider a tax shift from labour to consumption. In QUEST this policy shift is designed by reducing labour tax rates for each category of workers so as to obtain an ex-ante decrease of tax revenues equal to 1% of nominal GDP of the baseline simulation. At the same time, an increase of the consumption tax rate is introduced of a size that generates an ex-ante increase of fiscal revenues equal to 1% of nominal GDP of the baseline simulation. In ITEM, it is the social security contributions rate paid by the employers that is reduced (so as to obtain an ex-ante decrease of tax revenues equal to 1% of nominal GDP) while the consumption tax rate is increased in the same way as it has been done in QUEST.

The simulations results of the two models, reported in Figure 5, turns out to be very similar for some key variables showing a positive effect on GDP, consumption and employment,

[6] In QUEST the consumption response to a positive government spending becomes positive if labour adjustment costs tend to zero (see Ratto *et al.,* 2009).

although quantitative differences remain. In this case, endogenous growth plays an important role in explaining the GDP variation (0.30%), but the major contribution is given by employment (in QUEST as well as in ITEM, see Table 1).

In general, we observe that shifting the burden of taxation from labour to consumption reduces disincentives and distortions in the labour market giving rise to an increase in the level of employment and output.

In QUEST the positive effect on employment and output of the tax shift is enhanced by the endogenous growth mechanism and for this reason the beneficial effects of this policy reform continue to materialize also after 40 quarters. The increase in employment is followed by an increase in investment until the optimal capital-labour ratio is re-established. The beneficial effect of the tax shift is also observed on consumption, since the positive effect derived from higher net labour income prevails over the negative effect of a higher tax rate on consumption. As expected, the expansion of output has a negative impact on the terms of trade.

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 estimate a rise of GDP that is 0.38 percentage point above the level of the baseline scenario. Employment and the capital stock are also above their levels in the baseline simulation by roughly the same percentage amount. Similarly, real wages tend to increase reducing the positive effect on employment.

In this simulation there are not salient differences which are attributable to specific aspects of the two models, 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 in the policy reform scenario 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 the European Commission

(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 macroeconomic 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 the response to policy shifts.

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 that 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 significant methodological differences among the two approaches, the models exhibit quite similar patterns in the long run. Second, we observe a different response of capital and labour to policy shifts across the two models, that depends on differences in how the labour market and the accumulation process are modeled. In QUEST trade unions set wages in monopolistically competitive labour markets, while in ITEM firms set wages in a more competitive environment. Hence, QUEST is more suitable than ITEM to appraise the effects of structural labour market reforms in contexts where trade union power is relevant. The third point concerns the QUEST assumptions of rational expectations and forward-looking behavior that have important implications for agents' decisions.

We believe that, for simulating alternative economic policy scenarios, the joint consideration of simulations obtained with empirically validated macroeconometric models and those obtained with DSGE models like QUEST is of great help for assessing the dynamic response of variables to policy impulses and their transmission mechanisms.

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Table 1: Factors contributing to GDP long-run % variations

ITEM

	Shock				
	LP	**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				
	LP	**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
LP	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: LP: 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

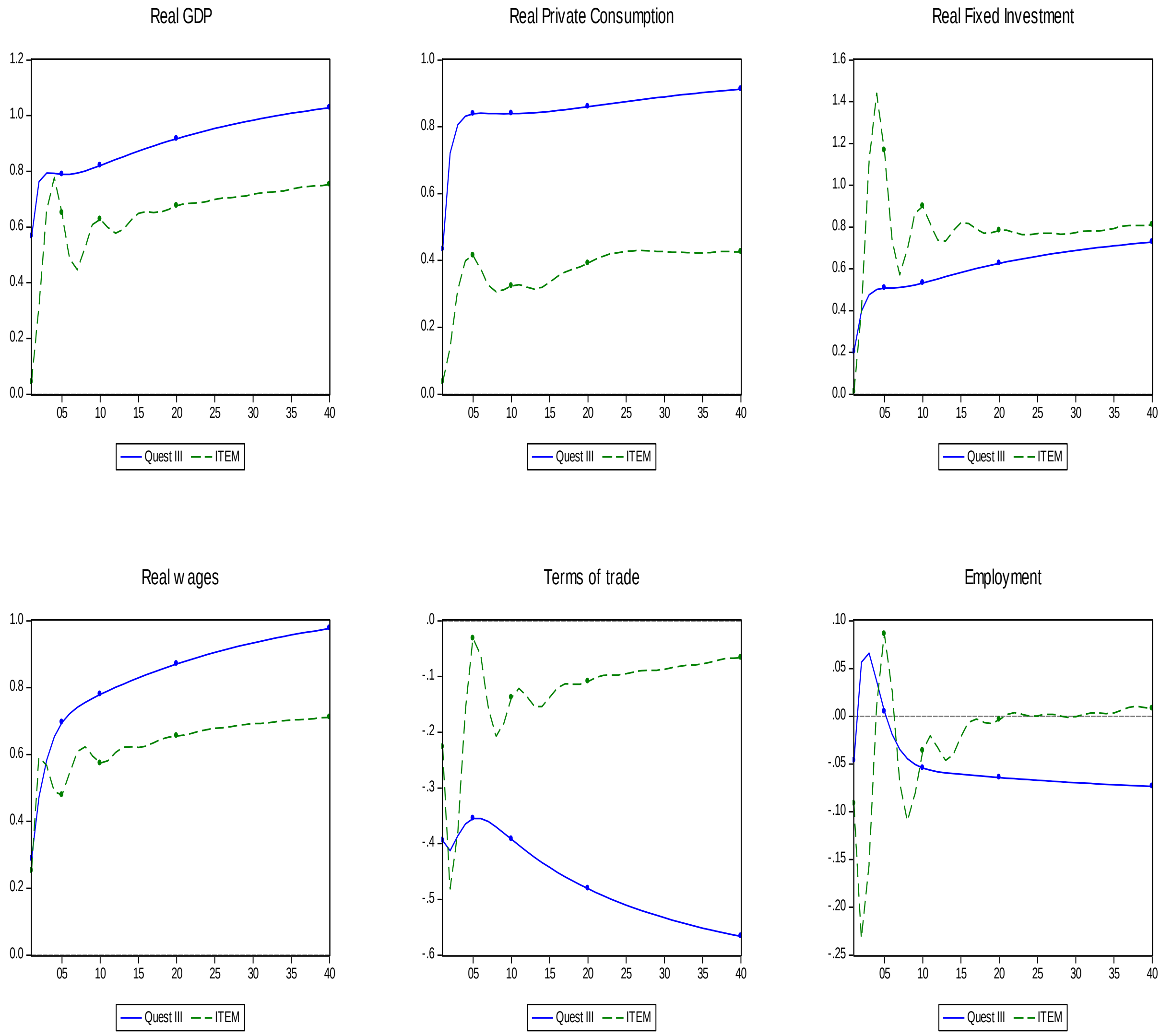


Figure 2. A one percent point reduction of the final goods mark-up

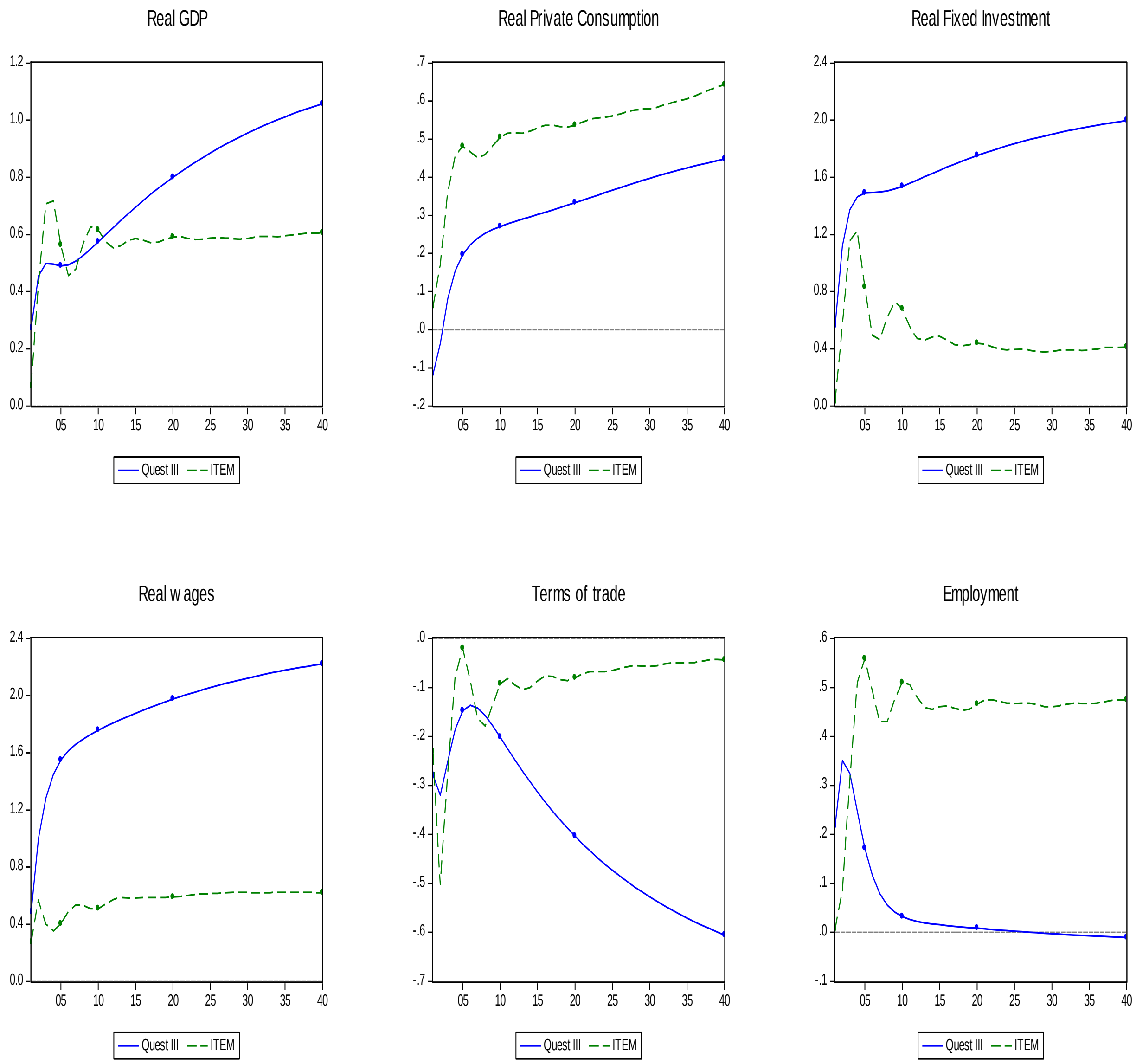


Figure 3. A one percent point reduction of the wage mark-up

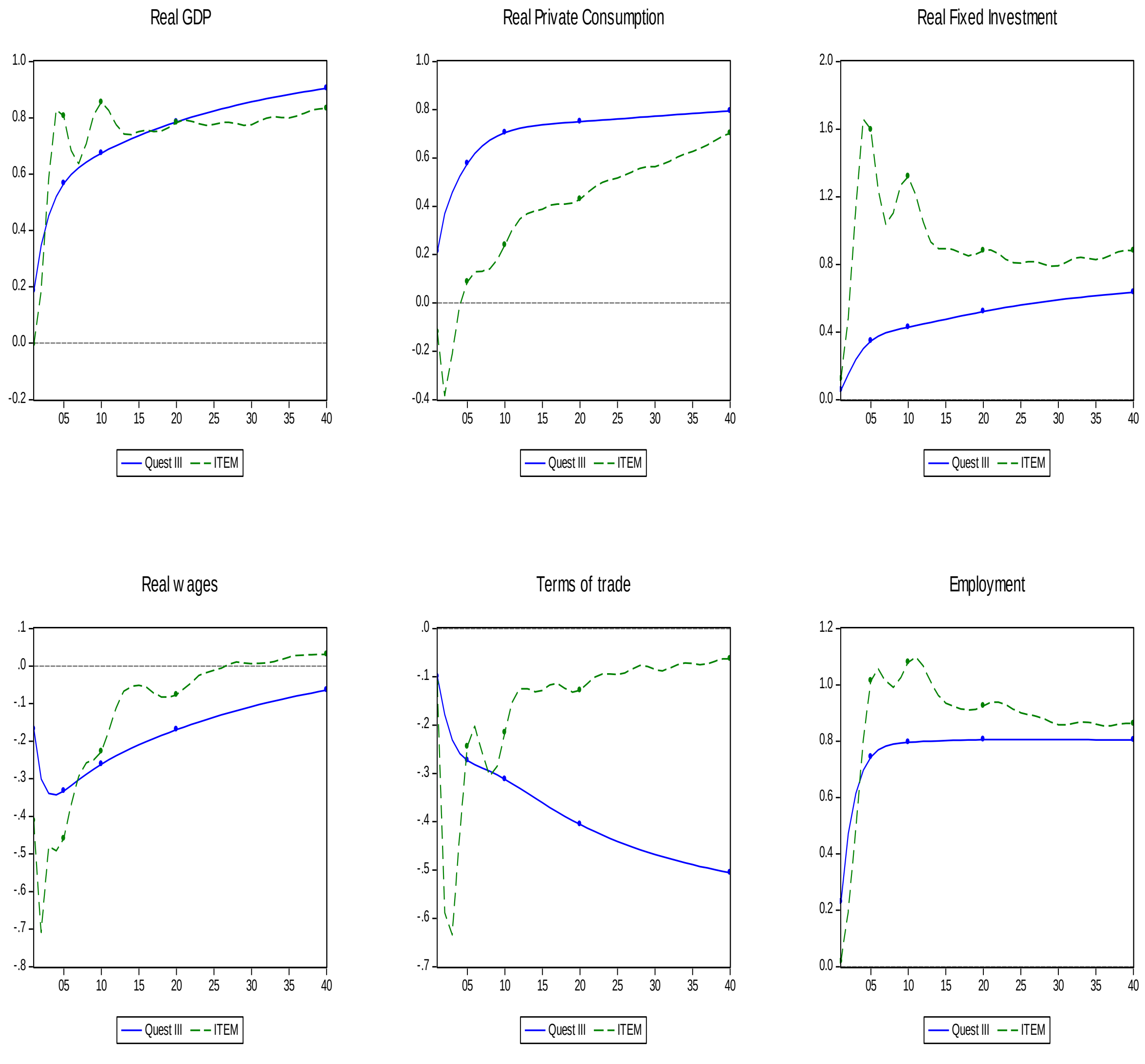


Figure 4. A one percent of GDP increase in public consumption

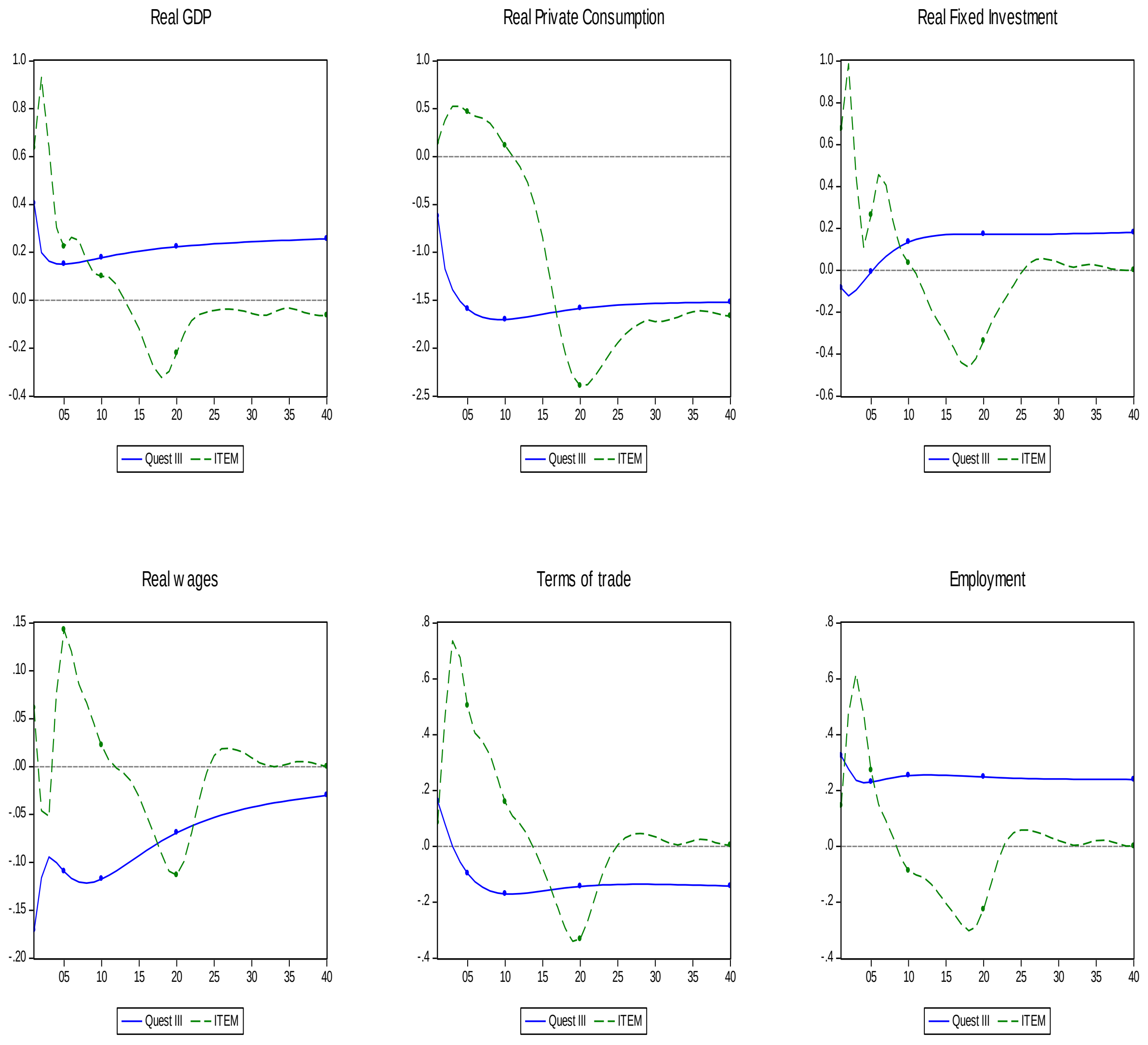
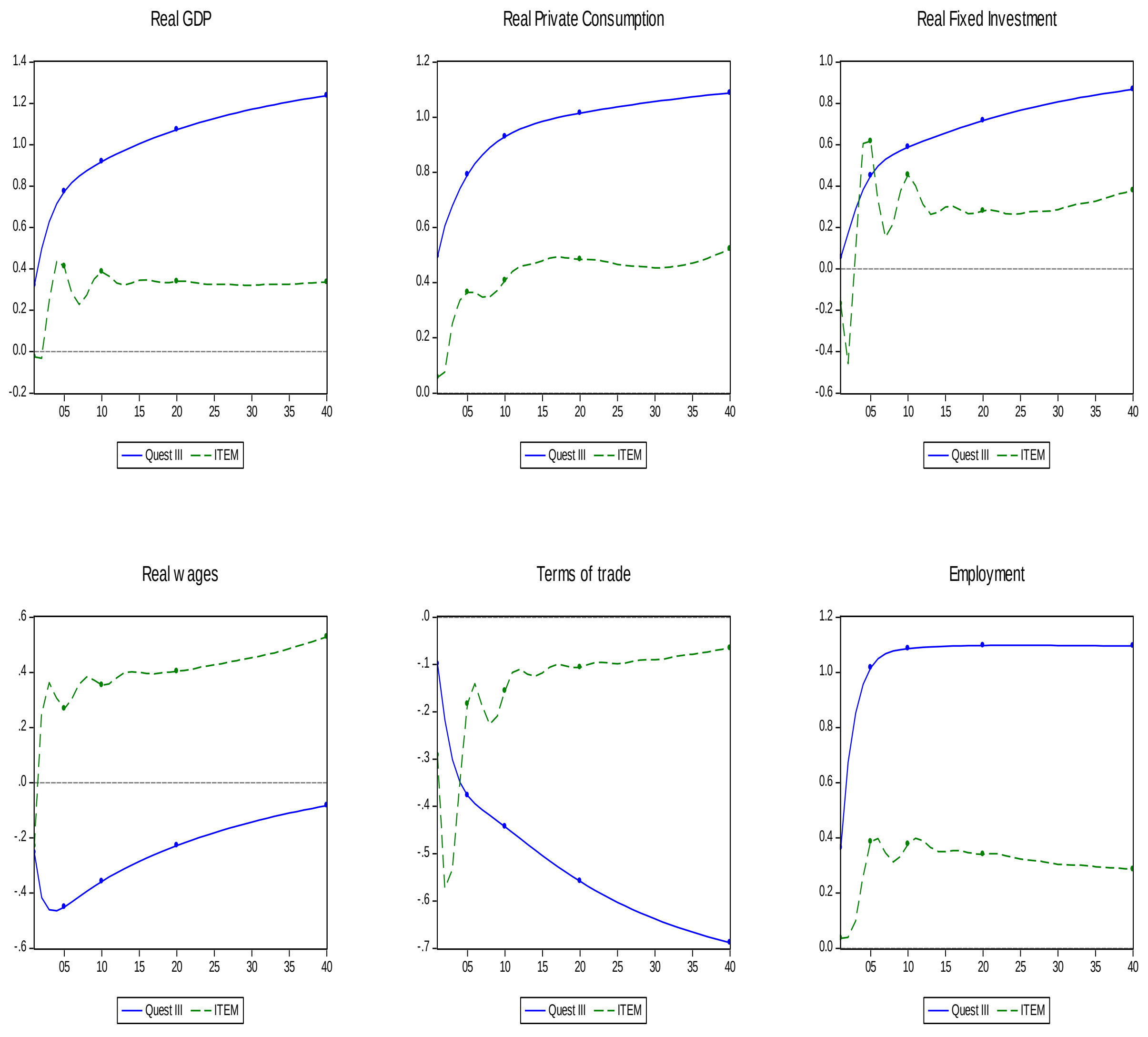


Figure 5. A one percent of GDP tax shift from labour to consumption



APPENDIX A

The Parameters' Calibration for Italy in QUEST III

R&D sector	
Researchers (L_A, % employment)	0.51
R&D (% GDP)	1.10
elast. of R&D wrt. labour (λ)	0.37
elast. of R&D wrt. dom. ideas (Φ)	0.70
elast. of R&D wrt. for. ideas (ω)	0.28
R&D efficiency (ν)	0.20
depr. rate of ideas (δ^A,%)	1.25
growth rate of ideas (g^A,%)	1.15
Intermediate sector	
mark up ($1/\theta$-1,%)	10.00
entry costs (FC_A)	0.45
risk premia on intangibles (rp^A,%)	2.02
Final g. sector	
mark up ($1/\eta$ -1,%)	21.03
depr. Rate of capital (δ,%)	1.52
Labour market	
low skilled pop. share (s_L,%)	50.00
medium skilled pop. share (s_M,%)	46.80
high skilled pop. share (s_H,%)	3.10
low skilled employment (L_L,%)	52.00
medium skilled employment (L_M,%)	73.70
high skilled employment (L_H,%)	81.10
skill elast. of subs (σL)	1.40
employment rate (L,%)	63.10
wage prem. high vs. medium (%)	37.30
wage prem. medium vs. low (%)	26.60
low skilled efficiency level (ef_L)	1.00
medium skilled efficiency level (ef_L)	2.30
high skilled efficiency level (ef_L)	6.90
labour adj. costs (γ_L,% of total)	18.00
Taxes/subsidies	
tax credit (τ^A,%)	30.00
tax rate on capital income (t^K,%)	33.00
consumption tax (t^C,%)	16.90
labour tax (t^L,%)	50.50
transfer (tr,% GDP)	17.00

Source: D'Auria *et al.* (2009).

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