

Barrios, Salvador et al.

**Working Paper**

## Dynamic scoring of tax reforms in the European Union

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## JRC TECHNICAL REPORTS

# Dynamic scoring of tax reforms in the European Union

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## Table of contents

Abstract .....	1
Acknowledgments .....	1
1 Introduction .....	2
2 Dynamic scoring of tax reforms in the EU: policy context and modelling choices .....	4
2.1. Policy context .....	5
2.2. Modelling choices .....	5
3 Modelling the second-round effects of tax reforms .....	7
3.1. The discrete choice labour supply model .....	7
3.2. The microsimulation model .....	8
3.3. The macroeconomic DSGE model .....	9
3.4. Aggregation .....	9
4 Labour market and tax incidence .....	10
4.1. The labour supply function .....	11
4.2. Labour supply elasticities .....	14
4.3. Tax incidence .....	17
5 Illustration: tax reforms in Belgium, Italy and Poland .....	19
5.1. First step: Labour market calibration and policy shocks .....	20
5.2. Second step: The macroeconomic impact .....	24
5.3. Third step: Microsimulation results .....	26
6. Conclusion .....	29
Appendix A. The discrete choice labour supply model .....	33
Appendix B. The QUEST model .....	35
Appendix C. The inter-temporal labour supply function in QUEST .....	41
Appendix D. QUEST Impulse responses .....	43
Appendix E. Budgetary and redistributive effects of the reforms .....	49
List of abbreviations and definitions .....	61
List of figures .....	62
List of tables .....	63

## **Abstract**

In this paper, we present a dynamic scoring analysis of tax reforms for European countries. In this analysis we account for the feedback effects resulting from the adjustment in the labour market and for the economy-wide reaction to tax policy changes. We combine the microsimulation model EUROMOD, extended to incorporate an estimated labour supply model, with the new Keynesian DSGE model QUEST, used by the European Commission for analysing fiscal and structural reform in EU member states. These two models are connected in two ways: by introducing tax policy shocks in QUEST, derived from computing changes in implicit tax rates using EUROMOD; and by calibrating the elasticity of labour supply and the non-participation rates, by skill categories, in QUEST from values calculated using EUROMOD and the estimated labour supply function. Moreover, we discuss aggregation issues and the consistency between the micro and macro modelling of labour supply and interpret the model interaction in terms of tax incidence analysis. We illustrate the methodological approach with the results obtained when scoring specific reforms in three EU Member States, namely, Italy, Belgium and Poland. We compare two different scenarios – one in which the behavioural response to tax changes over the medium term is ignored and another scenario where this behavioural dimension is embedded into the microsimulation model. Our results suggest that accounting for the behavioural reaction and macroeconomic feedback to tax policy changes enriches the tax reforms' analysis, by increasing the accuracy of the direct fiscal and distributional impact assessment provided by the microsimulation model for the three reforms considered. Our results are also in line with the evidence on dynamic scoring exercises, showing that most tax reforms entail relatively small feedback effects (see Gravelle, 2015, for a recent review focusing on the US dynamic scoring experience). In our particular setting, the relatively small behaviour effects are directly linked to the nature of the tax reforms implemented, where a decrease of the employees tax burden generates opposite wage and employment effects in the labour market.

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# 1 Introduction

In this paper we present a dynamic scoring approach which aims at measuring the second-round effects resulting from tax reforms in the European Union (EU). Dynamic scoring techniques consist in comparing the impact of alternative fiscal policy reforms, taking into account their full effect on the economy, in particular on its supply side, and therefore provide a more accurate estimation of their fiscal and equity impact than when considering these reforms in isolation (see Altshuler et al., 2005). Accounting for economy-wide interactions might result in different estimated effects of specific tax reforms on tax revenues and budget balances in case these affect economic agents' behaviour in a significant way (see Gravelle, 2015, for a recent review focusing on the US). Dynamic scoring has been little developed in the EU, the more so in a comparable manner across EU countries. Yet, such tool could prove very relevant for assessing the impact of discretionary tax measures in order to determine the true fiscal policy stance (see Buti and Van den Noord, 2004).

The motivation of our paper is twofold. First, we aim at contributing to the tax evaluation literature at the methodological level, by combining a microsimulation model with a dynamic stochastic general equilibrium one. This allows us to clearly distinguish between first and second round effects of tax policies. Second, we aim at developing a consistent framework to analyse the fiscal and distributional effects of tax reforms and the macroeconomic feedback effect to study the extent to which tax reforms can be self-financing. Such a framework is warranted in the context of the reinforced coordination and monitoring of national fiscal and structural reforms at EU level. We propose a tractable and consistent framework for modelling and analysing these reforms over the medium-term (i.e. 3 years), in line with the time horizon used in the context of the EU fiscal surveillance. In this way, we combine the direct budgetary and distributional effects of the tax reform, with second-round micro and macroeconomic effects. In particular, we obtain the microeconomic behavioural effects of tax reforms using a discrete choice econometric model estimated in combination with the EUROMOD microsimulation model. This econometric model follows the approach developed by Bargain, Orsini and Peichl (2014) based on a utility function where each individual (couple) can choose from a limited number of alternatives in terms of hours of work – non-participation, part-time, full-time and over-time. The discrete choice model is combined with the EU-wide microsimulation model EUROMOD, both using the same micro data in order to obtain disposable income, which works as a proxy for individual (household) consumption.<sup>1</sup> The macroeconomic effects are obtained by simulating the tax reforms of interest with the European Commission New-Keynesian model, QUEST.<sup>2</sup> The simulation of the tax reforms in QUEST is done via the introduction of permanent fiscal policy shocks consisting in changes in the implicit average tax rates for three different types of workers – low, medium and high skilled – which is provided by the EUROMOD model. Besides considering a full set of transmission mechanisms between the different agents that populate the model, QUEST provides the demand side of the labour market. In this way, the macroeconomic projections obtained from this model include also the behavioural reaction of firms. The macroeconomic projections correspond to the impulse-responses of the economic

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<sup>1</sup> See Sutherland (2001) and Sutherland and Figari (2007) for details on the EUROMOD model.

<sup>2</sup> See Ratto et al (2009) for details on the QUEST III model.

variables to the fiscal policy shocks representing the trajectory of the economy to return to its steady state. The last step of the dynamic scoring exercise consists in introducing the macroeconomic trajectories of price, wages and employment in EUROMOD over a three-year period and to analyse the corresponding changes in disposable income and tax liabilities.

We illustrate our approach with three examples of reform reflecting a wide range of effects affecting labour supply. The examples of reforms presented here are stylised reforms with the purpose of illustrating the methodology only, although they are also illustrative of the nature of most tax reforms enacted in practice. We consider an already implemented labour tax reforms such as the introduction of a labour tax credit in Italy, a proposed reform announced but not legislated yet in Poland consisting in an increase in the universal tax allowance and a hypothetical reform consisting in a reduction of the social security contributions for employees for the case of Belgium. These examples reflect the actual nature of most reforms affecting personal taxes or social security contributions which are in most cases gradual and affect disposable income only marginally (see in particular Castanheira et al., 2012). Our results suggest that accounting for the behavioural reaction and macroeconomic feedback to tax policy changes enriches the evaluation of the tax reforms, both on the fiscal and equity sides. These results show also that the model-based approach of dynamic scoring brings very realistic assessment of the impact of tax reforms which cannot be obtained with macro-models alone. Notice, however, that the behaviour impact of the reforms is relatively small. This seems a reasonable outcome, since the reforms considered do not introduce sizeable changes in the tax codes. This reflects in small changes in the implicit tax rates, which are introduced as permanent policy shocks in QUEST. Moreover, the reforms considered in this paper all tend to lower the tax burden on employees, reflecting into a decrease on the tax rates levied on employees in QUEST. In the QUEST labour market equilibrium, this ends up having a negative effect on gross wages, while employment increases. On aggregate terms, this yields a very mild change on the total wages paid in the economy and, consequently little evidence of self-financing tax cuts. We also discuss these results in terms of tax incidence whereby the legal impact of tax changes might differ from their economic effects. In the examples considered here we show that the tax cuts are partially appropriated by firms. Furthermore, in these examples, the labour market response in QUEST is mild, as the tax cuts are partially appropriated by firms, which are willing to hire more workers, but at a lower gross wage rate. Despite an increase in employment, a cut in the tax burden of employees reduces the tax base, e.g. lower gross wages and hence lower tax revenues. As a result, in the microsimulation set-up these small effects translate into overlapping fiscal and distributional effects when we compare the no behaviour with the behaviour scenarios. The relatively small macro feedback effect does not invalidate the usefulness of the dynamic scoring approach, however. It rather confirms the accuracy of the direct fiscal impact assessment provided by the microsimulation model for most reforms considered and is in line with the evidence on dynamic scoring suggesting that the macroeconomic impact of most tax reforms is usually low (see Gravelle, 2015).

Our particular setting further contributes to improve the accuracy of the tax reform evaluation in the following ways. First, we can mimic with great precision the tax reforms enacted in legislation in our microsimulation model, reflecting actual changes in the tax code, thus bringing additional realism to the analysis. Second, we use the microsimulation model to estimate the behaviour reactions to tax changes both at the intensive and extensive margins of labour supply, which are known to differ

significantly across individuals (e.g. depending on their skill level), possibly yielding significant macroeconomic effects (see in particular Blundell and Stoker, 2005). Third, we calibrate the macroeconomic model in its tax – tax rate on labour income – and labour parameters – wages, participation rate, elasticity of labour supply – using the microsimulation model, thus ensuring consistency between the micro and macro levels of analysis. Fourth, introducing the QUEST model in our analysis allow us to clearly analyse the workings of tax incidence, and we therefore we can distinguish the legal incidence of a given tax reform, as reflected by the change in the tax code, from its economic incidence. Fifth, the use of microsimulation model brings a precise assessment of the equity impact of reforms (e.g. impact across income decile) based on real micro data which inform about their fairness dimension, allowing a distinction between winners and losers in a precise and realistic manner.

Our approach opens up venues for future research and policy analysis. Our tax incidence analysis shows, for instance, that labour supply and labour demand elasticities are crucial to explain why a tax reform might fail to deliver their expected impacts and identify the reform's winners and losers. Moreover, the structural rigidities on wages and prices we find on factor and product markets, and which are modelled in QUEST, are also important to determine the speed of the economic adjustment, with the effects of the reforms occurring further in the future. Future analyses could be devoted to the analysis of more sizeable tax reforms combined with structural reforms in order to investigate possible complementarities between these different policy instruments. Ongoing extensions of the EUROMOD model will allow broadening the scope of the analysis by bringing in consumption tax reforms as well. For instance tax shifting between labour taxes (i.e. PIT or social security contributions) and consumption taxes aim at reducing the distortionary effect of taxation on employment but is also likely to impact on consumption and to have an impact on equity. The framework developed here could be accommodated to analyse these important policy questions as well.

The rest of the paper is organized as follows. Section 2 describes the EU policy context in which our analysis takes place together with an explanation of our modelling choices. In Section 3, we present the micro and the macroeconomic models used in the dynamic scoring exercise. Furthermore, in this section, we discuss the consistency and aggregation issues raised by the dynamic scoring exercise. In Section 4, we describe the way the micro and macro models interact through the labour market and derive labour supply elasticities at the micro and macro level. In Section 5, we illustrate our approach by implementing hypothetical tax reforms in three EU countries, namely Belgium, Italy and Poland. Our summary and conclusions are provided in Section 6.

## **2 Dynamic scoring of tax reforms in the EU: policy context and modelling choices**

The interaction between tax reforms and changes induced in the economy are multi-faceted. As Adam and Bozio (2009) put it, these changes "*affect the government's revenue and outgoings, so the full chain of consequences will determine the actual cost of tax and spending proposals.*" In this sense, it is necessary to capture not only the labour adjustment effects of the tax reforms, but also the overall economic effect, including in the product and factor markets. Mankiw and Weinzierl (2006) provide a good discussion on the effects of tax cuts, by considering two extreme cases: the



static scoring case, which assumes that there is no feedback effect on national income, and the Laffer curve, which shows that there is a concave relationship between tax rates and revenues. In this way, tax cuts can be self-financing if they have a positive effect on economic growth through incentives. These authors rely on the standard neoclassical growth model and find that in the US feedback effects of tax cuts have a significant effect, in particular for capital income taxes. They also point out that their results depend mainly on parameters such as the compensated elasticity of labour supply, the elasticity of substitution between capital and labour, and the externality to capital accumulation. Our analysis follows the approaches developed elsewhere combining both microsimulation and macroeconomic models (see Gravelle, 2014, and Altshuler et al., 2005, for a survey of this literature and practice specific to the US budgetary process). We combine a macroeconomic model – the QUEST model described thereafter – with a microsimulation model – EUROMOD – extended to account for labour supply adjustment (as explained in detail in Section 3). In what concerns the microsimulation set-up, we follow Gravelle (2014) by focusing on the supply side impact of tax reforms, discarding potential demand effect or crowding out which are not necessarily relevant when scoring tax reforms. These other effects are accounted for in the macroeconomic model.

## **2.1. Policy context**

Fiscal policy remains a Member States domain in the EU. The European Commission delivers policy recommendations aimed at promoting growth and sound public finances, in particular through the so-called European Semester process of policy monitoring, in order to ensure that Member States policies contribute to the objectives of the Union, in that case by pursuing sound public finances contributing to economic and financial stability. Accordingly the European Commission analyses the fiscal and structural reform policies of every Member State, provides recommendations, and monitors their implementation accordingly to an annual round of policy dialogue with the EU Member States, the so-called European Semester. In such context, the analysis of how fiscal and structural reforms can affect national budgets and Member States' economic performance as well is required. The assessment of national fiscal policies needs to factoring-in the macroeconomic feedback. The latter is especially relevant to determine the cyclically adjusted fiscal balances upon which national fiscal policy measures are gauged (see in particular Larch and Turrini, 2010). Recently the European Commission has also started to collect data on estimates of the impact of discretionary tax measures relying on the Member States' own assessment and providing information at a more disaggregated level (see in particular Barrios and Fagnoli, 2010). This data shows that discretionary measures can have non-negligible impact on tax revenues proceeds and tax revenues elasticities alike (see, in particular, Princen et al., 2013). Yet, this data emanates from Member States' own estimation methods, which are often left unspecified and are in all cases not comparable across countries given the differences in the definition of baseline scenarios and the method used for assessing the economy-wide impact of the reform. Their use for a common assessment of the impact of tax reforms across countries is therefore necessarily limited.

## **2.2. Modelling choices**

Recently the European Commission has started to use the microsimulation model EUROMOD in order to assess the fiscal and equity impact of tax reforms (see in particular Sutherland and Figari,

2013, for a description of the model). EUROMOD is a tax-benefit microsimulation model, which covers in a consistent manner the 28 Member States of the European Union. The model is a static tax and benefit calculator that makes use of representative microdata from the European Statistics on Income and Living Conditions survey (EU-SILC) and national SILC surveys to simulate individual tax liabilities and social benefit entitlements according to the rules in place in each Member State. Starting from gross incomes contained in the survey data (or estimated by the EUROMOD National teams if the net-gross conversion is not satisfactorily done), EUROMOD allows hence the simulation of most of the (direct) tax liabilities and (non-contributory) benefit entitlements and, ultimately, the analysis of the role played by each tax and benefit component in the formation of the household net disposable income. The model is unique in its area as it integrates taxes, social benefits and models tax expenditures into the same framework, thus accounting for interactions between which, in the European case, can have non-negligible impact, in particular in terms of work incentives, see in particular (Barrios et al., 2016).<sup>3</sup> Section 3 provides more additional details on the use of the EUROMOD model for the analysis presented in this paper. EUROMOD allows a consistent modelling of tax and social benefits system using harmonised survey data which follow the same standards across countries. It is then the natural candidate for performing analyses of the impact of discretionary tax reforms affecting households. In this sense EUROMOD can be used, like any other tax calculator, in order to evaluate the changes in effective tax rates led by a given reform which can in turn be incorporated as policy shocks in a macro-model in order to derive its macroeconomic impact.

We combine EUROMOD (extended to account for labour supply adjustment) with the DSGE model QUEST. The QUEST model is chosen for a number of reasons. Firstly, it is the standard model used by the European Commission in order to analyse the impact of fiscal and structural reforms in the EU Member States (see for instance In't Veld and Varga, 2014). Secondly, QUEST is particularly appropriate to analyse the adjustment of the economy over the medium-term accounting for the interaction between the economy and the fiscal and monetary policy stance. A dynamic general equilibrium model like QUEST can capture the behavioural responses in all macroeconomic variables in an open economy context, going beyond the direct impact of a specific tax reform as measured in EUROMOD. The latter is particularly relevant for the EU given the high level of integration between EU countries. It is thus relevant to use this model in the context of the assessment of the stability and convergence programmes submitted by the EU Member States to the European Commission which provides the Member States fiscal projections and underlying macroeconomic hypotheses over this time span as well. Thirdly, given that we focus on the labour supply adjustment, it is important that our modelling of labour supply in the micro and macro models is consistent, which is actually the case here, in particular given the general (and flexible) modelling of labour supply adopted at the micro-level and the strong microeconomic foundations of the QUEST model.

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<sup>3</sup> Note that some tax expenditures in EUROMOD are not modelled, especially when these are deductible against personal expenses, e.g. in particular education or health related tax expenditure. For an extension of spending-related tax expenditure in EUROMOD see Barrios et al. (2016).

## 3 Modelling the second-round effects of tax reforms

### 3.1. The discrete choice labour supply model

To estimate the labour supply responses to tax reforms, we estimate discrete choice models for each country of interest. This approach has recently been applied in a cross-country study for several European countries – Bargain, Orsini, and Peichl (2014), whose approach we follow closely. The compelling advantage of this approach consists in offering a unified framework to estimate labour supply behaviour for a wide range of countries. Discrete choice models have become increasingly popular in the labour supply literature since they have been used by Aaberge, Dagsvik, and Strøm (1995), Dagsvik (1994) and van Soest (1995). They offer a very appropriate framework that is based on the estimation of the same structural model separately for each country, thus netting out methodological differences and enabling consistent comparisons across countries.

We estimate a structural discrete choice labour supply model as in Bargain, Orsini, and Peichl (2014) for households and individuals using the microsimulation model EUROMOD and EU-SILC household data. Households are assumed to maximize utility and thereby face the standard consumption-leisure trade-off. In contrast to the classical “continuous choice” approach, we estimate a discrete choice model where agents can choose from a limited number of discrete alternatives. The framework has its theoretical roots in the Random Utility Model of McFadden (1973). Econometrically, it entails the specification and estimation of consumption-leisure preferences, and the evaluation of utility at each discrete alternative.<sup>4,5</sup> Labour supply decisions are taken from a discrete set of alternatives, that is, households can choose to work half-time (20 hours), full-time (40 hours), over-time (60 hours), or remain inactive (not participate in the labour market, supplying zero hours). In this way, the choice covers both extensive and intensive margins.<sup>6</sup> Utility consists of a deterministic part that is a function of observable variables, and an error term which can reflect optimization errors of the household, measurement error concerning the explanatory variables, or unobserved preference characteristics. For the deterministic part we specify a utility function that depends on both household characteristics and characteristics of the hours' category (most notably the associated work and leisure times and on the disposable income from working the respective amount of time, but also fixed costs of taking up work). By letting household characteristics enter the utility function, we allow for observed heterogeneity in household preferences. Household characteristics also influence how gross income translates into disposable income through the tax-benefit-function: disposable income is a function of household earnings, non-labour income, and household characteristics (e.g. age, marital status, number of children). We use recent European household datasets from the EU-SILC for household incomes and demographics, and the microsimulation model EUROMOD to calculate direct taxes, social insurance contributions and received benefits to obtain disposable incomes. The estimation is implemented as maximum

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<sup>4</sup> See van Soest (1995) or Hoynes (1996) among others.

<sup>5</sup> In contrast to the classical labour supply model where households choose from a continuous set of working hours (Hausman 1985), it is not necessary to impose tangency conditions, and in principle the model is very general. In practice, a functional form for the utility function has to be explicitly specified. However, the choice of functional form has no major influence on the estimated elasticities (see Löffler, Peichl, and Siegloch 2014).

<sup>6</sup> Estimation is possible even with non-convexities in households' budget sets and can be extended to joint estimation of couples in a relatively straightforward manner, as explained in Creedy and Kalb (2006), Aaberge, Colombino, and Wennemo (2009), and Bargain, Orsini, and Peichl (2014).

likelihood estimation. As is standard in the literature, we estimate single men, single women, and couples separately. Married couples are assumed to maximize a joint utility function where each combination of the two partners' hours is a distinct category (resulting in 16 categories for couples, compared to 4 for singles). Standard errors for elasticities can be obtained via bootstrap. Appendix A provides more detailed information on the econometric model.

Regarding the identification strategy, as the tax-benefit calculator EUROMOD accounts for a rich set of policies, we make use of the variation provided by nonlinearities and discontinuities inherent in the tax and social benefits systems. This is the usual source of variation for models estimated on cross-sectional data that cannot rely on variation over time, as explained in Bargain, Orsini and Peichl (2014).<sup>7</sup> Effective tax rates vary with household characteristics (such as marital status, age, family composition, virtual income, etc.). Although we include some of these characteristics in the estimated utility functions, tax-benefit rules condition on a richer variety of household characteristics (for example, detailed age of children, regional information or home-ownership status). Hence, the data provide variation in net wages that allows identification of the econometric model.

### 3.2. The microsimulation model

As explained above, for the discrete choice estimation, it is necessary to calculate the disposable incomes in each respective hours category. For this, we use the European microsimulation model EUROMOD and recent micro data from the European Union Statistics on Income and Living Conditions (EU-SILC). The micro data have been further harmonized within the EUROMOD project, to ensure similar income concepts are used together with comparable variable definitions (e.g. for education). We use EUROMOD to compute the reformed tax-benefit policy, as well as to evaluate the required points of the households' preference set to evaluate choice probabilities. We use the latest available version "G3.0+" of EUROMOD for our study, which includes tax and benefit systems for 28 countries of the European Union, from 2005 (varies across countries) up to 2015. Using EUROMOD, we calculate the corresponding disposable income, that is, apply the appropriate tax rules to calculate the after-tax income and then simulate social insurance contributions, as well as benefits and pensions the individual may be eligible for, and add those to the after-tax income.

In this study, we focus on specific tax reforms in Belgium, Italy and Poland. We use data with an income reference year of 2011, and we use the tax-benefit system of 2013 for the simulation of taxes and transfers. Note that since the 2013 tax systems are used, EUROMOD uprates the monetary data in the EU-SILC microdata input files, according to uprating factors based on the evolution of relevant prices indices and benefit law in the period. For each discrete choice category  $j$  and each household  $i$ , disposable income  $C_{ij}$  is calculated by aggregating all sources of household income, adding received benefits (family and social transfers), while subtracting direct taxes (on labour and capital income) and social security contributions.<sup>8</sup> In practice, this calculation is done by EUROMOD, based on the information on income and socio-demographic characteristics  $X_i$ , as is available in the EUROMOD version of EU-SILC.

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<sup>7</sup> See van Soest (1995) and Blundell et al. (2000).

<sup>8</sup> These tax-benefit calculations correspond to function  $d(\cdot)$ , as defined in (A.1.3) in Appendix A.

For the purpose of the labour supply estimation, we divide the base sample into three subsamples for each country, depending on the household type: we estimate the utility functions for couples, single men and single women (the latter two including single parents) separately. We restrict each estimation sample to adults aged between 18 and 60 that are available to take part flexibly in the labour market, thereby excluding disabled or retired people, those in education, self-employed, or farmers.<sup>9</sup>

### **3.3. The macroeconomic DSGE model**

The macroeconomic model used in this analysis is an extension of the European Commission New-Keynesian model, QUEST III (see Ratto et al, 2009), to include different skilled workers. This model is a three-region open-economy model, calibrated for the country of interest, the (rest of) euro area and the rest of the world. For each region, the model economy is populated by households and final goods producing firms. There is a monetary and fiscal authority, both following rule-based stabilisation policies. The domestic and foreign firms produce a continuum of differentiated goods. The goods produced in the home country are imperfect substitutes for goods produced abroad. The level of competition among firms is captured by the inverse elasticity of substitution between the goods varieties, which can be directly linked to the gross mark-up that firms charge over the marginal cost of production – higher degrees of substitutability imply lower mark-ups. From the consumers' side, we distinguish between households which are liquidity constrained and consume their disposable income and non-liquidity constrained (so-called Ricardian) households who have full access to financial markets. The latter group of households make decisions on financial and real capital investments. The model is a fully forward-looking dynamic model in which all investment decisions are based on the expected future stream of income. In order to measure the distributional consequences of policies we introduce three skill groups into the model earning different wages. Additionally, we identify the liquidity constrained households as low-skilled and the non-liquidity constrained households as medium- and high-skilled. By using the ISCED education classification, we define the share of population with up to lower secondary education (ISCED 0-2) as low-skilled, with up to upper secondary, non-tertiary education (ISCED 3-4) as medium skilled and the rest of the population as high-skilled. Appendix B explains in detail the main blocks of our macro model – households, firms, policies and trading sector.

### **3.4. Aggregation**

The interaction between the micro and macroeconomic models described above raises consistency issues related with the way agents' heterogeneity is handled in each of the frameworks. On the one hand, the discrete choice model allows us to obtain estimates of behavioural responses – labour supply, at the intensive and extensive margins, and household income elasticities – of different groups of workers, according to their socio-economic characteristics, such as age, gender, marital status and education, among others. On the other hand, the QUEST model provides the general equilibrium effects including other agents' behaviour like firms, and the impact on overall macroeconomic outcomes. This means that we need to combine different degrees of heterogeneity

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<sup>9</sup> For the Heckman-corrected wage estimation, we apply the same restrictions on the sample, but estimate the sample separately for women and men (that is, not separately by household types).

and methods of handling this heterogeneity among models. We will focus the discussion on aggregation on the choice of selected structural parameters of QUEST and the role of the labour market in shaping the interaction between the microsimulation model and the macro-DSGE model.

Aggregation is a controversial topic when using dynamic stochastic general equilibrium models for policy predictions. Chang, Kim and Schorfheide (2011) find biases in policy predictions due to the lack of invariance in the structural parameters in representative agent models, to different policy regimes. An important strand of the literature has been investigating the structural nature of the preferences and technology parameters of DSGE models under different policy regimes, including Altissimi, Siviero and Terlizzesse (2002), Fernández-Villaverde and Rubio-Ramírez (2007), Cogley and Yagihashi (2010), to cite just a few. This question has direct implications for the methods chosen to take DSGE models to the data, i.e. to quantitatively evaluate these models. In this paper, we calibrate the QUEST by selecting behavioural and technological parameters so that the model replicates important empirical ratios such as labour productivity, investment, consumption to GDP ratios, the wage share, the employment rate, given a set of structural indicators describing market frictions in goods and labour markets, tax wedges and skill endowments.<sup>10</sup> Most of the variables and parameters are taken from available statistical or empirical sources from the literature. The remaining parameters are pinned down by the mathematical relationships of the model equations and by the steady-state conditions. Regarding the labour market, we calibrate QUEST using the micro econometric information supplied by EUROMOD extended by the labour supply discrete choice model, in order to ensure consistency between the two models. In this way, we use the estimates for labour supply elasticities, by skill level, estimated by EUROMOD extended to labour supply to calibrate the parameter  $\kappa$  of the household utility function for the different skill groups considered. In doing so, we assume that these elasticities are structural parameters which are tied to the utility function and estimated labour supply and remain unchanged under a policy reform scenario. This means that when we implement the tax reform in QUEST by matching the tax rates on labour paid by employees ( $t_{W,s,t}$ ) and employers ( $t_{er,s,t}$ ) to the implicit tax rates obtained from our microsimulation model, we consider that in the baseline and in the reform scenario these elasticities do not change, which amount to assuming that the utility function remains unaltered.

## 4 Labour market and tax incidence

The labour market plays the key role in linking the micro and macro models in our analysis. Here we follow the analysis of Magnani and Mercenier (2007)<sup>11</sup>, which to some extent can be seen as a simplified version of linking the micro and macro models we use in our dynamic scoring analysis, in

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<sup>10</sup> Supplementary data associated with the calibration of the QUEST III model can be found in the online version of Ratto et al (2009) at <http://publications.jrc.ec.europa.eu/repository/handle/JRC46465>.

<sup>11</sup> They describe an exact aggregation of the results of a discrete choice model and a representative agent macroeconomic model, with constant elasticity of substitution/transformation utility function. They show that in order to ensure consistency between the micro and macro models, whereby both models can be characterized by similar equilibrium/optimality conditions, the calibration of the macro model labour parameters (labour elasticities and labour shares, fundamentally) must be tied to the statistical parameters of the probability distribution of the micro data. In Magnani and Mercenier (2007), like in our case, the labour market decisions at the micro level are modelled as a discrete-choice model, where choice probabilities are derived from a multinomial-logit distribution. They show that the micro and macro optimality conditions are identical if the "deep" parameter of the macroeconomic model – elasticity of substitution in the utility function – coincides with the dispersion parameter of the multinomial logit population from the discrete choice model, and the shares of time spent in leisure activities are matched to measures of the disutility of working (wage).

order to ensure consistency between our discrete choice labour supply model and the labour supply modelling in QUEST. Our aim is to compare the optimal labour supply produced in the micro and macroeconomic settings, in terms of how the decision is modelled. We also derive the labour supply elasticities for both the micro and macro models. Finally, we describe in detail how tax incidence works in the labour market modelled in QUEST.

#### 4.1. The labour supply function

Let us focus first on the modelling of the labour supply side of the labour market from the microeconomic perspective. We assume that each individual  $i$  faces alternatives of working 0, 20, 40 or 60 hours per week such that her preferences can be described by the following stochastic utility function:

$$V_{ij} = U_{ij}(C_{ij}, H_{ij}, \cdot) + \epsilon_{ij} \quad (1)$$

where  $\epsilon_{ij}$  is an independent and identically distributed error term for the each of the choice  $j$ , and follows an extreme value type I (EV-I) distribution. Then we can define the probability of  $i$  choosing alternative  $j \in \{0, 20, 40, 60\}$  as follows:

$$\begin{aligned} Prob_{ij} &= prob[V_{ij} \geq V_{ik}, \forall k \in \{0, 20, 40, 60\}, k \neq j] \\ &= prob[U_{ij}(C_{ij}, H_{ij}, \cdot) + \epsilon_{ij} \geq U_{ik}(C_{ik}, H_{ik}, \cdot) + \epsilon_{ik}, \forall k \in \{0, 20, 40, 60\}, k \neq j] \\ &= prob[U_{ij}(C_{ij}, H_{ij}, \cdot) - U_{ik}(C_{ik}, H_{ik}, \cdot) \geq \epsilon_{ik} - \epsilon_{ij}, \forall k \in \{0, 20, 40, 60\}, k \neq j] \\ &= prob[\epsilon_{ik} - \epsilon_{ij} \leq U_{ij}(C_{ij}, H_{ij}, \cdot) - U_{ik}(C_{ik}, H_{ik}, \cdot), \forall k \in \{0, 20, 40, 60\}, k \neq j] \\ &= F(\epsilon_{ik} - \epsilon_{ij}) \end{aligned} \quad (2)$$

Since we have assumed that  $\epsilon_{ij} \sim EV - I$ , then we can write the generalized extreme value distribution function as follows:

$$F(\epsilon_{i0}, \epsilon_{i20}, \epsilon_{i40}, \epsilon_{i60}) = exp[-H(e^{-\epsilon_{i0}}, e^{-\epsilon_{i20}}, e^{-\epsilon_{i40}}, e^{-\epsilon_{i60}})] \quad (3)$$

Where function  $H$  satisfies all the necessary conditions to ensure that  $F$  is a cumulative distribution function. Following Magnani and Mercenier (2007), we assume that the following functional form for  $H^f$  is:

$$H^f(\epsilon_{i0}, \epsilon_{i20}, \epsilon_{i40}, \epsilon_{i60}) = \sum_{s \in \{0, 20, 40, 60\}} \epsilon_{is}^{1/\mu} \quad (4)$$

Given the above functional form of  $H$ , then the cumulative distribution  $F$  is equal to the product of double exponential distributions that characterize the behaviour of  $V_{ij}$  for each alternative of working hours such that:

$$H^f(e^{-\epsilon_{i0}}, e^{-\epsilon_{i20}}, e^{-\epsilon_{i40}}, e^{-\epsilon_{i60}}) = \sum_{s \in \{0, 20, 40, 60\}} (e^{-\epsilon_{is}})^{1/\mu} = \sum_{s \in \{0, 20, 40, 60\}} e^{-(\epsilon_{is}/\mu)} \quad (5)$$

and  $F$  assumes the following form:

$$F(\epsilon_{i0}, \epsilon_{i20}, \epsilon_{i40}, \epsilon_{i60}) = exp\left[-\sum_{s \in \{0, 20, 40, 60\}} e^{-(\epsilon_{is}/\mu)}\right] = \prod_{s \in \{0, 20, 40, 60\}} exp\left[-e^{-(\epsilon_{is}/\mu)}\right] \quad (6)$$

Then, according to McFadden theorem, the probability of  $i$  choosing alternative  $j$  is given by:

$$Prob_{ij} = \mu \frac{\partial \ln H(e^{U_{i0}}, e^{U_{i20}}, e^{U_{i40}}, e^{U_{i60}})}{\partial U_{ij}} \quad (7)$$

where  $\mu$  is the dispersion parameter of the extreme value distribution. The probability we are looking for can be obtained by substituting (5) into (7) to obtain:

$$Prob_{ij} = \frac{e^{U_{ij}/\mu}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}/\mu}} \quad (8)$$

which, when  $\mu = 1$ , is equivalent to :

$$Prob_{ij} = \frac{e^{U_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}}. \quad (9)$$

Then, the expected number of hours supplied by individual  $i$  will be given by:

$$L_i = \sum_{j \in \{0,20,40,60\}} Prob_{ij} * j = \sum_{j \in \{0,20,40,60\}} \left( \frac{e^{U_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \right) * j = \frac{\sum_{j \in \{0,20,40,60\}} j * e^{U_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \quad (10)$$

Consider now that a given individual  $i$  belongs to a particular sub-population group that share the same socio-economic characteristics, and that there are  $N$  statistically identical and independent individuals in this sub-population group. Then, within this group, the expected number of hours supplied will be given by:

$$L = \sum_{i=1}^N L_i = \sum_i^N \left[ \frac{\sum_{j \in \{0,20,40,60\}} j * e^{U_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \right] \quad (11)$$

Note that equation (11) is a simplified analytical expression of the labour supply function for a group of individuals sharing the same socio-economic characteristics. We can also compute the expected number of individuals in this population subgroup that will choose any of the working hours' alternatives. For instance, the expected number of individuals supplying zero hours, i.e. individuals deciding not to participate in the labour market, is equal to:

$$L_{j=0} = Prob_{i0} * N = \left( \frac{e^{U_{i0}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \right) * N \quad (12)$$

Similarly, the expected number of working individuals, i.e. individuals supplying non-zero working hours, is equal to:

$$L_{j \neq 0} = (1 - Prob_{i0}) * N = \left( 1 - \frac{e^{U_{i0}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \right) * N = N - L_{j=0} \quad (13)$$

In more general terms, the expected number of individuals choosing any alternative  $j$  of the setting of alternatives is equal to:

$$L_j = Prob_{ij} * N = \left( \frac{e^{U_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \right) * N \quad (14)$$

We turn now to the macroeconomic setting. In QUEST the labour market is populated by workers, and firms. The QUEST model therefore takes into account both the supply and demand of labour. Focusing only on the partial equilibrium, this translates into a system of equations that allows finding the equilibrium wage and working hours. In this way, and abstracting from other general



equilibrium effects, the referred system is presented below (and graphically sketched in more detail in section 5):<sup>12</sup>

$$\left\{ \begin{array}{l} \frac{V_{1-L,h,s,t}}{U_{C,h,s,t}} \frac{1}{\eta_{s,t}} = \frac{W_{s,t}(1-t_{w,s,t}-b)}{P_{c,t}(1+t_{c,t})} \\ P_{j,t} \frac{\partial Y_{j,t}}{\partial L_{j,s,t}} \eta_{j,t} = (1+t_{er,s,t}) W_{s,t} + \frac{\partial \Gamma^L(L_{j,L,t}, L_{j,M,t}, L_{j,H,t})}{\partial L_{j,s,t}} \end{array} \right. \text{ for } s \in \{H, M, L\} \quad (15)$$

where the first equation of the system<sup>13</sup> results from the combination between the first order conditions with respect to consumption and labour – i.e. is the inter-temporal and the intra-temporal optimality conditions, respectively – resulting from the household problem, and the second equation of the system results from maximizing firms profits with respect to labour.<sup>14</sup> From this system in (15), we obtain the partial equilibrium pair of hours worked and wage rate  $(L_{s,t}^*, W_{s,t}^*), s \in \{H, M, L\}$ . Notice that the decisions modelled in the supply side of the labour market have similar aspects in both micro and macro settings: both consider maximization of individual/household utilities, which depend on consumption and leisure. However, in the macro setting, the number of hours worked in equilibrium is derived from intersecting labour supply and labour demand functions, i.e. QUEST take into account the demand of labour. This demand effect, which is basically constrained by the labour demand elasticity to wages, is not considered in the micro framework but rather taken as given by the macro-economic conditions described by the DSGE model.<sup>15</sup> Considering the following functional form of the household utility function in QUEST, given by expressions (16) and (17) below<sup>16</sup>, for skill group  $s \in \{H, M, L\}$ ,

$$V_{1-L,h,s,t} = \frac{\omega_s}{(1-L_{i,s,t})^{\kappa}}, s \in \{H, M, L\} \quad (16)$$

and,

$$U_{C,h,s,t} = \frac{1-habc}{C_{i,t}-habcC_{t-1}}, s \in \{H, M, L\} \quad (17)$$

and substituting them in the inter-temporal condition of the system in (15), we obtain the expression for the labour supply function in QUEST:

$$L_{i,s,t} = 1 - \left[ \frac{\omega_s}{\eta_{s,t}(1-habc)} \frac{P_{c,t}(1+t_{c,t})(C_{i,t}-habcC_{t-1})}{W_{s,t}(1-t_{w,s,t}-b)} \right]^{1/\kappa} \Leftrightarrow L_{i,s,t} = 1 - \left[ \frac{\omega_s}{\eta_{s,t}} \frac{1}{W_{s,t}(1-t_{w,s,t}-b)} \frac{P_{c,t}(1+t_{c,t})}{U_{C,h,s,t}} \right]^{1/\kappa} \quad (18)$$

If we now consider that there are  $N$  identical households on the skill group  $s \in \{H, M, L\}$  we can rewrite (18) as follows:

<sup>12</sup> Note that QUEST is characterized by the system of all the equilibrium conditions of economic agents, laws of motion of state endogenous variables and shocks, and feasibility conditions, and as such the solution of the model implies solving this system, and having all the (approximated) conditions met simultaneously in the steady state.

<sup>13</sup> This corresponds to equation B.7 in Appendix B.

<sup>14</sup> This corresponds to equation B.15 in Appendix B.

<sup>15</sup> Notice that not considering labour demand in the micro model can be problematic in what concerns the coherence between the micro and macro settings. It may be difficult to obtain convergence on the main economic aggregates between the two models.

<sup>16</sup> These correspond to expressions B.2 and B.3 in Appendix B.

$$L_{s,t} = N \left( 1 - \left[ \frac{\omega_s}{\eta_{s,t}} \frac{1}{W_{s,t}(1-t_{W,s,t}-b)} \frac{P_{c,t}(1+t_{c,t})}{U_{c,h,s,t}} \right]^{1/\kappa} \right) \quad (19)$$

Expression (19) can be compared with expression (13), the expected number of individuals that was derived in our simplified discrete choice setting. First of all, notice that both expressions are optimality conditions derived from a utility maximization problem, conditional on how much the household wants to consume. To see this better, we can write expression (19) in the following terms:

$$L_{s,t} = N(1 - g(X_t; T_t; \Omega)) \quad (20)$$

where  $g(\cdot)$  is a function of a vector of aggregated endogenous variables,  $X_t$ , a vector of policy exogenous variables,  $T_t$ , and a vector of parameters,  $\Omega$ , with  $X_t = (C_{i,t}, W_{s,t}, P_{c,t}; \eta_{s,t})$ ;  $T_t = (t_{W,s,t}, t_{c,t}, b)$ ;  $\Omega = (\kappa, \omega_s, habc)$ .

In a similar way, we can rewrite (13) as follows:

$$L_{j \neq 0} = N(1 - F(U_{ij}; \Theta)) \quad (21)$$

where  $F(\cdot)$  is the distribution function depending on the arguments of the deterministic utility function  $U_{ij} = (C_{ij}, H_{ij}, Z_{ij})$  and on a set of parameters  $\Theta$ . However, while expression (19) denotes the optimal amount of labour services supplied, in terms of total number of hours, for any level of the net adjusted wage – intensive margin –, expression (13) denotes the expected number of individuals working in the economy – extensive margin. Furthermore, notice that, in QUEST, unemployment is obtained endogenously and is equal to:

$$UNEMPL = 1 - NPART_{L,t} - L_{L,t} \quad (22)$$

where  $NPART$  is the non-participation rate. In QUEST households only decide on the amount of hours supplied in the labour market, but they do not choose between unemployment and non-participation, explicitly. The non-participation rate is calibrated as the proportion of inactive in the total population. The non-participation rate ( $NPART$ ) must therefore be seen as an exogenous policy variable characterising the generosity of the benefit system. However, in our discrete choice model the choice of non-participation, or being unemployed voluntarily, is one of the possible alternatives of individual  $i$ . The choice of participating in the labour market is nested together with the decision on supplying different number of hours (which can be seen as the different working modalities). We reconcile the two models on this issue by calibrating in QUEST the non-participation rate according to the expected number of individuals that choose to be out of the labour market, i.e. equation (12) in the discrete choice model.

## 4.2. Labour supply elasticities

In our dynamic scoring exercise, labour market elasticities are crucial to understand the effects of a particular tax reforms on the households' disposable income, in particular, and on the economy as a whole. More specifically, the labour supply elasticity is a good measure of the work effort incentives, and, in this way, crucial to understand the effects of the tax reforms implemented on the workers behaviour. Moreover, the analysis of the elasticities in both models is important to see whether we

can calibrate QUEST with the elasticities obtained from our microeconomic model, so that a greater consistency can be achieved in linking the two models.

In what follows we derive analytically the labour supply elasticities in the micro and macro settings, and see how these relate to each other. Recall that in what concerns QUEST, the parameter that we are interested in calibrating is the parameter  $\kappa$ .<sup>17</sup> This parameter relates the Frisch elasticity to the inter-temporal elasticity of substitution, as we will see in what follows.

In QUEST, the Frisch elasticity is defined as the elasticity of the labour supply, as defined in equation (19), with respect to the wage, maintaining the marginal utility of consumption constant. In this way, we can define the Frisch elasticity as follows:

$$\varepsilon_{L,W}^F = \frac{\partial L_{s,t} / L_{s,t}}{\partial W_{s,t} / W_{s,t}} \Leftrightarrow \varepsilon_{L,W}^F = \frac{1}{\kappa} \left( \frac{N - L_{s,t}}{L_{s,t}} \right) \quad (23)$$

The elasticity in (23) suggests a positive relationship between wages and labour supply, depending on the level of labour hours supplied. This implies that the Frisch elasticity might differ (and, in fact, it will) for the three skill groups considered in QUEST. In this way, we expect that some groups will be more reactive to changes in the wage level than others. Besides the Frisch elasticity, another important result in macroeconomic models such as QUEST is how labour supply evolves over time, given temporary changes in the wages path. This is known as the inter-temporal elasticity of substitution,  $\varepsilon^{IES}$ . In this way, this elasticity measures the relation between the changes in the ratio of labour supplied tomorrow and today, and the ratio of wages paid tomorrow and today. In order to derive this elasticity, we need to find the inter-temporal labour supply function, where we can relate the path of labour supply with the path of wages. We present the derivation of the inter-temporal labour supply elasticity in Appendix C. Denoting  $\frac{1 - L_{i,s,t+1}}{1 - L_{i,s,t}} = (1 - \widehat{L}_{i,s})$  and  $\frac{W_{s,t+1}}{W_{s,t}} = \widehat{W}_s$ , the inter-temporal labour supply function is given by:

$$(1 - \widehat{L}_{i,s}) = \left[ \beta(1 + i_t) \frac{\eta_{s,t}}{\eta_{s,t+1}} \frac{1 - t_{W,s,t} - b}{1 - t_{W,s,t+1} - b} \right]^{1/\kappa} (\widehat{W}_s)^{-1/\kappa} \quad (24)$$

We can now compute the elasticity of inter-temporal substitution for leisure since the results are very easily extrapolated in terms of labour supply. We apply logarithms to equation (24) and then compute the derivative of the  $\ln(1 - \widehat{L}_{i,s})$  with respect to  $\ln(\widehat{W}_s)$ . In this way, we obtain the following expression:

$$\ln(1 - \widehat{L}_{i,s}) = \frac{1}{\kappa} \ln \left[ \beta(1 + i_t) \frac{\eta_{s,t}}{\eta_{s,t+1}} \frac{1 - t_{W,s,t} - b}{1 - t_{W,s,t+1} - b} \right] - \frac{1}{\kappa} \ln(\widehat{W}_s) \quad (25)$$

and

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<sup>17</sup> Please check the functional form given in expression (B.3) in Appendix B.

$$\frac{d \ln(\widehat{1-L_{i,s}})}{d \ln(\widehat{W_{s,t}})} = -\frac{1}{k} \Leftrightarrow \frac{d(\widehat{1-L_{i,s}})/(\widehat{1-L_{i,s}})}{d(\widehat{W_{s,t}})/(\widehat{W_{s,t}})} = -\frac{1}{k} \Leftrightarrow \varepsilon_{1-L_{i,s}}^{IES} = -\frac{1}{k} \quad (26)$$

As we can observe from expression (26), parameter  $k$  guides the elasticity of inter-temporal substitution, and the smaller this parameter is, the higher (in absolute terms) is this elasticity, and the more willing is the household to change the path of leisure (or labour), given temporary changes in wages. Moreover, we can see clearly that the relation between the Frisch elasticity and the inter-temporal elasticity of substitution depends on the parameter  $k$ . In this way, we can establish the following relation between the two elasticities:

$$\varepsilon_{L,W}^F = -\varepsilon_{1-L_{i,s}}^{IES} \left( \frac{N-L_{s,t}}{L_{s,t}} \right) \quad (27)$$

In the nonlinear discrete choice econometric model, labour supply elasticities cannot be derived analytically. However, using the estimated structural utility function, we can calculate choice probabilities for varying incomes. Wage elasticities are calculated after simulating a marginal increase in the wage rate and predicting the probability distribution over the choice categories for the increased wage rate. The wage elasticity is defined as the change in expected working hours (that is, the probability-weighted average of working hours) with respect to the change in the wage rate. Similarly, we calculate expected incomes, benefits, and tax payments before and after the simulated income change. In this way, using the estimated structural utility function, we predict the probability distribution over the hour's categories that emerge after simulating a marginal increase in the wage rates. As the estimated utility function depends on the net income, the predicted probability distribution will change after the simulated income change. Recall from equation (10) the expected hours supplied by household  $i$ . Denote by  $\tilde{U}_{ij}$  the predicted utility of the household from working  $j$  hours at the marginally increased wage rate. Then expected hours for the new wage can be calculated in the same way:

$$\tilde{L}_i = \frac{\sum_{j \in \{0,20,40,60\}} j * e^{\tilde{U}_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{\tilde{U}_{is}}} = \sum_{j \in \{0,20,40,60\}} \widetilde{Prob}_{ij} * j. \quad (28)$$

The labour supply elasticity can be calculated as the change in predicted hours with respect to the marginal change in the wage rate:

$$\varepsilon_{L_i,W} = \frac{\partial L_i / L_i}{\partial w_i / w_i} = \frac{(\tilde{L}_i - L_i) / L_i}{(\tilde{w}_i - w_i) / w_i} \quad (29)$$

The econometric framework from which the elasticity is calculated is static in nature. We rely on cross sectional data and do not observe households at multiple points in time. Moreover, the econometric model does not encompass saving decisions. The elasticities we estimate are uncompensated – Marshallian – elasticities. The Marshallian elasticity is related by the Slutsky equation to the compensated – Hicksian (Hicksian) income elasticity. In studies focusing on the deadweight loss of taxation or steady state responses to tax changes, the Hicksian elasticity is the crucial parameter. However, these studies usually assume that tax revenue is redistributed as a lump

sum payment to households, shutting off the income effect. As we do not make this assumption, tax changes have income effects, and the Marshallian elasticity is the appropriate parameter to use. In principle, we could obtain the Hicksian elasticity as the residual of the Marshallian elasticity (the one we estimate) and the income effect (which we could calculate by simulating a marginal increase in non-labour income) but since we focus on a situation with income effects, we refrain from doing so.<sup>18</sup>

Comparing the elasticities defined both in the micro and in macroeconomic settings, we conclude that, in fact, the elasticity defined in (29) is the micro-equivalent to the elasticity derived in (23), i.e. the Frisch elasticity, in the macro setting. This is a very important result, because we can greatly improve the consistency between the two models by calibrating the Frisch elasticity with the labour supply elasticities estimated from the discrete choice model. In this way, parameter  $\kappa$  in QUEST can be obtained from the following expression:

$$\kappa = \frac{1}{\varepsilon_{L,W}^F} \frac{N-L_{S,t}}{L_{S,t}} \quad (30)$$

where  $\varepsilon_{L,W}^F = \varepsilon_{L_i,W}$ .

### 4.3. Tax incidence

For our exercise is very important to assess how the tax incidence mechanism works in the labour market defined in the QUEST model. In this way, following Fullerton and Metcalf (2002) analysis of tax incidence and considering the labour market of the QUEST model, workers face the statutory burden of paying the fraction  $t_w$  of the gross wage, receiving the net wage defined as follows (for simplicity we abstract here from time and skill type indices):

$$NW = (1 - t_w)W \quad (31)$$

The firms pay gross wages and social insurance contributions, i.e. a total compensation of employees defined by:

$$TC = (1 + t_{er})W \quad (32)$$

where  $W$  is the gross wage, facing, in this way, the statutory tax rate of  $t_{er}$ . However, the economic incidence of these taxes may be different from their legal incidence, and this will basically depend on the labour supply and demand elasticities with respect to wages. As in Fullerton and Metcalf (2002), let us define labour supply elasticity with respect to net wage as follows:

$$\varepsilon_{LS} = \frac{dL_S/L_S}{dNW/NW} = \frac{dL_S/L_S}{d[(1-t_w)W]/[(1-t_w)W]} \cong \frac{\widehat{L_S}}{\widehat{W} - \widehat{t_w}}, \quad (33)$$

where the symbol  $\widehat{\phantom{x}}$  represents percent changes. The changes in labour supply will depend on the changes on gross wages, taxes and on the elasticity parameter as follows:

$$\widehat{L_S} = (\widehat{W} - \widehat{t_w})\varepsilon_{LS} \quad (34)$$

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<sup>18</sup> Note that Bargain et al. (2014) estimate uncompensated, income and compensated elasticities using EUROMOD. They find that income effects are almost zero and hence the difference between compensated and uncompensated elasticities is small.

In the same way, we can define labour demand elasticity with respect to the total compensation of employees as follows:

$$\varepsilon_{LD} = \frac{dL_d/L_d}{dTC/TC} = \frac{dL_d/L_d}{d[(1+t_{er})W]/[(1+t_{er})W]} \cong \frac{\widehat{L_d}}{\widehat{W} + \widehat{t_{er}}} \quad (35)$$

and the changes in labour demand will depend equally on gross wages, taxes and on the elasticity parameter as follows:

$$\widehat{L_d} = (\widehat{W} + \widehat{t_w})\varepsilon_{LD} \quad (36)$$

Tax changes will lead to a new equilibrium in the labour market, which implies that:

$$\widehat{L_s} = \widehat{L_d}. \quad (37)$$

Substituting (34) and (36) into (37), we find that, in order to reach the new equilibrium, changes in gross wages will be given by the following expression:

$$\widehat{W} = \frac{\varepsilon_{LS}}{\varepsilon_{LS} - \varepsilon_{LD}} \widehat{t_w} + \frac{\varepsilon_{LD}}{\varepsilon_{LS} - \varepsilon_{LD}} \widehat{t_{er}}. \quad (38)$$

Since in QUEST,  $0 < \varepsilon_{LS} < \infty$  and  $\varepsilon_{LD} < 0$ , the final change in the equilibrium wage will depend on the relative magnitude of the elasticities and the signs and magnitude of the fiscal policy shocks, i.e., the relative changes in  $t_w$  and  $t_{er}$ . In the same way, we can also find the changes in the net wages and total compensation of employees, given the changes in the tax rates for employees and employers. Consider the definition of net wages in (31). Applying logarithms and differentiating, we obtain:

$$\widehat{NW} = \widehat{W} - \widehat{t_w}. \quad (39)$$

Substituting (38) in (39), we obtain that:

$$\widehat{NW} = \frac{\varepsilon_{LD}}{\varepsilon_{LS} - \varepsilon_{LD}} (\widehat{t_w} + \widehat{t_{er}}) \quad (40)$$

The ratio  $\frac{\varepsilon_{LD}}{\varepsilon_{LS} - \varepsilon_{LD}}$  is negative. This means that there is an inverse relationship between the change in total taxes on labour and net wages. The same algebraic reasoning can be done in order to find the change in the total compensation of employees. Consider in this case the definition of the total compensation in (2). Applying logarithms and differentiating, we obtain:

$$\widehat{TC} = \widehat{W} + \widehat{t_{er}}. \quad (41)$$

Substituting (38) in (41), we obtain that:

$$\widehat{TC} = \frac{\varepsilon_{LS}}{\varepsilon_{LS} - \varepsilon_{LD}} (\widehat{t_w} + \widehat{t_{er}}) \quad (42)$$

The ratio  $\frac{\varepsilon_{LS}}{\varepsilon_{LS} - \varepsilon_{LD}}$  is positive. This means that there is a direct relationship between the change in total taxes on labour and the total compensation. As we can conclude, tax incidence in QUEST, i.e. the sharing of the tax burden between workers and firms, will depend on the sign and magnitude of the elasticities of supply and demand.

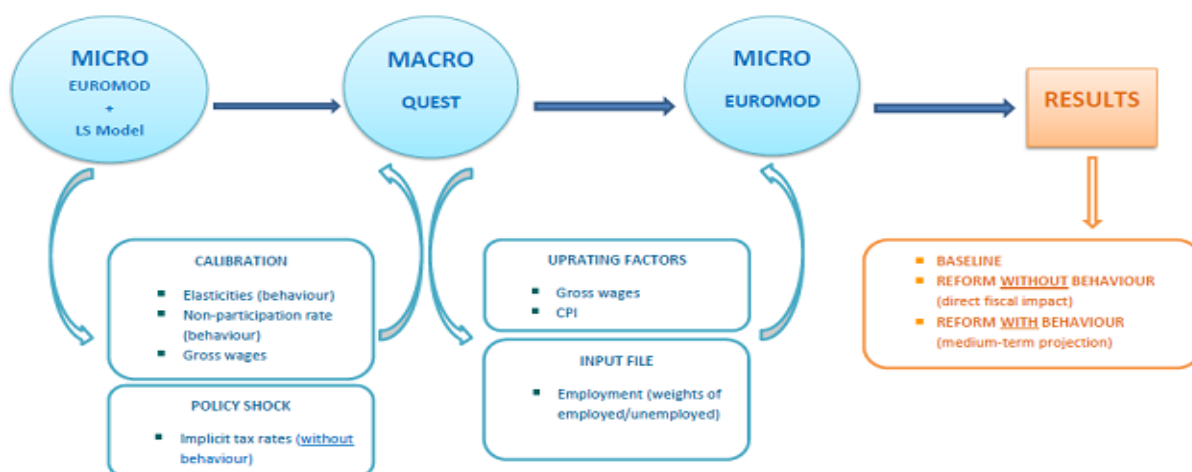
## 5 Illustration: tax reforms in Belgium, Italy and Poland

To illustrate the usefulness of our methodology, we analyse the potential effects of a series of tax reforms implemented in three countries: Belgium, Italy, and Poland.<sup>19</sup> The selected reforms have a common objective, aiming at reducing the tax burden on labour. To that end, we simulate the implementation of the following reforms:

- i. *In Belgium*: a reduction of the social security contributions for employees from 13.07% to 9.07% (by cutting 3% from pensions and 1% from medical care contributions);
- ii. *In Italy*: the introduction of a labour tax reduction in the form of a non-refundable in-work tax credit amounting to EUR 80;
- iii. *In Poland*: an increase in the universal tax allowance from PLN 556 up to PLN 1,440, which would imply that the amount of income exempt from the personal income tax would rise from PLN 3,090 to PLN 8,000.

The methodological steps followed in our dynamic scoring exercise are summarized in Figure 1.

**Figure 1. Dynamic scoring methodological steps**



As we can observe, we start from the microeconomic setup, using EUROMOD to calibrate selected parameters in QUEST and to calculate the policy shocks to be introduced in that model. In this way, EUROMOD augmented with the labour supply discrete choice estimation is used not only to compute the labour supply elasticities, by skill level, but also to estimate the non-participation rate, by skills. The policy shocks are obtained by simply running the EUROMOD model for the baseline and reform scenarios – no behavioural reaction included – and obtaining the change on the implicit tax rates of employees from going from one scenario to the other. In this case, since the reforms aimed at reducing employees' tax burden, we expect that the implicit tax rates go down, and in this way, these shocks will be negative. The second step consists in introducing the policy shocks in QUEST and running this model in order to obtain medium term – three years – trajectories for some selected variables of interest. These are the price level, employment and gross wages. Finally, these

<sup>19</sup> The simulated reforms for Italy and Poland are based on actual national tax reform proposals.

trajectories are imputed back into EUROMOD. This imputation consists, on the one hand, in setting the uprating factors embedded in EUROMOD for the price level and wages by skills according to the QUEST trajectories for the next three years, and, on the other, on adjusting the weights of the employed and the rest of the population, in the micro-data input file, in order to match the change in the employment variable in QUEST. At this point, we can obtain the fiscal and redistributive effects of the tax reforms implemented by simply running EUROMOD, for the baseline and reform scenarios.

This methodological approach can somehow relate to some type of "bottom-up/top-down" approach, as described in Savard (2003), with the difference that this author refers to interactions between a microsimulation model and a (CGE) model, instead of a DSGE model.<sup>20</sup> Savard (2003) draws specific attention to the problems of coherence/convergence between the micro and the macro sides of the analysis and presents an approach "to examine the coherence between the household model and the CGE model, introducing a bi-directional link and, therefore, obtaining a converging solution between the two models". In our exercise, we do not have the "bi-directional link" or any measure of the convergence of aggregates, such as labour supply/unemployment, in the two models. This may be a limitation of our analysis, which can be softened by calibrating parameters such as labour supply elasticities, and the nonparticipation rate (*NPART*) in QUEST, according to these same parameters obtained from the microeconomic/microsimulation frameworks. Furthermore, Savard (2003) also notes that the main idea underlying the interaction between the micro and the macroeconomic models is to consider the different contributions/perspectives. To illustrate this insight, Savard (2003) notices that if one interacts a CGE model where the behaviour of the representative household is a perfect aggregate of the behaviour of the households considered in the microeconomic analysis, there is no point in interacting the two models, because the household behaviour will be fully captured by any of the models and there will be no value-added in using the interaction of the two. In our particular case, we cannot claim that our micro/macro models are perfectly substitutable. However we do ensure that in both models the labour supply is consistently modelled in both the micro and the macroeconomic settings.

## **5.1. First step: Labour market calibration and policy shocks**

As referred previously, we start from the microeconomic framework to estimate the labour supply elasticities and the expected non-participation rate, which we will later use to calibrate QUEST. Moreover, we also obtain the policy shocks that will later be introduced in QUEST.

In order to obtain the elasticities and the expected non-participation rate, we use version G3.0 of the EUROMOD microsimulation model, together with the datasets based on the 2012 version of EU-SILC.<sup>21</sup> EUROMOD is then linked with the labour supply discrete choice model. For the simulation of the tax reforms, we choose 2013 tax-benefit rules as the baseline.<sup>22</sup> We predict labour supply based on the estimated labour supply model both for the baseline and the reform scenario. Uprating

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<sup>20</sup> Savard (2003) aims at analysing poverty and inequality problems in a setting that reconciles the microeconomic behaviour with the macroeconomic aggregates, such as prices, factor remunerations, unemployment and consumption/expenditure.

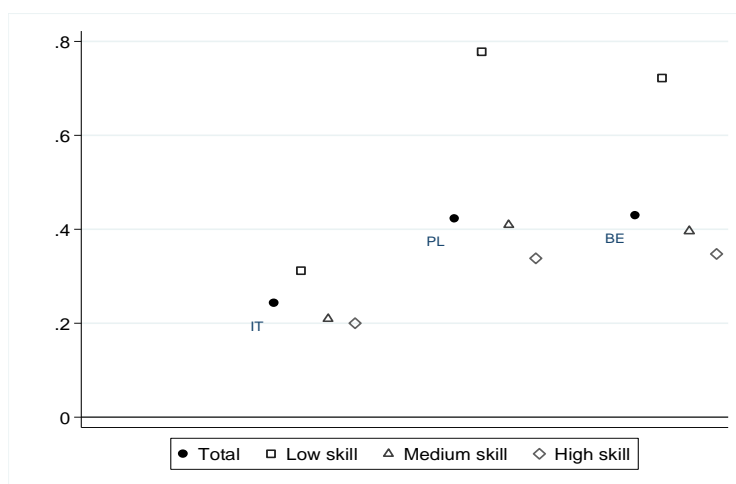
<sup>21</sup> This is the most recent dataset available that can be linked with tax-benefit rules for the income reference period which is necessary for the estimation of the labour supply model.

<sup>22</sup> This is the most recent policy year that can be simulated with EUROMOD at the time of writing this paper.



factors are used to update the non-simulated income components to 2013. In practical terms, the link between EUROMOD and labour supply estimation model is implemented according to the following methodological steps. First, we estimate the hourly wage rate, from a sample of active individuals (excluding self-employed), using a Heckman style model. In this estimation, we assume that the predicted hourly wage rate is constant for any number of hours supplied by the individuals in the labour market. We then observe the number of hours each individual supplies in the market and assign her to the closest category of the labour supply choices – in our case, to one of the four alternatives: 0, 20, 40 and 60 hours. Having the wage rate and the labour choice in terms of hours, we can now compute the budget for singles and couples, for each of the four alternatives considered in the labour choice set.<sup>23</sup> From here, and using EUROMOD, we calculate household disposable incomes in the (hypothetical and actual) hour categories. We do this once for the baseline wage estimation in order to estimate the structural discrete choice model, and once using a wage rate that is increased by a small amount (1% of the wage rate). The wage distribution increased by 1% is used to predict the change in labour supply that arises from the marginal wage change and to calculate the labour supply elasticities for the three skill levels. The latter will be used to calibrate the parameter  $\kappa$  of the DSGE model QUEST, as explained in previous sections. We present below – Figures 2 and 3 – the results found for these elasticities, by skill level, for the countries of interest. We find that the labour supply of the low-educated is somewhat more sensitive than for the high-educated, especially in Poland and Belgium, where they are twice as large (see Figure 2). We also notice that most of the response is on the extensive margin of the elasticity (see Figure 3), with extensive margin elasticities exceeding intensive margin elasticities by almost 67% in Italy and 46% in Poland, while in Belgium the extensive margin elasticity is more than twice as large as the intensive margin elasticity. Consequently, the decision to participate is much more reactive to wage incentives compared to the decision on the weekly hours supplied by the worker, which is in line with the literature on elasticities.<sup>24</sup>

**Figure 2. Elasticity Estimates (by skill group)**



<sup>23</sup> For instance, for a household consisting of one single, we will have four different gross labour incomes, while for a household consisting on a couple we will have 16 different gross incomes, depending on all the combinations of hours chosen by the two partners.

<sup>24</sup> For a detailed analysis on elasticities see Chetty et al (2012), and Chetty (2012).

**Figure 3. Elasticity Estimates (by margin)**

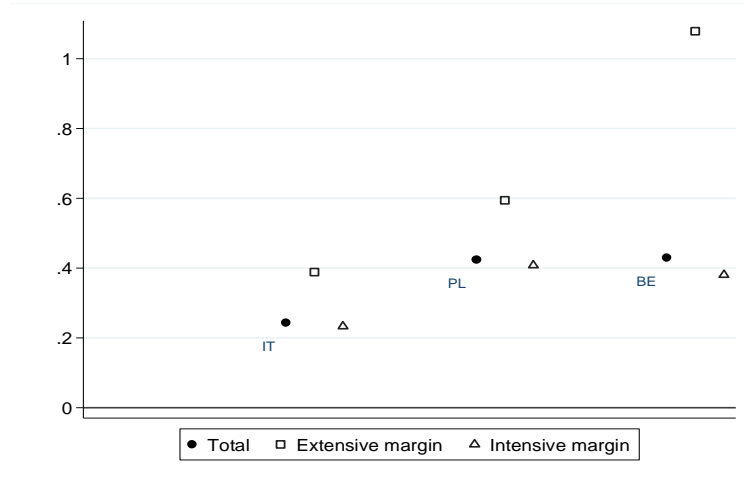


Table 1 below shows the figures for the elasticities, by skill level, and the correspondent value for parameter  $\kappa$ , by skill level, in QUEST, which was obtained using expression (23), where the population and employment figures came from the sample of active individuals used in the estimation process.

**Table 1. Calibration of labour supply elasticity parameter in QUEST**

Countries	Elasticities			Parameter $\kappa$		
	High	Medium	Low	High	Medium	Low
Belgium	0.357	0.395	0.716	0.351	0.631	0.978
Italy	0.199	0.201	0.301	0.896	1.497	2.485
Poland	0.311	0.271	0.598	0.515	1.776	1.173

As for the expected number of voluntary unemployed, by skill level, this is also obtained from the discrete choice model, following expression (12) and according to the estimated probabilities of choosing to supply zero hours in the labour market. Table 2 shows the non-participation rates obtained for the different skill level and the countries of interest following equation (22), and which were used also to calibrate QUEST.

**Table 2. Calibration of non-participation rates in QUEST**

Parameter	Belgium	Italy	Poland
$NPART_H$	0.057	0.079	0.102
$NPART_M$	0.107	0.132	0.214
$NPART_L$	0.246	0.290	0.270

Finally, we also need to obtain the changes in the implicit tax rates in order to shock QUEST. Given the nature of the reforms described above, only the implicit tax rate for employees will change. Here we follow the implicit tax rate definition of the European Commission (2013) in order to derive the baseline and reform values of the implicit tax rates of employees. Notice also that in our analysis we are only interested in knowing the effect of the tax cuts on labour income. This means that we need to find which share of the personal income tax liability is due to labour income, i.e. wages, in order to obtain the implicit tax rate on labour. To this labour tax liability we still need to add the social insurance contributions paid by employees ( $SIC_{EE}$ ) and employers ( $SIC_{ER}$ ), by skill group  $s \in \{H, M, L\}$ . Hence, the definition of the total implicit tax rate is the following:

$$itr_s = \frac{\sum_i w_i * PIT_i + SIC_{EE} + SIC_{ER}}{Gross\ Wages + SIC_{ER}}, s \in \{H, M, L\} \quad (43)$$

where  $w_i$  is the weight of wages on the total taxable income of taxpayer  $i$ , defined as:

$$w_i = \frac{Gross\ wages_i}{Total\ taxable\ income_i} \quad (44)$$

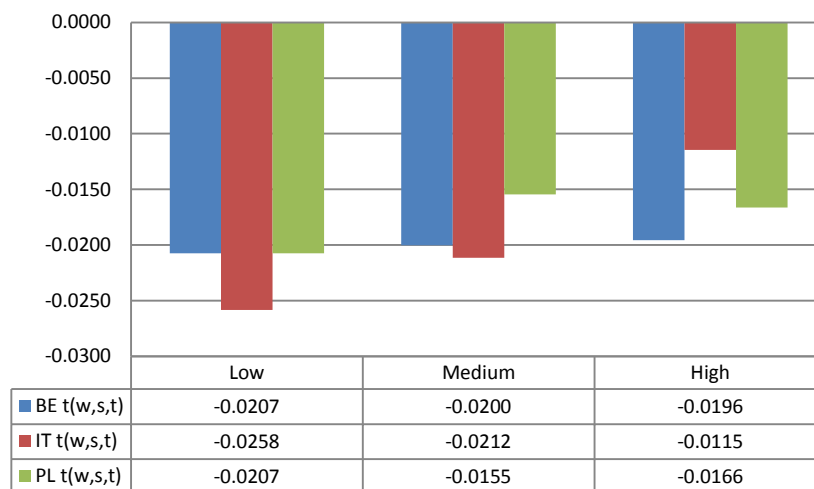
Moreover, we define the implicit tax rates for employees and employers according to expressions (56) and (57) below:

$$itr_{EE,s} = \frac{\sum_i w_i * PIT_i + SIC_{EE}}{Gross\ Wages + SIC_{ER}}, s \in \{H, M, L\} \quad (45)$$

$$itr_{ER,s} = \frac{SIC_{ER}}{Gross\ Wages + SIC_{ER}}, s \in \{H, M, L\} \quad (46)$$

In this way, we need to compute expression (45) in the baseline and the reform scenarios for each country. The difference between the two scenarios will be introduced as a permanent fiscal shock in the macroeconomic model QUEST. Notice that these changes are only due to the changes implemented in the tax system of each country and, at this point, do not include any behavioural effect, i.e. wages are maintained constant when computing the  $itr_{EE,s}$  in the reform scenario. In this way, and using EUROMOD, we obtain the following changes in the implicit tax rates for employees, in each of the countries of interest, shown in Figure 4.

**Figure 4: Fiscal policy shocks (pp differences)**



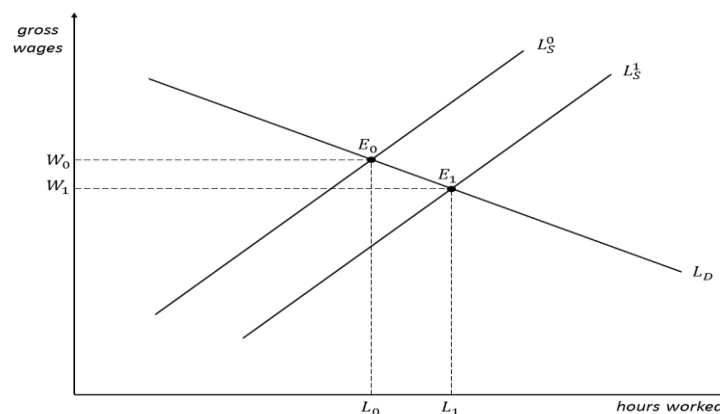
Overall, we can observe that the simulated reforms decrease the tax burden on employees. The magnitude of the shocks across skill groups is different across countries, however, in accordance

with the reform implemented in each country. For this reason, we notice a progressive impact in Italy and, to a less extent, in Belgium, while in Poland the middle-skilled workers are affected by the largest fiscal policy shock. On average, we have simulated in QUEST a decrease of the overall tax burden. However, notice that the size of the shocks is very small, which will result in very small changes in the trajectories of the macroeconomic variables from the baseline scenario, as we will confirm in the next section.

## 5.2. Second step: The macroeconomic impact

In this exercise, QUEST was calibrated for the following three regions: the country of interest (i.e., respectively Belgium, Italy and Poland), the euro area and the rest of the world. As explained in the previous section, we have calibrated the parameter  $\kappa$  and the nonparticipation rate,  $NPART$ , with the figures obtained from the discrete choice econometric model.<sup>25</sup> The changes in the implicit tax rates on labour paid by employees for each of the three countries of interest are introduced as permanent policy shocks in QUEST. For that we have also set off the debt-stabilization rule – equation (B.21) in Appendix B – for the first fifteen years. Selected impulse response functions for the labour market variables – net real wages, total compensation of employees, gross real wages, and employment – generated by the fiscal shocks described above can be found in the Appendix D (graphs D.1 to D.12). For the three countries, we observe similar patterns (although varying in magnitude) for the labour market variables. This was expected since the pattern of the shocks was also similar in the three countries (decreased tax burden for employees). We observe that net real wages jump for all skill groups, right after the fiscal shock is introduced and then remain relatively steady during the rest of the period. The total compensation of employees, for all skill groups, falls, in the same way as gross wages, since the tax burden of employers remain constant in our simulations. Employment increases over the simulation period (with varying rates for the different countries and the different skill groups), compared with their initial level. Although the general equilibrium effects will influence the numerical results – since output, consumption, capital utilisation and prices are fully endogenous in the model –, Figure 5 below illustrates the basic wage setting mechanism in the model illustrating in particular the role played by tax incidence.

**Figure 5. Partial equilibrium view of the wage-setting mechanism in QUEST**



<sup>25</sup> For a complete description of the full calibration of QUEST see the online version of Ratto et al (2009) at <http://publications.jrc.ec.europa.eu/repository/handle/JRC46465>. In this paper, we focus only on the calibration of selected parameters related directly to the labour market.

In Figure 5,  $L_D$  is the labour demand function, corresponding to equation (B.15) in Appendix B, assuming  $Y$ ,  $K$  and  $ucap$ , are constant and no adjustment costs, for simplicity.  $L_S$  is the labour supply function, equivalent of equation (B.7) in Appendix B, assuming all other variables constant except real gross wages and labour. Let us also assume that in this partial equilibrium setting, movements of the labour supply and labour demand functions are only due to the changes in the labour tax rates,  $t_{w,s,t}$  and  $t_{er,s,t}$ . So, when  $t_{w,s,t}$  decreases, workers are willing to offer more labour services for all levels of the gross wage, and  $L_S$  moves down and to the right (i.e. from  $L_S^0$  to  $L_S^1$ ). In the new equilibrium, gross wages are lower and at this new wage rate firms will be willing to hire more labour. This result is indeed confirmed by our impulse response functions for employment and wages, for the three countries. These results are also consistent with the partial equilibrium analysis of tax incidence in Fullerton and Metcalf (2002), described analytically in Section 4.3. In particular, the responses of net wages (gross wages less taxes on labour income paid by employees) and of the total compensation of employees (gross wages plus taxes on labour income paid by employers) to an increase in labour tax are negative and positive, respectively, and are constrained by the elasticity of labour supply ( $\varepsilon_{L,S} > 0$ ) and labour demand ( $\varepsilon_{L,d} < 0$ ), as shown previously. Our shocks imply that  $\widehat{t_w} < 0$  and  $\widehat{t_{er}} = 0$ , then from equation (38) gross wages should go down, i.e.  $\widehat{W} < 0$ . In the same way, and now from equation (40), we should expect the net wages to rise in the new equilibrium. Note that  $(\widehat{t_w} + \widehat{t_{er}}) < 0$ , for all the countries and, according to equation (40), there is an inverse relationship between the change in total taxes on labour income and net wages. This is also confirmed by the impulse response functions of the net wages. Finally, in what concerns the total compensation of employees paid by the firms, and according to equation (42), we should expect it to decrease. Equation (42) implies a positive relationship between the change in total taxes on labour income and the total compensation. In our case,  $(\widehat{t_w} + \widehat{t_{er}}) < 0$ . So, the total compensation of employees will decrease to reach the new equilibrium. Again this is shown in the impulse response functions of the total compensation of employees, for the three countries, in Appendix D. The final annualized macroeconomic impact on the variables of interest from the tax reforms is summarized in Table 3 below.

**Table 3. Macro impact of the tax reforms (annualized % deviation from baseline) on the variables of interest**

	Belgium			Italy			Poland		
	T+1	T+2	T+3	T+1	T+2	T+3	T+1	T+2	T+3
<b>GDP</b>	0.101	0.239	0.385	0.154	0.191	0.235	0.113	0.218	0.289
<b>Price level</b>	-0.033	-0.076	-0.096	-0.002	-0.075	-0.113	-0.065	-0.182	-0.275
<b>Real consumption</b>	0.166	0.158	0.179	0.352	0.351	0.385	0.145	0.194	0.215
<b>Employment</b>									
Low skilled	0.117	0.307	0.507	0.161	0.270	0.342	0.150	0.334	0.471
Medium skilled	0.168	0.406	0.615	0.237	0.390	0.462	0.185	0.391	0.517
High skilled	0.210	0.475	0.673	0.184	0.241	0.271	0.217	0.421	0.523
<b>Gross real wage</b>									
Low skilled	-0.163	-0.318	-0.381	-0.140	-0.204	-0.191	-0.142	-0.267	-0.295
Medium skilled	-0.266	-0.445	-0.481	-0.259	-0.324	-0.279	-0.227	-0.348	-0.338
High skilled	-0.333	-0.521	-0.512	-0.148	-0.149	-0.108	-0.245	-0.343	-0.307
<b>Net gross real wage</b>									
Low skilled	2.470	2.311	2.185	2.987	2.921	1.385	2.317	2.189	1.681

Medium skilled	2.326	2.143	2.106	2.371	2.303	2.350	2.101	1.977	1.988
High skilled	2.369	2.176	2.185	1.344	1.342	1.385	1.745	1.645	1.681
<b>Total compensation of employees</b>									
Low skilled	-0.163	-0.318	-0.381	-0.140	-0.204	-0.191	-0.142	-0.267	-0.295
Medium skilled	-0.266	-0.445	-0.481	-0.259	-0.324	-0.279	-0.227	-0.348	-0.338
High skilled	-0.333	-0.521	-0.512	-0.148	-0.149	-0.108	-0.245	-0.343	-0.307

Finally, it is important to emphasize that the changes in employment and gross real wages have opposite signs. This generates counteracting behaviour effects which will result in very small differences between the "no behaviour" and "behaviour" scenarios, as we will confirm in the next section.

### 5.3. Third step: Microsimulation results

In our next step, we input the impulse responses for employment, gross real wages and consumer price index generated by the QUEST model back into the microsimulation model in order to get the medium-term projections in tax revenues, contributions, benefits and disposable incomes. Alternatively, we also simulate a second scenario under which the second round effects, i.e. the behavioural response to the tax change and macroeconomic feedback, are disregarded. As already mentioned in the previous sections, since the macroeconomic trajectories imply small and counteracting changes on gross wages and employment for all the three countries, we expect that the differences between the no behaviour and behaviour scenarios will be very small.

We analyse both scenarios over the period  $t_0$  to  $t_3$  and compare the variation in tax revenues, social insurance contributions, and disposable income against the baseline. Out of the two scenarios, the implementation of the reforms in the absence of second-round effects is the most straightforward, as it involves the revision of the corresponding policy, *ceteris paribus*. In other words, we apply the tax system of the policy year  $t_0$  to the subsequent three years, accommodating only the adjustments in the monetary variables by using the standard uprating factors. As explained previously, in EUROMOD, the uprating factors are utilized as discount factors to update monetary variables to the price level of the year for which the tax system is analysed. This update is necessary because the input data files to EUROMOD always come with a lag, given that they are survey data. The input data files used here are based on EU-SILC 2012 survey data, which do not correspond with the most recent (simulated) tax-benefit system that is modified with the simulated reforms. Therefore, the uprating factors allow for time consistency between the monetary variables of the survey and the tax system under analysis. The only shortfall of this approach concerns the missing uprating factors for the policy year 2016 (as the latest available version of EUROMOD runs on the 2015 tax and social benefit systems). In order to overcome this limitation, for each monetary variable we estimate the 2016 uprating factors by taking into account the European Commission forecast of proxy variables (or the same variable, when available).<sup>26</sup> Assessing the fiscal and equity impact of the same tax reforms embedding the second-round effects is done by amending the uprating factors according to

<sup>26</sup> The European Commission macroeconomic forecast are publicly available in the AMECO database, [http://ec.europa.eu/economy\\_finance/db\\_indicators/ameco/index\\_en.htm](http://ec.europa.eu/economy_finance/db_indicators/ameco/index_en.htm).

the macroeconomic feedback provided by the QUEST model (Table 3) for prices, employment and wages. This is specifically done in two steps, as follows:

- i) We incorporate the macro impact of the tax reforms on employment by adapting the input dataset to accommodate the QUEST trajectories for the medium-term. In order to do so, we create a different micro-dataset for each year  $t_1, t_2, t_3$  in which we increase the weights of the skill group of employed according to the corresponding impulse response, while, at the same time, scaling down the weights for the unemployed in the sample, up to the point where the total population reaches its initial value.
- ii) The impulse response for the consumer price index is integrated in EUROMOD as a correction to the correspondent uprating factor; For gross wages we apply the same approach as for the CPI, with the only exception of creating three subgroups of the uprating factor according to each skill category.

We subsequently run the microsimulation model to quantify the overall budgetary and distributional effects of the reforms, under the two scenarios.

The results are presented in detail in the Graphs included in Appendix E. Graphs E.1 to E.6 provide the dynamic scoring results of each reform focusing on their impact of tax revenues considered separately from the overall budgetary effects, i.e., we only look at the tax variables directly affected by the reform – social insurance contributions in Belgium, in-work tax credit in Italy, and universal tax allowance in Poland – while Graphs E.7 to E.12 provide both the direct and indirect impact of the reforms by broad categories of tax revenues (i.e. personal income taxes and social insurance contributions) as well as the impact on household disposable income by income decile.

In this way, from graphs E.1 to E.6 we observe that:

- i. *In Belgium* – as expected, Graph E.1 shows that the employee social insurance contributions decrease both in the presence and in the absence of second-round effects when considering the change in pension insurance and health insurance contributions. This drop is bigger in the second-round effect scenario, since the new equilibrium in the labour market implies lower gross wages, and consequently lower social insurance contributions. However, the positive effects on employment counterbalances the negative effect on wages from the second year onwards and yield lower tax revenues losses in  $t_3$  (which corresponds to the year 2016 in our simulations). Still, the overall tax revenue loss entailed by the reform remains very similar – approximately 4.3 billion euros – in both scenarios and for both social insurance contributions considered. Considering now the distribution of the changes in social insurance contributions across deciles (considering together the pension and health contributions, Graph E.2), we observe this same pattern, with the positive effects on employment balancing the negative ones on gross wages. It is important to note that Graph E.2 depicts the evolution in the average social insurance contribution per employee and income decile such that the differences between Graph E.1 and E.2 can be explained by the distribution of employed/unemployed across the deciles. In this way, we see that the positive effect on employment being stronger in the bottom deciles, while the negative effect on gross wages dominating in the top deciles.

- ii. *In Italy* – the in-work refundable tax credit is marginally higher in the second-round effect scenario (see Graph E.3). This results from the increase in employment after the reform due to the positive reaction of labour supply, and the fact that the tax credit is a lump-sum amount given to employees. However, when we consider the total personal income tax revenues, this increase on the tax expenditures is compensated by the positive effect of the reform on the number of people liable to personal taxes such that the total personal income tax liability increases. This shows a very modest evidence of a self-financing tax cuts. In order to see this more clearly, we first calculated the difference in PIT revenues in the two scenarios including and excluding the second-round effect. Second, we calculated the same difference for the in-work refundable tax credit. And third we computed the ratio between these two values in order to calculate the percentage of tax revenue losses which were partly covered by the increase in tax revenues from the increase in PIT and found that only 1.4% of the tax credit seems to be self-financed by the positive effects on employment. From the distribution of the in-work tax credit across deciles (see Graph E.4), we observe that when considering the behaviour effects, the tax credit generates slightly higher positive effects for the middle deciles, with no labour incentives being created to the first and second deciles. It seems then that this reform is not effectively targeting the poorer part of the income distribution, i.e. the bottom deciles. This may be due to the fact that, these bottom deciles are mainly composed by pensioners which cannot benefit from the in-work tax credit, and by less skilled unemployed with relatively less probabilities of finding a job.
- iii. *In Poland* - Similarly to the Italian case, the universal allowance is higher in the behaviour scenario, due to the positive effects on employment (see Graph E.5). However, we do not obtain any self-financing of the tax cut in this case, since the personal income tax revenues obtained in the second-round effects scenario are slightly lower than the ones obtained without considering the second-round effects. In this case, the negative effects on gross wages seem to overweight the positive ones on employment. In what concerns the distribution of the universal tax allowance across deciles (see Graph E.6), it seems also that this reform generates higher incentives to enter the labour market for the middle deciles, less to the top ones and almost none to the bottom ones.

Considering now the aggregate categories of total tax revenues, total personal income taxes, social insurance contributions and disposable incomes, in graphs E.7 to E12, we observe that:

- i. *In Belgium* – the reduction by 4% of social insurance contributions paid by employees leads to a fall in government revenues (see Graph E.7). This downturn leads to an increase in revenues from the personal income tax, as the taxable income, which is net of social contributions broadens. This effect is slightly lower when we consider second-round effects since gross wages decrease pushing total tax revenues down slightly. This negative effect overweighs the positive effect of employment on revenues. In what concerns the social insurance contributions paid by employers these are exactly the same in the baseline and no second-round effects scenarios, since the reform did not change the tax burden on employers. However, accounting for the second-round effects we observe that these go down and then recover by the end of the period of analysis. This is likely to be due to the combination of the decrease in gross wages and correspondent decrease in contributions



paid and the increase in employment, which, as we can observe from Table 3, becomes stronger at the end of the period. From a distributional point of view, the reform has a clear positive impact on equivalised household disposable incomes, the first decile being the only one worse off, only at the end of the period of analysis and in the behaviour scenario (see Graph E.8). The effect seems regressive for lower deciles, which benefit less from the reform compared with the top part of the income distribution. We also observe that the impact of including second-round effects in the analysis is extremely small – the blue and green lines almost overlap, with the behaviour reaction slightly pushing down the positive effects of the reform, given that decrease of gross wages offsets the increase in employment.

- ii. *In Italy* – as expected, the introduction of the in-work tax credit induces a fall in the personal income tax revenues (see Graph E.9). Given the counteracting changes in wages and employment, considering the second-round effect does not affect the projected impact on personal income taxes. However, we see that social insurance contributions increase by the end of the period, reflecting the positive effect on employment. This explains also the slight lower negative effect of the reform on total tax revenues once the second-round effects are factored in. The impact of the tax credit on household income depends on the distribution of the beneficiaries across the household income distribution, but in this case it seems that the very bottom and top parts of the income distribution benefit less from the introduction of the tax credit (see Graph E.10), as noticed earlier. Again, given the effects in gross wages and employment counteract each other, on average in each decile the second-round effect have little impact on projected disposable income. Moreover notice that the progressive tax system will also accommodate the decrease in wages, leading to closing even more the differences between the two scenarios.
- iii. *In Poland* – the increase in the basic tax allowance cuts down the revenues from the personal income tax by almost one-third from the baseline level (see Graph E.11). Taking into account the second-round effects of the tax policy change, the impact is again negligible. However, in this case, the employment effects seem to be weaker than in the case of Italy: they only seem to affect the social insurance contributions at the end of the period of analysis, where the blue line is slightly above the green one. From a redistributive and dynamic perspective, the repercussions of the reform on the equivalised household disposable income seem stronger on the top part of the distribution denoting a somewhat regressive reform. In the same way, the impact of the second-round effects is very small (see Graph E.12).

## 6. Conclusion

We propose a framework to analyse the impact of tax reforms in EU Member States, taking into account first and second order effects of the reforms. For this purpose, we have combined a microsimulation model, augmented to include a labour supply behaviour response, with a new Keynesian DSGE model. We establish a coherent link between the two models, in particular in what respects aggregation, by calibrating the macro-model in line with the micro data, the labour market parameters and other exogenous variables such as the non-participation rate. In order to illustrate our methodology, in this exercise we have quantified the effects of tax cuts in three EU member

states: Belgium, Italy and Poland. Preliminary results indicate that, in all three countries considered i.e., a fall in social security contributions in Belgium, the introduction of a working tax credit in Italy and an increase in the allowances for the personal income tax, have all positive effects on individual's disposable income, and reduce total tax revenues, as expected. Moreover, the second-round effect of these reforms, which include the behaviour reactions from a labour supply perspective and the macroeconomic feedback, seem to have little impact compared with the first-round effects of the reforms. This is a result of two main factors: first the tax cuts introduced as changes in the implicit tax rates paid by employees are relatively small; second, the lower tax burden enjoyed in the reform scenario by employees is partially benefiting also the firms, by pushing gross wages down. On the other end, this generates a positive effect on employment, since firms are now willing to hire more employees, who are now willing to work at a lower gross wage, since the tax burden has been reduced. In this way, we obtain counteracting effects of wages and employment which in aggregate terms reduce the second round effects of the tax reforms.

Our approach opens up venues for future research and policy analysis. Our analysis could also be extended to account for other types of behavioural adjustment to tax policy reforms, in particular reforms affecting consumption or saving behaviour. Ongoing extensions of the EUROMOD model broadening the coverage of EUROMOD to consumption taxation (see Decoster et al. 2014) could be used for this purpose..

## References

- Aaberge, R. Dagsvik, J. and Strom, S. 1995. "Labour Supply Responses and Welfare Effects of Tax Reforms." *Scandinavian Journal of Economics* 97(4):635–59.
- Aaberge, R., Colombino, U., & Wennemo, T. (2009). Evaluating alternative representations of the choice sets in models of labour supply. *Journal of Economic Surveys*, 23(3), 586-612.
- Adam, S., & Bozio, A. (2009). Dynamic scoring. *OECD Journal on Budgeting*, 9(2), 107.
- Altissimo, F., Siviero, S., & Terlizzese, D. (2002). How deep are the deep parameters?. *Annales d'Economie et de Statistique*, 207-226.
- Altshuler, R., N. Bull, J. Diamond, T. Dowd and P. Moomau (2005). The role of dynamic scoring in the federal budget process: closing the gap between theory and practice. *American Economic Review*, 432-436.
- Bargain, O., Orsini, K., & Peichl, A. (2014). Comparing labour supply elasticities in europe and the united states new results. *Journal of Human Resources*, 49(3), 723-838.
- Barrios, S., & Fagnoli, R. (2010), Discretionary measures and tax revenues in the run-up to the financial crisis (No. 419), Directorate General Economic and Financial Affairs, European Commission.
- Barrios, S., Fatica, S., López, D. M., & Mourre, G. (2016). The fiscal effects of work-related tax expenditures in Europe. *Public Finance Review*, forthcoming.
- Barrios, S. F. Figari, L. Gandullia and S. Riscado (2016), The fiscal and equity impact of tax expenditures in the EU: evidence from microsimulation modelling, Joint Research Centre, European Commission.
- Buti, M., and P. Van den Noord (2004). Fiscal policy in EMU: Rules, discretion and political incentives Economic Papers 206, Directorate General Economic and Financial Affairs (DG ECFIN), European Commission.
- Callan, T., van Soest, A. and Walsh, J. (2009). Tax Structure and Female Labour Supply: Evidence from Ireland. *Labour* 23(1):1–35.
- Castanheira, M., G. Nicodeme and P. Profeta (2012), "On the political economics of tax reforms: survey and empirical assessment", *International Tax and Public Finance*, 19, 598–624.
- Chang, Y., Kim, S. B., & Schorfheide, F. (2013). Labour-market heterogeneity, aggregation and policy (in) variance of DSGE model parameters. *Journal of the European Economic Association*, 11(s1), 193-220.
- Chetty, R. (2012). Bounds on elasticities with optimization frictions: A synthesis of micro and macro evidence on labour supply. *Econometrica*, 80(3), 969-1018.
- Chetty, R., Guren, A., Manoli, D., & Weber, A. (2012). Does indivisible labour explain the difference between micro and macro elasticities? A meta-analysis of extensive margin elasticities. In *NBER Macroeconomics Annual 2012, Volume 27* (pp. 1-56). University of Chicago Press.
- Cogley, T., & Yagihashi, T. (2010). Are DSGE Approximating Models Invariant to Shifts in Policy?. *The BE Journal of Macroeconomics*, 10(1).
- Creedy, J. and G. Kalb (2005). Discrete Hours Labour Supply Modelling: Specification, Estimation and Simulation. *Journal of Economic Surveys* 19(5), 697–733.
- Creedy, J., & Kalb, G. (Eds.). (2006). Dynamics of Inequality and Poverty (Vol. 13). *Emerald Group Publishing*.
- Dagsvik, J. (1994). Discrete and continuous choice, max-stable processes, and independence from irrelevant attributes. *Econometrica: Journal of the Econometric Society*, 1179-1205.

European Commission (2013). Taxation trends in the European Union – Data for the EU Member States, Iceland and Norway. Economy and Finance, Statistical books.

Fernández-Villaverde, J., & Rubio-Ramirez, J. (2007). How structural are structural parameters? Fullerton, D., and Metcalf, G. E. (2002). Tax incidence. *Handbook of public economics*, 4, 1787-1872.

Gravelle, J. (2015), Dynamic Scoring, *Journal of Policy Analysis and Management* 34 (4): 970-977.

Hausman, J. (1985). The econometrics of nonlinear budget sets. *Econometrica: Journal of the Econometric Society*, 1255-1282.

Hoynes, H. (1996). Welfare Transfers in Two- Parent Families: Labour Supply and Welfare Participation Under AFDC- UP. *Econometrica* 64(2), 295–332.

Keane, M., and Moffitt, R. (1998). A structural model of multiple welfare program participation and labour supply. *International economic review*, 553-589.

Löffler, M., Peichl, A., & Siegloch, S. (2014). Structural labour supply models and wage exogeneity. *ZEW-Centre for European Economic Research Discussion Paper*, (14-040).

McFadden, D. (1973). Conditional logit analysis of qualitative choice behavior.

Magnani, R., & Mercenier, J. (2007). On linking microsimulation and applied GE by exact aggregation of heterogeneous discrete-choice making agents (No. 2007-06). *THEMA (Théorie Economique, Modélisation et Applications)*, Université de Cergy-Pontoise.

Mankiw, N. G., & Weinzierl, M. (2006). Dynamic scoring: a back-of-the-envelope guide. *Journal of Public Economics*, 90(8), 1415-1433.

Price, R. W., T.T. Dang, and Y. Guillemette (2014). New Tax and Expenditure Elasticity Estimates for EU Budget Surveillance, OECD Economics Department Working Papers 1174, Paris.

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.

Savard, L. (2003). Poverty and income distribution in a CGE-household micro-simulation model: top-down/bottom up approach.

Sutherland, H. (2001). EUROMOD: An integrated European benefit-tax model (No. EM9/01). *EUROMOD Working Paper Series*.

Sutherland, H., & Figari, F. (2013). EUROMOD: the European Union tax-benefit microsimulation model (No. EM8/13). *EUROMOD Working Paper*.

Train, K. (2009). Discrete choice methods with simulation. *Cambridge University press*.

Van Soest, A. (1995). Structural models of family labour supply: a discrete choice approach. *Journal of human Resources*, 63-88.

## Appendix A. The discrete choice labour supply model

As Bargain, Orsini, and Peichl (2014), we opt for a flexible discrete choice model.<sup>27</sup> In our baseline, we specify consumption-leisure preferences using a quadratic utility function with fixed costs.<sup>28</sup> The deterministic part of utility of a couple  $i$  at each discrete choice  $j = 1, \dots, J$  can be written as:

$$U_{ij} = \alpha_{ci}C_{ij} + \alpha_{cc}C_{ij}^2 + \alpha_{hfi}H_{ij}^f + \alpha_{hmi}H_{ij}^m + \alpha_{hff}(H_{ij}^f)^2 + \alpha_{hmm}(H_{ij}^m)^2 + \alpha_{chf}C_{ij}H_{ij}^f + \alpha_{chm}C_{ij}H_{ij}^m + \alpha_{hmf}H_{ij}^fH_{ij}^m - \eta_j^f \cdot 1(H_{ij}^f > 0) - \eta_j^m \cdot 1(H_{ij}^m > 0) \quad (\text{A.1})$$

with household consumption  $C_{ij}$  and spouses' work hours  $H_{ij}^f$  and  $H_{ij}^m$ . The  $J$  choices for a couple correspond to all combinations of the spouses' discrete hours (for singles, the model above is simplified to only one hour term  $H_{ij}$ , and  $J$  is simply the number of discrete hour choices for this person). Coefficients on consumption and work hours are specified as:

$$\begin{aligned} \alpha_{ci} &= \alpha_c^0 + Z_i^c \alpha_c + u_i \\ \alpha_{hfi} &= \alpha_{hf}^0 + Z_i^f \alpha_{hf} \\ \alpha_{hmi} &= \alpha_{hm}^0 + Z_i^m \alpha_{hm}, \end{aligned} \quad (\text{A.2})$$

i.e. they vary linearly with observable taste-shifters  $Z_i$  (including polynomial form of age, presence of children or dependent elderly persons and dummies for education). The term  $\alpha_{ci}$  can incorporate unobserved heterogeneity, in the form of a normally-distributed error term  $u_i$ , for the model to allow random taste variation and unrestricted substitution patterns between alternatives.<sup>29</sup> We include fixed costs of work into the model that help explain that there are very few observations with a small positive number of hours worked. These costs, denoted by  $\eta_j^k$  for  $k = f, m$ , are non-zero for positive hours choices.<sup>30</sup> In general, the approach is flexible and allows imposing few constraints<sup>31</sup>. One restriction sometimes taken in the literature is to require the utility function to be monotonically increasing in consumption, as this can be seen as a minimum consistency requirement of the econometric model with economic theory. When the fraction of observations with an implied negative marginal utility of consumption is more than 5% we impose positive marginal utility as a constraint in the likelihood function.<sup>32</sup> For each labour supply choice  $j$ , disposable income is calculated as a function

$$C_{ij} = d(w_i^f H_{ij}^f, w_i^m H_{ij}^m, y_i, X_i) \quad (\text{A.3})$$

<sup>27</sup> This model has been used in well-known contributions for Europe, like van Soest (1995), Aaberge, Dagsvik, and Strøm (1995) and Blundell et al. (2000), or the US, like Hoynes (1996) and Keane and Moffitts (1998).

<sup>28</sup> Other common specifications include Box-Cox or translog utility. However, the choice of the functional form is not a significant driver of labour supply elasticities (Löffler, Peichl, and Siegloch 2014).

<sup>29</sup> By unrestricted substitution patterns we mean that the model does not impose the "Independence from Irrelevant Alternatives" assumption that is implicit in the conditional or multinomial logit model. Formally, this makes the model a mixed logit model, which we estimate using maximum simulated likelihood (see Train 2009).

<sup>30</sup> Introducing fixed costs of work, estimated as model parameters as in Bargain, Orsini, and Peichl (2014), Callan, van Soest, and Walsh (2009) or Blundell et al. (2000), improves the fit of the model.

<sup>31</sup> See Bargain, Orsini, and Peichl (2014) and van Soest (1995).

<sup>32</sup> We choose the lowest multiplier that ensures at least 95% of the observations with positive marginal utility of consumption through an iterative procedure. To speed up estimation, we refrain from estimating the model with unobserved heterogeneity in these cases, that is, we do not include an error term in the coefficient  $\alpha_{ci}$ .

of female and male earnings,  $w_i^f H_{ij}^f, w_i^m H_{ij}^m$ , non-labour income  $y_i$  and household characteristics  $X_i$ . We denote disposable income by  $C$  to stress its equivalence with consumption. In this static setting, we do not model a savings decision of the household. The elasticities we estimate are hence Marshallian elasticities.<sup>33</sup> We argue below that this elasticity concept is appropriate to use for calibration of the elasticity in the macroeconomic model. We simulate the tax-benefit function  $d$  in (A.1.3) using the tax-benefit calculator EUROMOD. Disposable income needs to be calculated at the discrete set of choices, that is, only certain points on the budget curve have to be evaluated. We obtain wage rates for individuals by dividing earnings by working hours in the choice category.<sup>34</sup> As our sample includes individuals that are not observed to be working, we estimate a Heckman selection model for wages and use predicted wages for all observations<sup>35</sup>. As the model is stochastic in nature, the full specification of the labour supply model is obtained after including i.i.d. error terms  $\epsilon_{ij}$  for each choice  $j = 1, \dots, J$ . That is, total utility at each alternative is

$$V_{ij} = U_{ij} + \epsilon_{ij}, \quad (\text{A.4})$$

with the observable part of utility  $U_{ij}$  being defined as above in (A.1.). The error terms can represent measurement errors or optimization errors of the household. Under the assumption that errors follow an extreme value type I (EV-I) distribution, the (conditional) probability for each household  $i$  of choosing a given alternative  $j$  has the explicit analytical solution below.<sup>36</sup>

$$p_{ij} = \frac{e^{U_{ij}}}{\sum_{k=1}^J e^{U_{ik}}}. \quad (\text{A.5})$$

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<sup>33</sup> Hicksian elasticities can be obtained by additionally estimating income elasticities and using the Slutsky decomposition.

<sup>34</sup> We use hours normalized through rounding to the nearest hours category instead of actual hours to reduce division bias, as in Bargain, Orsini, and Peichl (2014).

<sup>35</sup> Using predicted wages for all observations further reduces selection bias (see Bargain, Orsini, and Peichl 2014). It is common practice to first estimate wage rates and then use them in a labour supply estimation, (see Creedy and Kalb 2005; Creedy and Kalb 2006; Löffler, Peichl, and Siegloch 2014).

<sup>36</sup> See McFadden (1974) or Creedy and Kalb (2006).

## Appendix B. The QUEST model.

The household sector consists of a continuum of households  $h \in [0,1]$ . A share  $(1-\varepsilon)$  of these households is not liquidity constrained and indexed by  $i \in [0, 1-\varepsilon]$ . They have access to financial markets where they can buy and sell domestic assets (government bonds), accumulate physical capital which they rent out to the final goods sector. The remaining share  $\varepsilon$  of households is liquidity constrained and indexed by  $k \in (1-\varepsilon,1]$ . These households cannot trade in financial and physical assets and consume their disposable income each period. We identify the liquidity constrained households as low-skilled and the non-liquidity constrained households as medium- and high-skilled. For each skill group we assume that households (liquidity and non-liquidity constrained) supply differentiated labour services to unions which act as wage setters in monopolistically competitive labour markets. The unions pool wage income and distribute it in equal proportions among their members. Nominal rigidity in wage setting is introduced by assuming that the households face adjustment costs for changing wages. Non-liquidity constrained households maximise an intertemporal utility function in consumption and leisure subject to a budget constraint. These households make decisions about consumption ( $C_{i,t}$ ), and labour supply ( $L_{i,z,t}$ ), the purchases of investment good ( $J_{i,t}$ ) and government bonds ( $B_{i,t}$ ), the renting of physical capital stock ( $K_{i,t}$ ), and receive wage income ( $W_{s,t}$ ), unemployment benefits ( $bW_{s,t}$ ), transfer income from the government ( $TR_{i,t}$ ), and interest income on bonds and capital ( $i_b, i_{K,t}$ ). Hence, non-liquidity constrained households face the following Lagrangian

$$\begin{aligned} \max_{\left\{ \begin{array}{l} C_{i,t}, L_{i,z,t}, B_{i,t} \\ J_{i,t}, K_{i,t} \end{array} \right\}_{t=0}^{\infty}} V_{i,0} = E_0 \sum_{t=0}^{\infty} \beta^t & \left( U(C_{i,t}) + \sum_z V(1-L_{i,z,t}) \right) \\ - E_0 \sum_{t=0}^{\infty} \lambda_{i,t} \frac{\beta^t}{P_t} & \left( (1+t_{C,t})P_{C,t}C_{i,t} + B_{i,t} + P_{I,t}(J_{i,t} + \Gamma^J(J_{i,t})) - (1+i_{t-1})B_{i,t-1} \right. \\ & - \sum_z (1-t_{w,z,t})W_{z,t}L_{i,z,t} - bW_{z,t}(1-NPART_{i,z,t} - L_{i,z,t}) \\ & - (1-t_K)(i_{K,t-1} - rp_K)P_{I,t-1}K_{i,t-1} - t_K\delta_K P_{I,t-1}K_{i,t-1} \\ & \left. - TR_{i,t} - PR_{fin,i,t} \right) \\ - E_0 \sum_{t=0}^{\infty} \lambda_{i,t} \xi_{i,t} \beta^t & (K_{i,t} - J_{i,t} - (1-\delta_K)K_{i,t-1}) \end{aligned} \quad (B.1)$$

where  $z$  is the index for the corresponding medium ( $M$ ) and high-skilled ( $H$ ) labour type respectively ( $z \in \{M, H\}$ ). The budget constraints are written in real terms with the price for consumption and investment ( $P_{C,t}, P_{I,t}$ ) and wages ( $W_{z,t}$ ) divided by GDP deflator ( $P_t$ ). All firms of the economy are owned by non-liquidity constrained households who share the total profit of the final good sector firms,  $PR_{fin,i,t}$ . As shown by the budget constraints, all households pay consumption taxes ( $t_{C,t}$ ), wage income taxes ( $t_{w,z,t}$ ) and capital income taxes ( $t_K$ ) less depreciation allowances ( $t_K\delta_K$ ) after their earnings on physical capital. When investing into tangible capital the household requires premium  $rp_K$  in order to cover the increased risk on the return related to these assets. The utility function is additively separable in consumption ( $C_{i,t}$ ) and leisure ( $1-L_{i,z,t}$ ). We assume log-utility for consumption and allow for habit persistence in consumption (with parameter  $habc$ ) as follows:

$$U(C_{i,t}) = (1 - habc) \log(C_{i,t} - habcC_{i-1}) \quad (B.2)$$

We assume CES preferences with common elasticity but a skill specific weight ( $\omega_s$ ) on leisure. This is necessary in order to capture differences in employment levels across skill groups. Thus preferences for leisure are given by:

$$V(1 - L_{i,s,t}) = \frac{\omega_s}{1 - \kappa} (1 - L_{i,s,t})^{1 - \kappa}, \quad s \in \{L, M, H\} \quad (B.3)$$

with  $\kappa > 0$ . The investment decisions with respect to real capital are subject to convex adjustment costs, which are given by:

$$\Gamma_J(J_{i,t}) = \frac{\gamma_K}{2} \frac{(J_{i,t})^2}{K_{i,t-1}} + \frac{\gamma_I}{2} (\Delta J_{i,t})^2. \quad (B.4)$$

where  $\gamma_K$  and  $\gamma_I$  are parameters.

The first order conditions of the household with respect to consumption, financial and real assets are given by the following equations:

$$\frac{\partial V_0}{\partial C_{i,t}} \Rightarrow U_{C,i,t} - \lambda_{i,t} (1 + t_{C,t}) \frac{P_{C,t}}{P_t} = 0 \quad (B.5a)$$

$$\frac{\partial V_0}{\partial B_{i,t}} \Rightarrow -\lambda_{i,t} + E_t \left( \lambda_{i,t+1} \beta (1 + i_t) \frac{P_t}{P_{t+1}} \right) = 0 \quad (B.5b)$$

$$\frac{\partial V_0}{\partial K_{i,t}} \Rightarrow E_t \left( \lambda_{i,t+1} \frac{\beta P_{L,t}}{P_{t+1}} ((1 - t_K)(i_{K,t} - r p_K) + t_K \delta_K) \right) - \lambda_{i,t} \xi_{i,t} + E_t (\lambda_{i,t+1} \xi_{i,t+1} \beta (1 - \delta_K)) = 0 \quad (B.5c)$$

$$\frac{\partial V_0}{\partial J_{i,t}} \Rightarrow - \left( 1 + \gamma_K \left( \frac{J_{i,t}}{K_{i,t-1}} \right) + \gamma_I \Delta J_{i,t} \right) + E_t \left( \frac{1}{1 + i_t} \frac{P_{L,t+1}}{P_{L,t}} \gamma_I \Delta J_{i,t+1} \right) + \xi_{i,t} \frac{P_t}{P_{L,t}} = 0 \quad (B.5d)$$

Liquidity constrained households do not optimize but simply consume their current income at each date. Real consumption of these households is thus determined by the net wage income plus benefits and net transfers, as follows:

$$(1 + t_{C,t}) P_{C,t} C_{L,t} = (1 - t_{w,L,t}) W_{L,t} L_{L,t} + b W_{L,t} (1 - NPART_{L,t} - L_{L,t}) + TR_{L,t} \quad (B.6)$$

Within each skill group a variety of labour services are supplied which are imperfect substitutes to each other. Thus, trade unions can charge a wage mark-up ( $1/\eta_{st}$ ) over the reservation wage<sup>37</sup>. The

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<sup>37</sup> The mark-up depends on the intra-temporal elasticity of substitution between differentiated labour services within each skill groups ( $\sigma_s$ ) and fluctuations in the mark-up arise because of wage adjustment costs and the fact that a fraction ( $1 - sfw$ )



reservation wage is given as the marginal utility of leisure divided by the corresponding marginal utility of consumption. The relevant net real wage to which the mark up adjusted reservation wage is equated is the gross wage adjusted for labour taxes, consumption taxes and unemployment benefits, which act as a subsidy to leisure. Thus, the wage equation is given as

$$\frac{V_{1-L,h,s,t}}{U_{C,h,s,t}} \frac{1}{\eta_{s,t}} = \frac{W_{s,t}(1-t_{w,s,t}-b)}{P_{c,t}(1+t_{c,t})} \text{ for } s \in \{L, M, H\},^{38} \quad (\text{B.7})$$

where  $b$  is the benefit replacement rate. The aggregate of any household specific variable  $X_{h,t}$  in per capita terms is given by

$$X_t = \int_0^1 X_{h,t} dh = (1-\varepsilon)X_{i,t} + \varepsilon X_{k,t}. \quad (\text{B.8})$$

Hence, aggregate consumption and employment are given by

$$C_t = (1-\varepsilon)C_{i,t} + \varepsilon C_{k,t} \quad (\text{B.9})$$

and

$$L_t = (1-\varepsilon)L_{i,t} + \varepsilon L_{k,t}. \quad (\text{B.10})$$

We assume that final goods producers work under monopolistic competition setting and each firm produces a variety of the domestic good which is an imperfect substitute for varieties produced by other firms. Final output of firm  $j$  ( $Y_{j,t}$ ) is produced using capital  $K_{j,t}$  and a labour aggregate ( $L_{j,t}$ ) in a Cobb-Douglas technology, subject to a fixed cost  $FC_{j,t}$ , as follows:

$$Y_{j,t} = (L_{j,t} - FC_{j,t})^\alpha (u_{j,t} K_{j,t})^{1-\alpha} - FC_{j,t} \quad (\text{B.11})$$

with

of workers is indexing the growth rate of wages  $\pi_w$  to wage inflation in the previous period

$$\eta_{s,t} = 1 - 1/\sigma_s - \gamma_W / \sigma_s (\beta(sfw\pi_{W,t+1} - (1-sfw)\pi_{W,t-1}) - \pi_{W,t}).$$

<sup>38</sup> In order to find the wage equation, consider the problem of representative household  $i$ , of a subgroup  $s$  of the population given by (B.1). Then, the first order conditions with respect to labour ( $L_{i,z,t}$ ) is the following:

$$\frac{\partial V_0}{\partial L_{i,z,t}} = 0 \Leftrightarrow V'(1-L_{i,z,t}) = \frac{\lambda_{i,t}}{P_t} (1-t_{w,z,t}-b)W_{z,t}$$

We can now combine the above condition with the first order condition with respect to consumption, given by condition (2.2.5a), to obtain the intra-temporal condition on the optimal household choices on consumption and labour:

$$\frac{V'(1-L_{i,z,t})}{U'(C_{i,t})} = \frac{(1-t_{w,z,t}-b)W_{z,t}}{P_{c,t}(1+t_{c,t})}$$

We can recognize in the above condition equation (B.7), which determines the equilibrium wage. In fact, and as mentioned before, since within each sub-group  $s$  the labour services supplied are imperfect substitutes of each other, the trade unions can charge a wage mark-up ( $1/\eta_{s,t}$ ) over the reservation wage, which is given by the ratio of the marginal utilities of leisure and consumption, i.e. the left-hand side of the above equation.

$$L_{j,t} = \left( \Lambda_L^{\frac{1}{\mu}} (\chi_L L_{j,L,t})^{\frac{\mu-1}{\mu}} + \Lambda_M^{\frac{1}{\mu}} (\chi_M L_{j,M,t})^{\frac{\mu-1}{\mu}} + \Lambda_H^{\frac{1}{\mu}} (\chi_H L_{j,H,t})^{\frac{\mu-1}{\mu}} \right)^{\frac{\mu}{\mu-1}}, \quad (\text{B.12})$$

where  $L_{L,t}^j$ ,  $L_{M,t}^j$  and  $L_{H,t}^j$  denote the employment of low, medium and high-skilled by firm  $j$  respectively. Parameter  $\Lambda_s$  is the corresponding share parameter ( $s \in \{L, M, H\}$ ),  $\chi_s$  is the efficiency unit, and  $\mu$  is the elasticity of substitution between different labour types. The term  $FC_L^j$  represents overhead labour and  $u_t^j$  is the measure of capacity utilisation. The objective of the firm is to maximise the present discounted value of profits:

$$PR_{j,t} = P_{j,t} Y_{j,t} - \sum_s (1 + t_{er,s,t}) W_{j,s,t} L_{j,s,t} - i_t^K P_{j,t} K_{j,t} - (\Gamma^P(P_{j,t}) + \Gamma^L(L_{j,L,t}, L_{j,M,t}, L_{j,H,t}) + \Gamma^u(u_{j,t})) \quad (\text{B.13})$$

where  $i^K$  denotes the rental rate of capital  $t_{er,s,t}$  stands for the implicit tax rate on labour levied on the employers. Following Ratto et al. (2009), we assume that firms face technological constraints which restrict their price setting, employment and capacity utilisation decisions. These constraints are captured by the corresponding adjustment costs  $(\Gamma^P + \Gamma^L + \Gamma^u)$ . It can be shown that in a symmetric equilibrium, when  $P_{j,t} = P_t, \forall j$ , firms charge a mark-up over the marginal cost of production (MC):

$$P_{j,t} = \frac{1}{\eta_{j,t}} MC_{j,t} \quad (\text{B.14})$$

where  $\eta_{j,t}$  is the inverse price mark-up factor which is defined as a function of the elasticity of substitution ( $\sigma^d$ ), changes in inflation ( $\pi$ ) and the mark-up shock ( $\varepsilon_{mkp}$ )<sup>39</sup>. Skill-specific labour demand can be obtained from the first order condition with respect to labour:

$$P_{j,t} \frac{\partial Y_{j,t}}{\partial L_{j,s,t}} \eta_{j,t} = (1 + t_{er,s,t}) W_{j,s,t} + \frac{\partial \Gamma^L(L_{j,L,t}, L_{j,M,t}, L_{j,H,t})}{\partial L_{j,s,t}^j}, \quad s \in \{L, M, H\}, \quad (\text{B.15})$$

where the marginal product of labour, the corresponding adjustment costs and the gross mark-up factor will jointly determine the optimally chosen level of low-, medium- and high-skilled employment level. Similarly, the demand for capital is constrained by the corresponding first order condition:

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<sup>39</sup> We follow Ratto et. al (2009) and allow for additional backward looking elements by assuming that a fraction  $(1-sfp)$  of firms index price increases to inflation in  $t-1$ ,  $\eta_{j,t} = \eta = 1 - 1/\sigma^d - \gamma_P \left( \beta(sfp E_t \pi_{t+1} + (1-sfp)\pi_{t-1}) - \pi_t \right) + \varepsilon_{mkp}$ , where  $\gamma_P$  is the corresponding adjustment cost parameter.

$$(1-\alpha)P_{j,t} \frac{\partial Y_{j,t}}{\partial K_{j,t}} \eta_{j,t} = i_{K,t} P_{j,I,t} \quad (\text{B.16})$$

where  $P_{j,I,t}$  is the price of investment goods while  $i_{K,t}$  is the rental rate of capital. Finally, the first order condition for capacity utilisation is:

$$(1-\alpha)P_{j,t} \frac{\partial Y_{j,t}}{K_{j,t} ucap_{j,t}} \eta_{j,t} = i_{K,t} P_{j,I,t} \quad (\text{B.17})$$

In this model we have a fiscal authority which manages a public budget. On the expenditure side we distinguish between government consumption ( $G_t$ ), government investment ( $IG_t$ ), government transfers ( $TR_t$ ) and unemployment benefits ( $BEN_t$ ), where

$$BEN_t = \sum_s b W_{s,t} (1 - NPART_{s,t} - L_{s,t}), s \in \{L, M, H\}. \quad (\text{B.18})$$

Government revenues  $R_t^G$  are made up of taxes on consumption as well as capital and labour income:

$$R_t^G = t_{C,t} P_{C,t} C_{i,t} + \sum_s (t_{w,s,t} + t_{er,s,t}) W_{s,t} L_{s,t} + t_K i_{K,t-1} P_{I,t-1} K_{i,t-1} - t_K \delta_K P_{I,t-1} K_{i,t-1}. \quad (\text{B.19})$$

Government debt ( $B_t$ ) evolves according to

$$B_t = (1+i_t) B_{t-1} + G_t + IG_t + TR_t + BEN_t - R_t^G. \quad (\text{B.20})$$

The labour tax ( $t_{w,t}$ ) is used for controlling the debt to GDP ratio, according to the following rule:

$$\Delta t_{w,t} = \tau_B \left( \frac{B_{t-1}}{Y_{t-1}} - b^T \right) + \tau_{DEF} \Delta \left( \frac{B_t}{Y_t} \right), \quad (\text{B.21})$$

where  $\tau_B$  captures the sensitivity with respect to deviations from  $b^T$ , the government debt target, and  $\tau_{DEF}$  controls the sensitivity of the tax-rule with respect to changes in the debt to output ratio. Note that this budget balanced rule is turned off when simulating the tax reforms considered in this paper.

Monetary policy is modelled via the following Taylor rule, which allows for some smoothness of the interest rate response ( $i_t$ ) to the inflation and output gap:

$$i_t = \gamma_{ilag} i_{t-1} + (1 - \gamma_{ilag}) (r_{EQ} + \pi_{TAR} + \gamma_{inf} (\pi_{C,t} - \pi_{TAR}) + \gamma_{ygap} \hat{y}_t) \quad (\text{B.22})$$

The central bank has a constant inflation target ( $\pi_{TAR}$ ) and it adjusts interest rates whenever actual consumer price inflation ( $\pi_{C,t}$ ) deviates from the target and it also responds to the output gap ( $\hat{y}_t$ )

via the corresponding  $\gamma_{inf}$  and  $\gamma_{ygap}$  coefficients. There is also some inertia in nominal interest rate setting over the equilibrium real interest rate  $r_{EQ}$  determined by  $\gamma_{ilag}$ . Output gap is defined as deviation of capital and labour utilisation from their long run trends. Note that in our multi-country setting, members of the euro area do not have independent monetary policy. In this way, we assume that the European Central Bank sets interest rate by taking into account the euro area wide aggregate inflation and output gap changes in its Taylor-rule.

Finally, in what concerns the trading sector and in order to facilitate aggregation, we assume that households, the government and the final goods sector have identical preferences across goods used for private consumption, investment and public expenditure. Let  $Z_t \in \{C_t, I_t, G_t, IG_t\}$  be the demand of households, investors or the government as defined in the previous section. Then their preferences are given by the following utility function:

$$Z_t = \left( (1-\rho)^{\frac{1}{\sigma_{im}}} Z_{d,t}^{\frac{\sigma_{im}-1}{\sigma_{im}}} + \rho^{\frac{1}{\sigma_{im}}} Z_{f,t}^{\frac{\sigma_{im}-1}{\sigma_{im}}} \right)^{\frac{\sigma_{im}}{\sigma_{im}-1}}, \quad (B.23)$$

where  $\rho$  is the share parameter and  $\sigma_{im}$  is the elasticity of substitution between domestic ( $Z_{d,t}$ ) and foreign produced goods ( $Z_{f,t}$ ).

## Appendix C. The inter-temporal labour supply function in QUEST

Consider the QUEST model described in Appendix B. Consider also the labour supply function in equation (19), derived in Section 4.1. In order to derive the inter-temporal labour supply function, one needs to combine the intra-temporal optimality condition with the intra-temporal one (the Euler equation). Let us consider first the intra-temporal optimality condition given by equation (B.7) and write it one period ahead, as follows:

$$\frac{V_{1-L,h,s,t+1}}{U_{C,h,s,t+1}} \frac{1}{\eta_{s,t+1}} = \frac{W_{s,t+1}(1-t_{W,s,t+1}-b)}{P_{c,t+1}(1+t_{c,t+1})} \quad (C.1)$$

As before, from this condition we can obtain the labour supply function of the  $N$  households in group  $s$ , one period ahead:

$$L_{s,t+1} = N \left( 1 - \left[ \frac{\omega_s}{\eta_{s,t+1}} \frac{1}{W_{s,t+1}(1-t_{W,s,t+1}-b)} \frac{P_{c,t}(1+t_{c,t+1})}{U_{C,h,s,t+1}} \right]^{1/\kappa} \right) \quad (C.2)$$

We can now substitute in (C.2) the marginal utility of consumption  $U_{C,h,s,t+1}$  by its expression one period ahead, given the functional form in expression (B.2):

$$L_{s,t+1} = N \left( 1 - \left[ \frac{\omega_s}{\eta_{s,t+1}} \frac{1}{W_{s,t+1}(1-t_{W,s,t+1}-b)} \frac{P_{c,t}(1+t_{c,t+1})}{1-habc} (C_{i,t+1} - habcC_t) \right]^{1/\kappa} \right) \quad (C.3)$$

At this point, we need to consider also the intertemporal optimality condition of the household problem – the Euler equation. This condition is obtained by combining the first order conditions with respect to consumption and bonds of the household problem, i.e. equations (B.5a) and (B.5b) respectively, and it explains the path of consumption over time. From these two conditions, we obtain an expression for the Lagrangian multiplier,  $\lambda_{i,t}$ :

$$\lambda_{i,t} = \frac{P_t}{P_{c,t}} \frac{U_{C,i,t}}{1+t_{c,t}} \quad (C.4)$$

And writing (C.4) one period ahead, we get:

$$\lambda_{i,t+1} = \frac{P_{t+1}}{P_{c,t+1}} \frac{U_{C,i,t+1}}{1+t_{c,t+1}} \quad (C.5)$$

Now that we have the expressions of the Lagrangian multiplier, at  $t$  and  $t+1$ , we can substitute them in the first order condition with respect to bonds to obtain the Euler equation:

$$\frac{U_{C,i,t}}{P_{c,t}(1+t_{c,t})} \frac{1}{\beta(1+i_t)} = E_t \left[ \frac{U_{C,i,t+1}}{P_{c,t+1}(1+t_{c,t+1})} \right] \quad (C.6)$$

where we can explicitly include the expressions of the marginal utility of consumption at  $t$  and  $t+1$ . Then, the Euler equation can be re-written as follows:

$$E_t [P_{c,t+1}(1+t_{c,t+1})(C_{i,t+1} - habcC_t)] = \beta(1+i_t)P_{c,t}(1+t_{c,t})(C_{i,t} - habcC_{t-1}) \quad (C.7)$$

The next step is to include the Euler equation derived in equation (C.7) in the labour supply function, equation (C.3) to obtain a relation between the labour supplied tomorrow and consumption today, as follows:

$$L_{s,t+1} = N \left( 1 - \left[ \frac{\omega_s}{\eta_{s,t+1}} \frac{1}{W_{s,t+1}(1-t_{W,s,t+1}-b)} \frac{\beta(1+i_t)P_{c,t}(1+t_{c,t})(C_{i,t}-habcC_{t-1})}{1-habc} \right]^{1/\kappa} \right) \quad (C.8)$$

Recurring again to the intra-temporal optimality condition, and substituting the marginal utilities of leisure and consumption, we find that:

$$P_{c,t}(1+t_{c,t})(C_{i,t}-habcC_{t-1}) = \frac{\eta_{s,t}(1-habc)}{\omega_s} W_{s,t}(1-t_{W,s,t}-b)(1-L_{i,s,t})^\kappa \quad (C.9)$$

Substituting the previous result in the labour supply equation given by (C.8), we will obtain finally an expression which includes  $L_{s,t+1}$ ,  $L_{i,s,t}$ ,  $W_{s,t+1}$  and  $W_{s,t}$ , shown below.

$$L_{s,t+1} = N \left( 1 - \left[ \frac{\eta_{s,t}}{\eta_{s,t+1}} \frac{W_{s,t}(1-t_{W,s,t}-b)}{W_{s,t+1}(1-t_{W,s,t+1}-b)} \beta(1+i_t)(1-L_{i,s,t})^\kappa \right]^{1/\kappa} \right) \quad (C.10)$$

After some algebraic computations we can derive the following expression, which relates the path of leisure hours (and labour supply) with the path of wages, as follows:

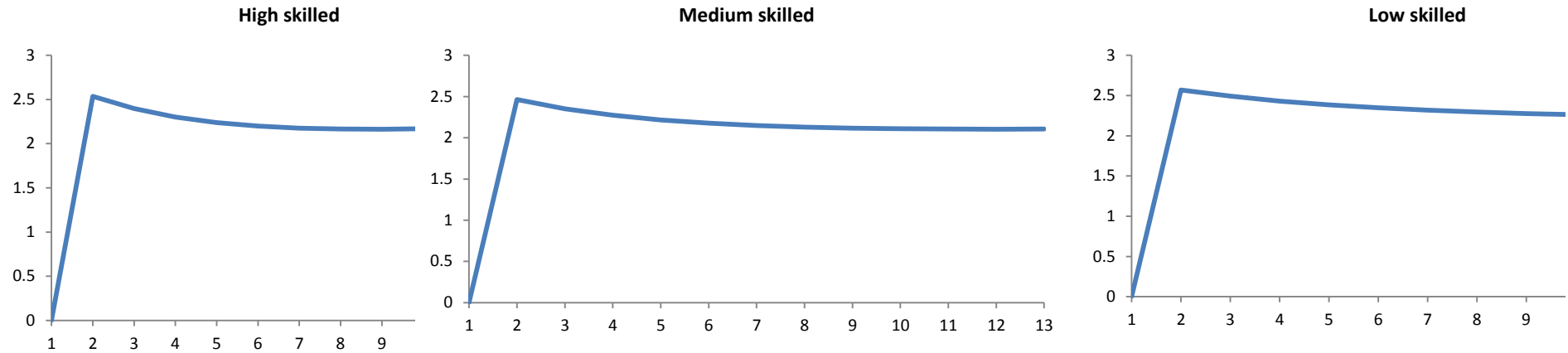
$$\frac{1-L_{i,s,t+1}}{1-L_{i,s,t}} = \left[ \beta(1+i_t) \frac{\eta_{s,t}}{\eta_{s,t+1}} \frac{1-t_{W,s,t}-b}{1-t_{W,s,t+1}-b} \right]^{1/\kappa} \left( \frac{W_{s,t+1}}{W_{s,t}} \right)^{-1/\kappa} \quad (C.11)$$

Similarly to the Euler equation, equation (C.11) represents the inter-temporal optimality condition for leisure (labour). We can now denote  $\frac{1-L_{i,s,t+1}}{1-L_{i,s,t}} = (1-\widehat{L}_{i,s})$  and  $\frac{W_{s,t+1}}{W_{s,t}} = \widehat{W}_s$  and rewrite equation (C.11) as follows:

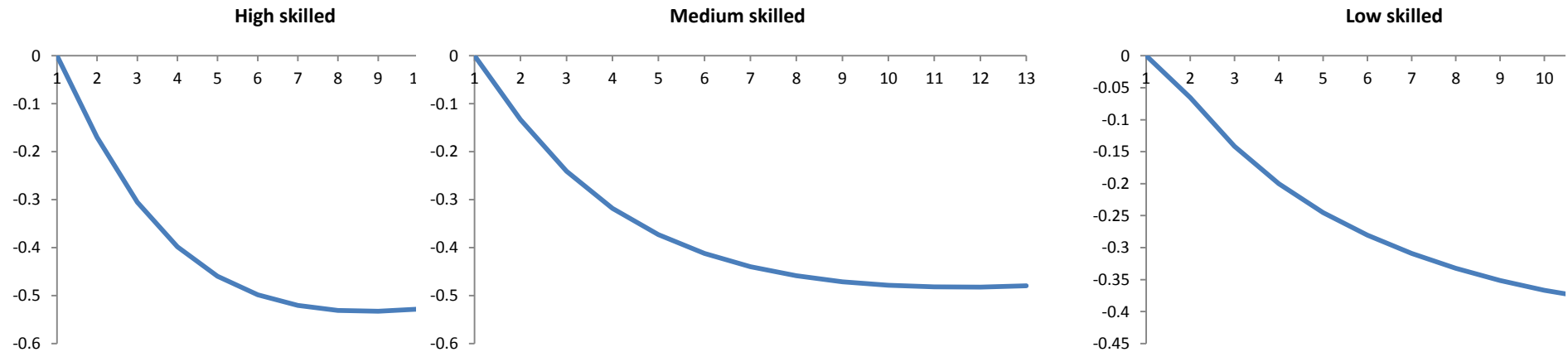
$$(1-\widehat{L}_{i,s}) = \left[ \beta(1+i_t) \frac{\eta_{s,t}}{\eta_{s,t+1}} \frac{1-t_{W,s,t}-b}{1-t_{W,s,t+1}-b} \right]^{1/\kappa} (\widehat{W}_s)^{-1/\kappa} \quad (C.12)$$

## Appendix D. QUEST Impulse responses

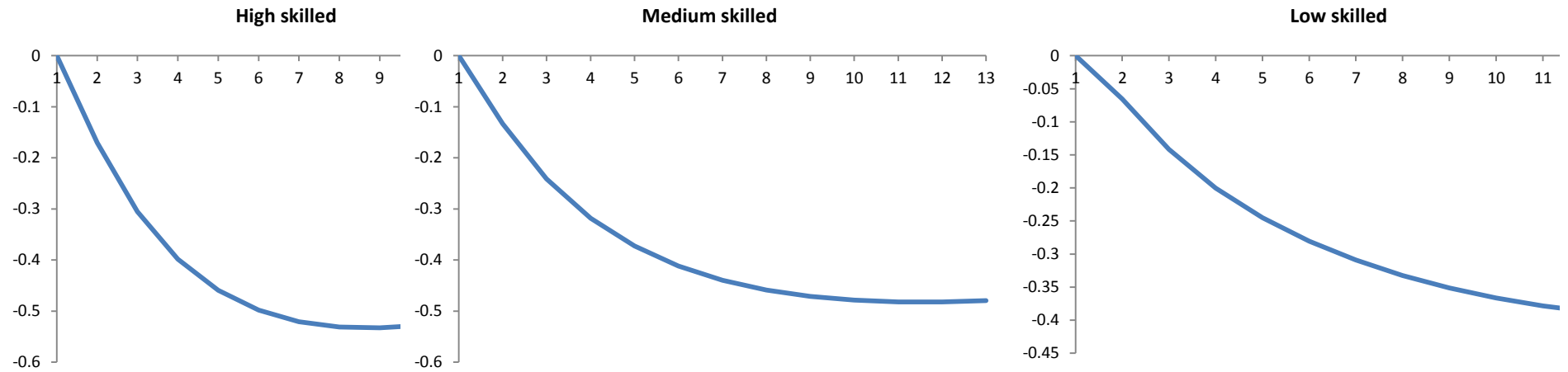
### D.1 Net real wage of employees, per skill level (% quarterly change from baseline) – Belgium



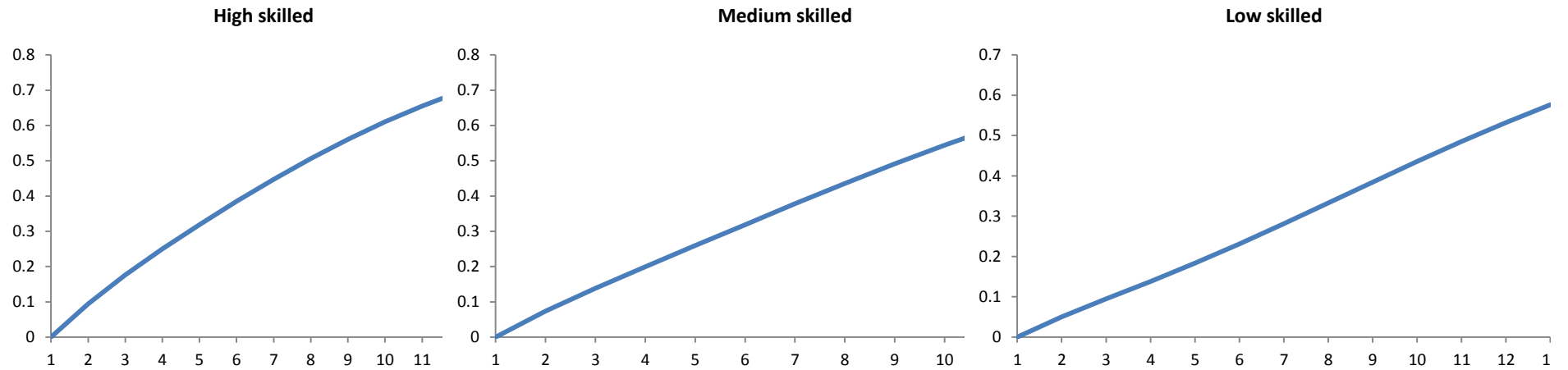
### D.2 Total compensation of employees, per skill level (% quarterly change from baseline) – Belgium



### D.3 Gross real wage, per skill level (% quarterly change from baseline) – Belgium

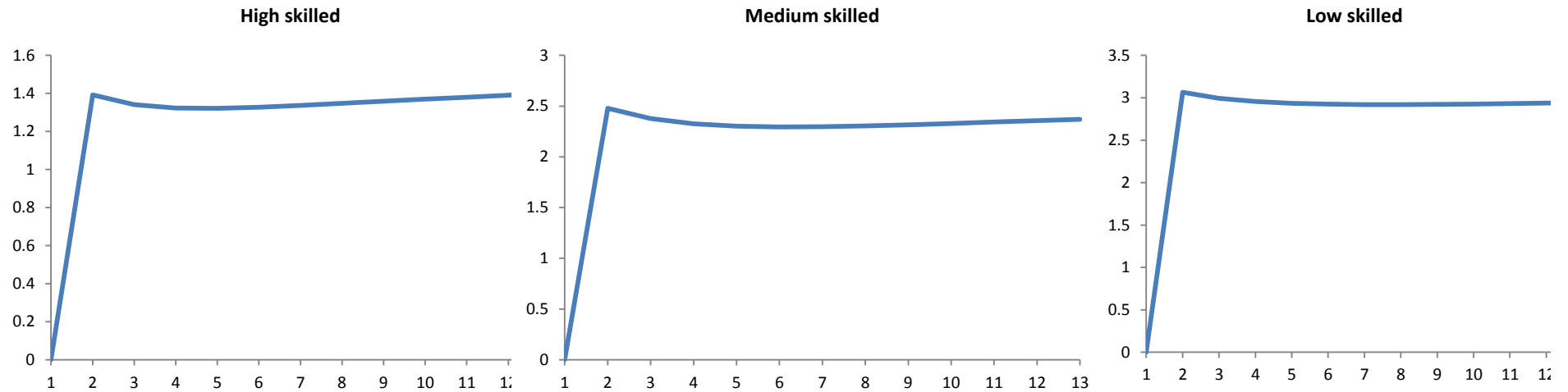


### D.4 Employment, per skill level (% quarterly change from baseline) – Belgium

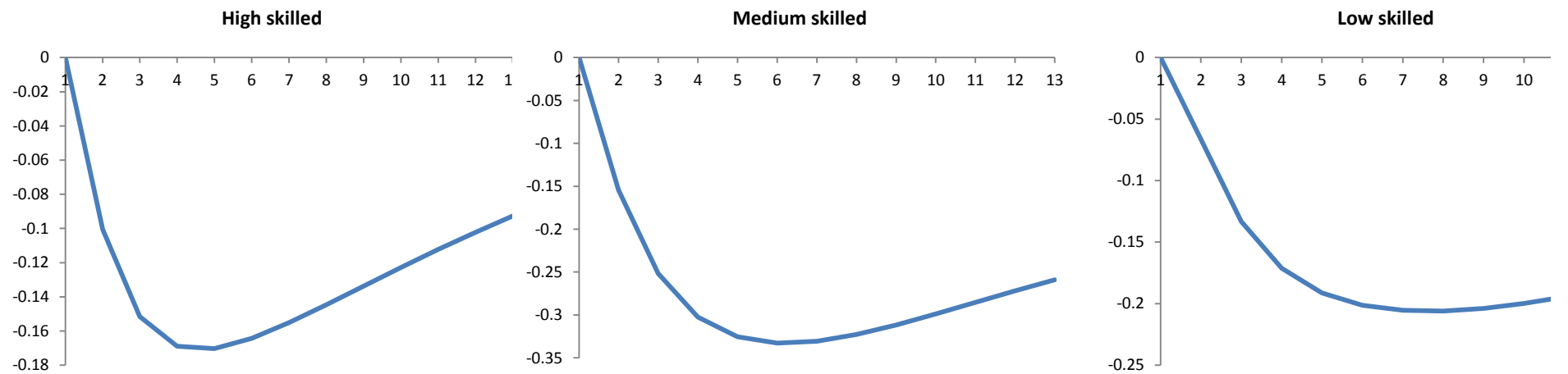




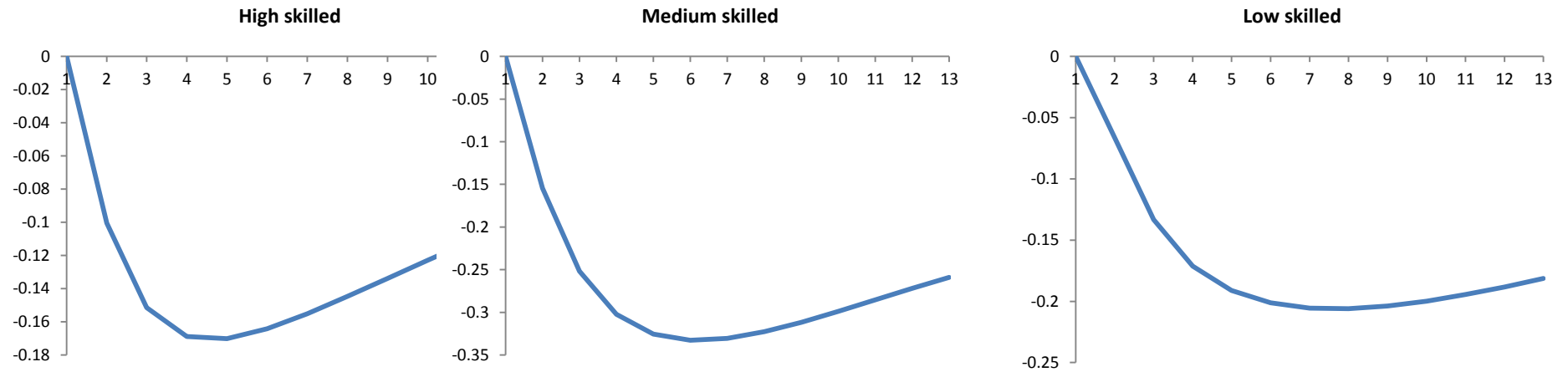
### D.5 Net real wage of employees, per skill level (% quarterly change from baseline) – Italy



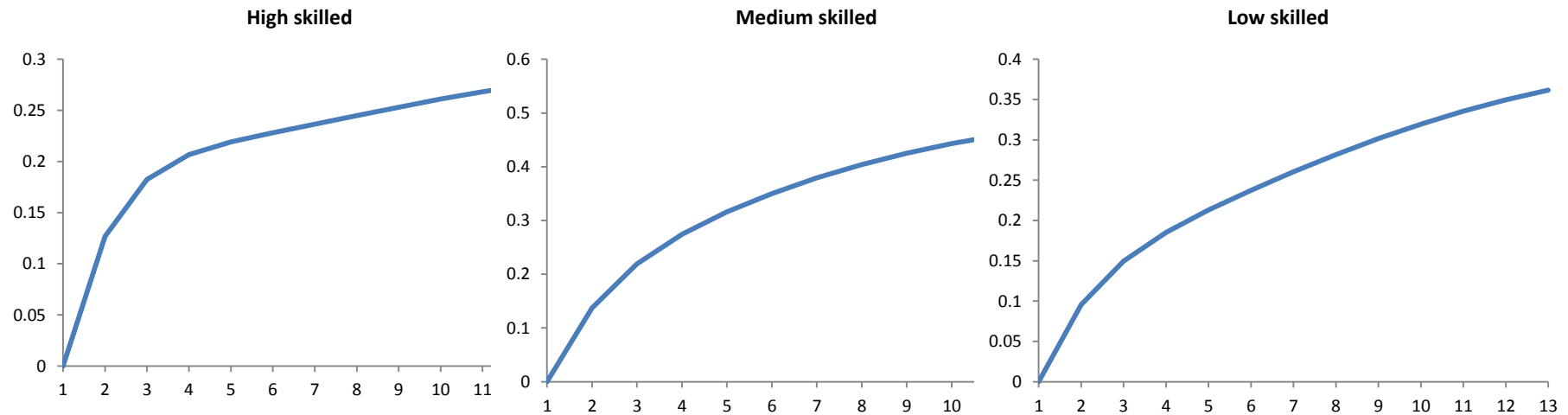
### D.6 Total compensation of employees, per skill level (% quarterly change from baseline) – Italy



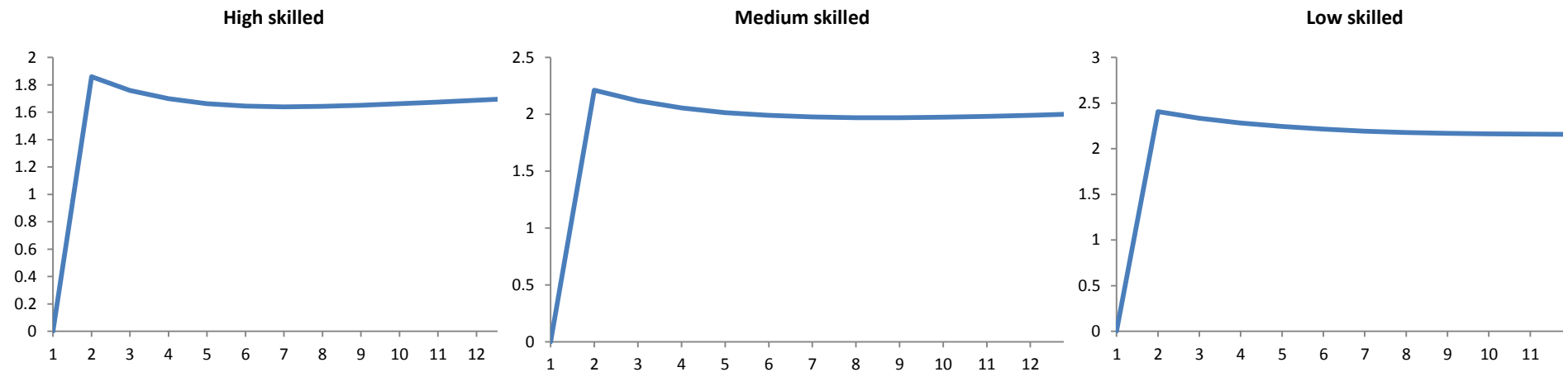
### D.7 Gross real wage, per skill level (% quarterly change from baseline) – Italy



### D.8 Employment, per skill level (% quarterly change from baseline) – Italy



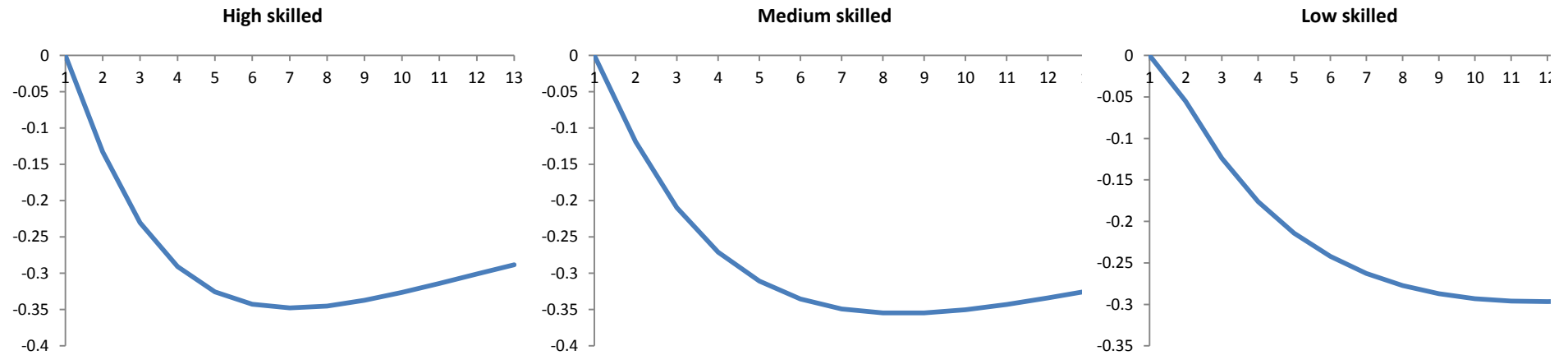
**D.9 Net real wage of employees, per skill level (% quarterly change from baseline) – Poland**



**D.10 Total compensation of employees, per skill level (% quarterly change from baseline) – Poland**



**D.11 Gross real wage, per skill level (% quarterly change from baseline) – Poland**

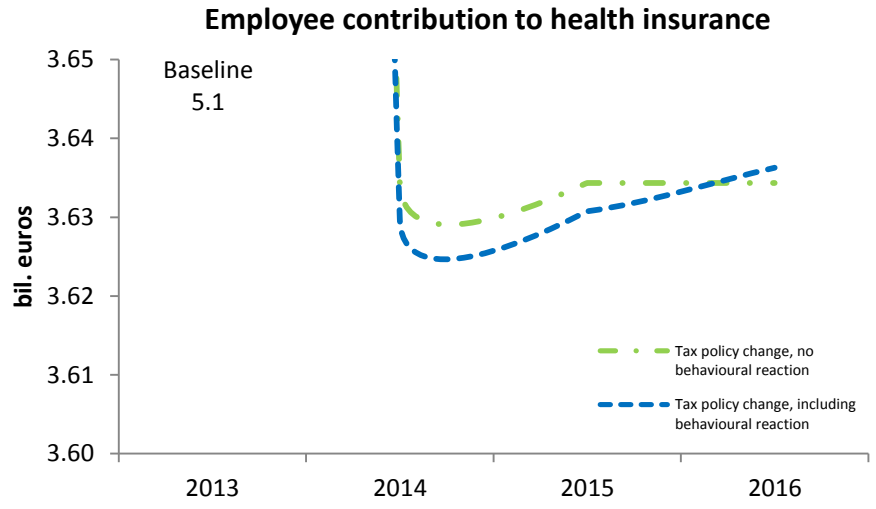
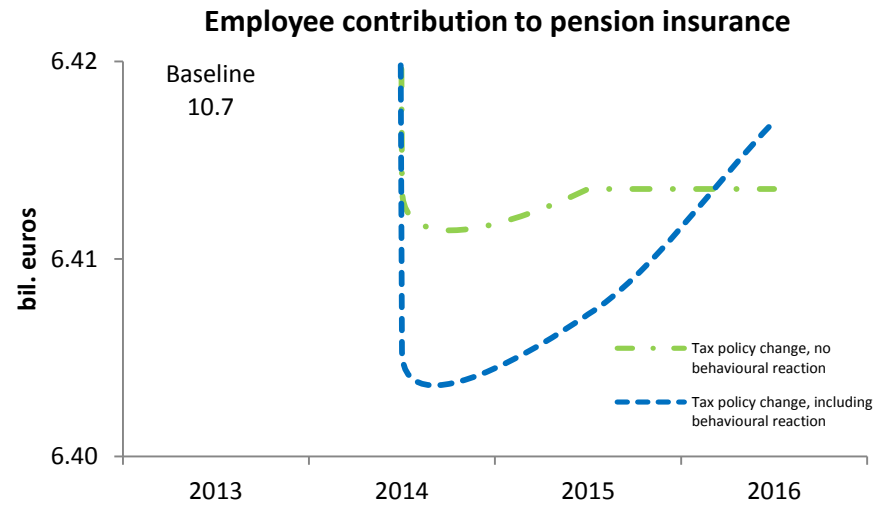


**D.12 Employment, per skill level (% quarterly change from baseline) – Poland**

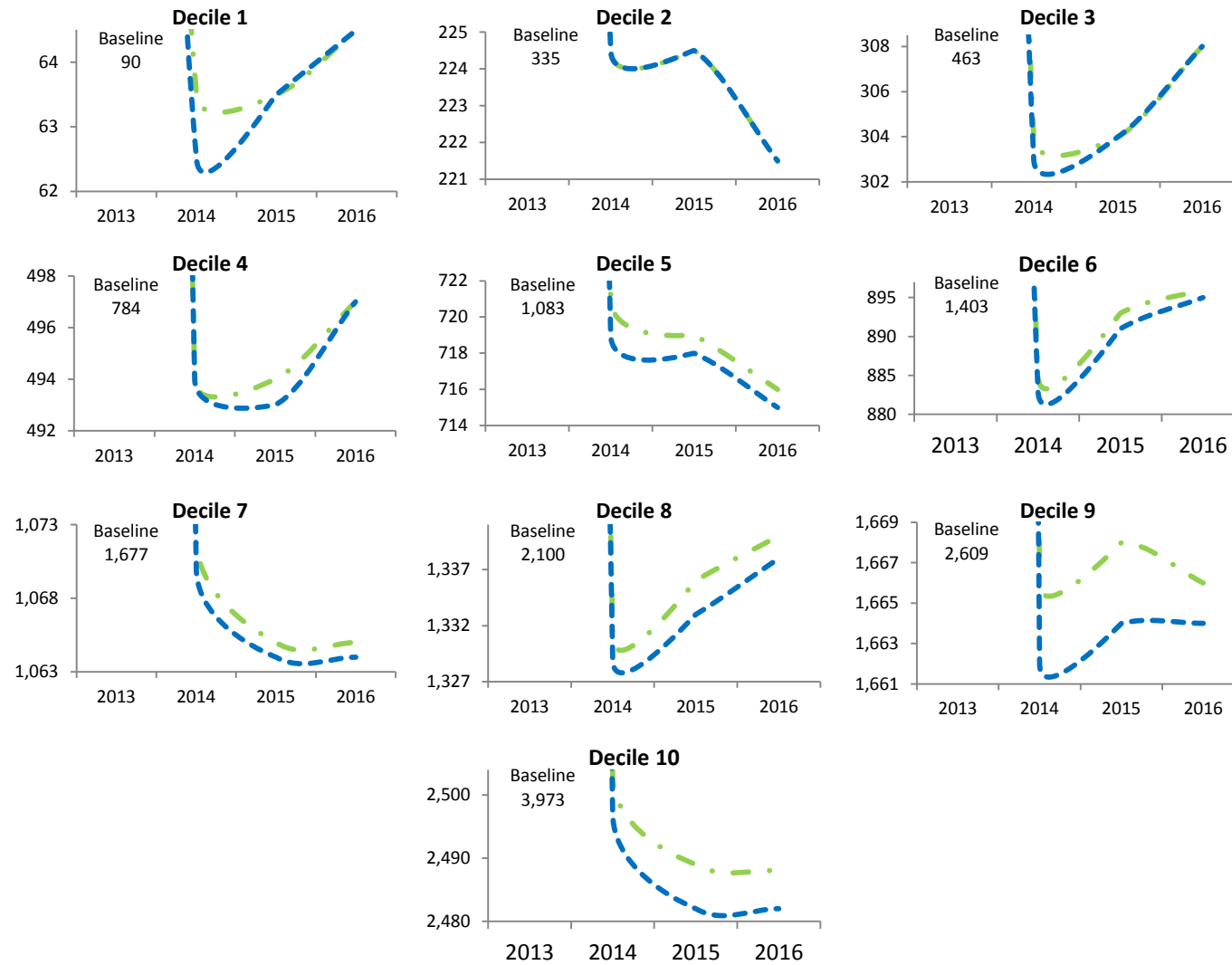


Appendix E. Budgetary and redistributive effects of the reforms

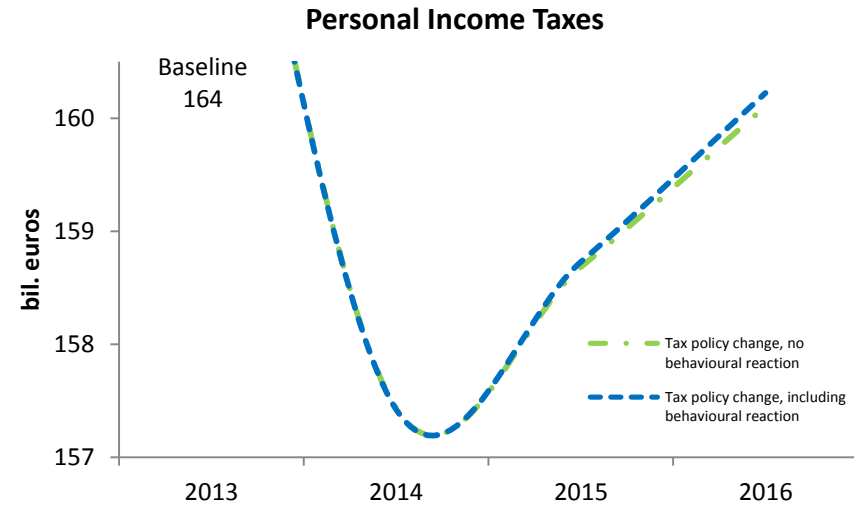
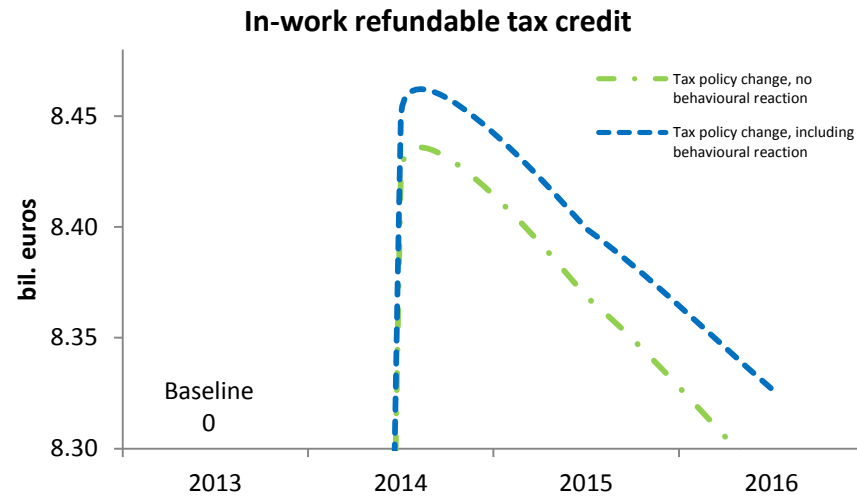
E.1 Employee contribution impact in EUROMOD incorporating macro feedback on prices, wages and employment – Belgium



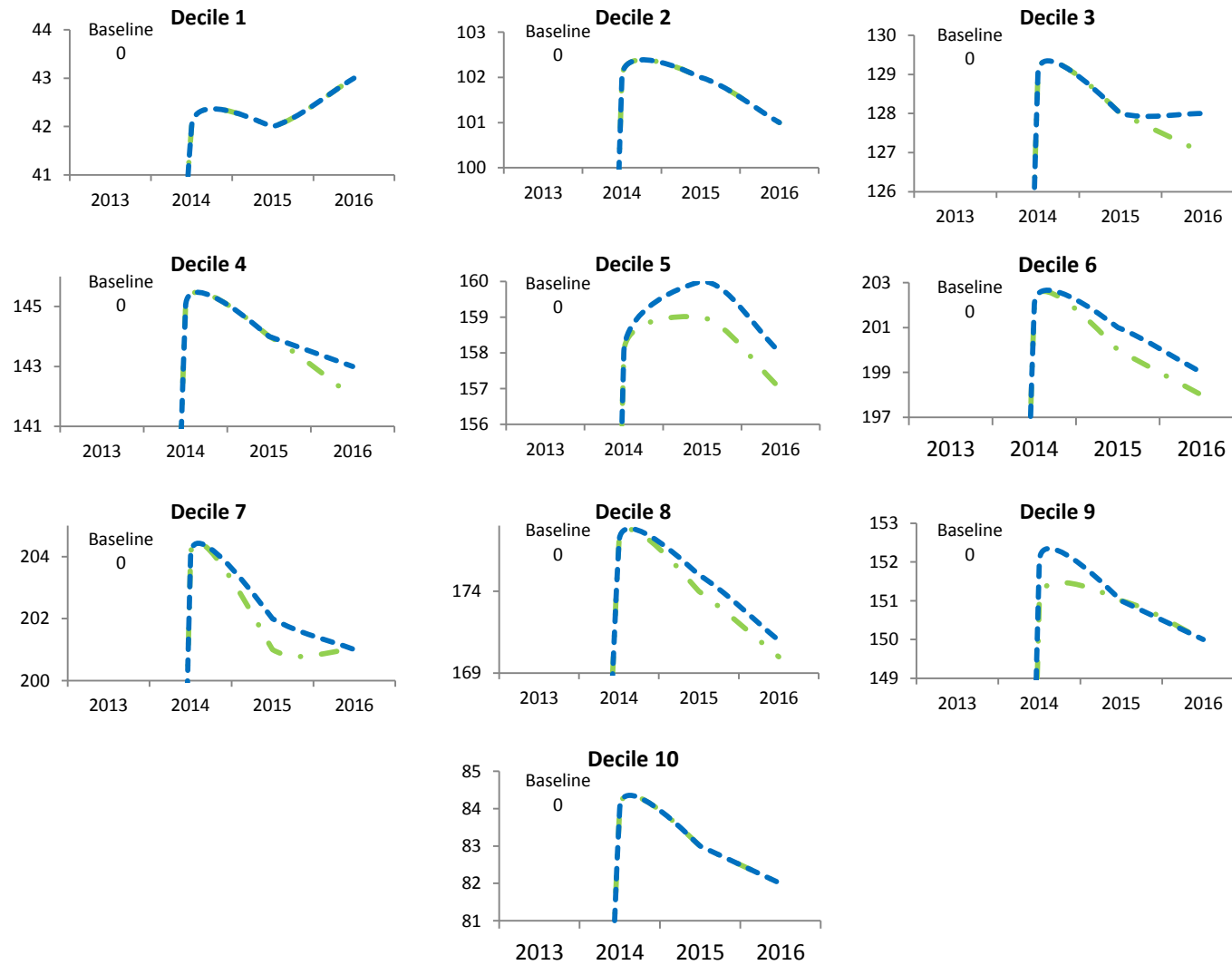
## E.2 Impact on employee contribution to pension and health insurance by income decile – Belgium



### E.3 Tax revenues impact in EUROMOD incorporating macro feedback on prices, wages and employment – Italy

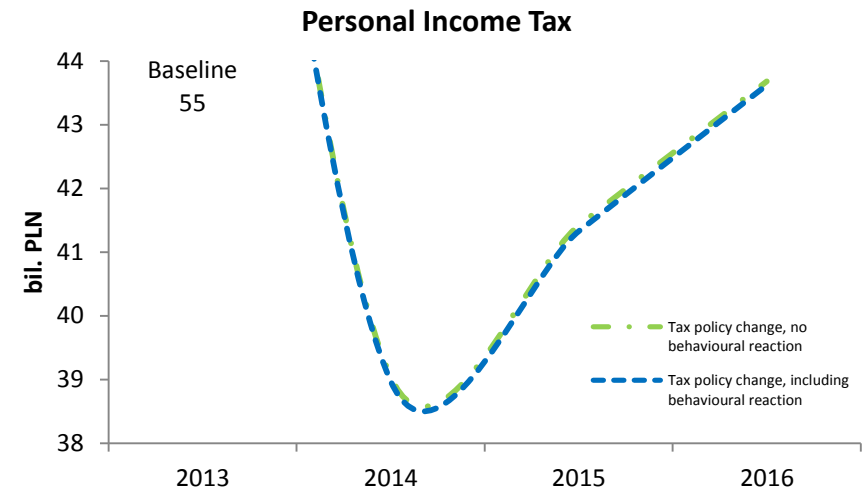
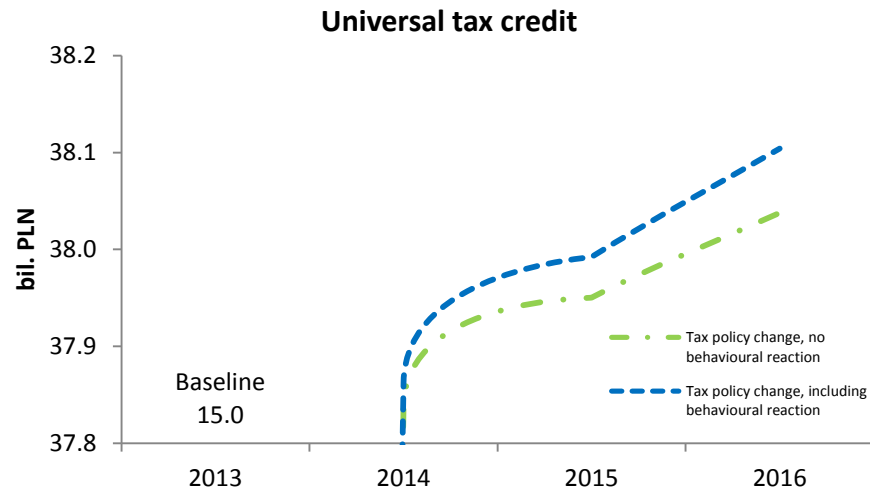


#### E.4 Impact on in-work refundable tax credit by income decile – Italy

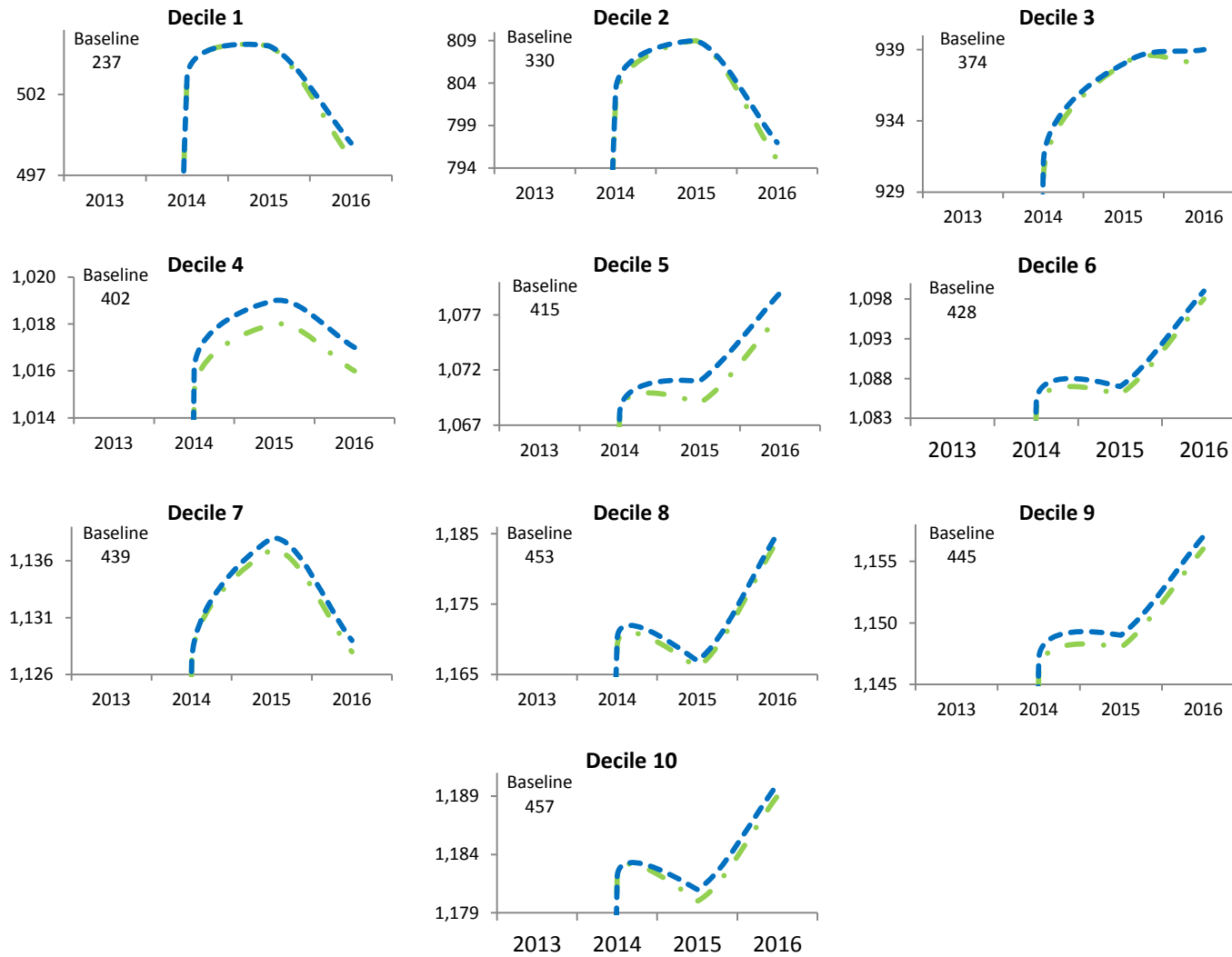




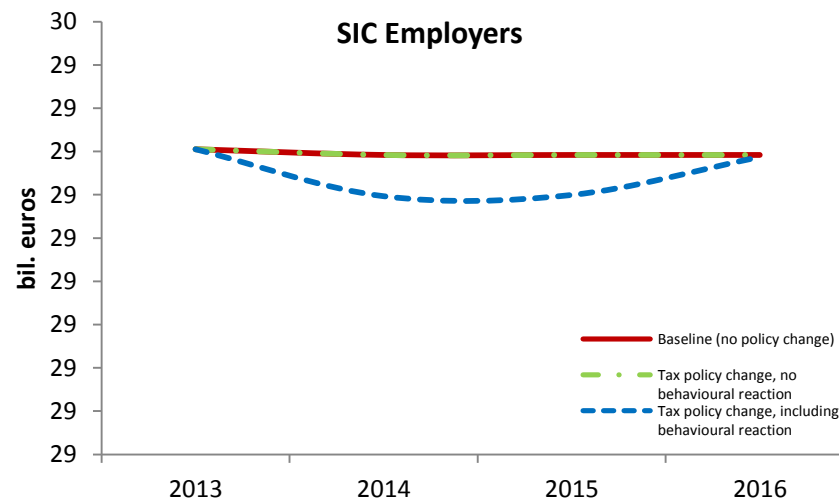
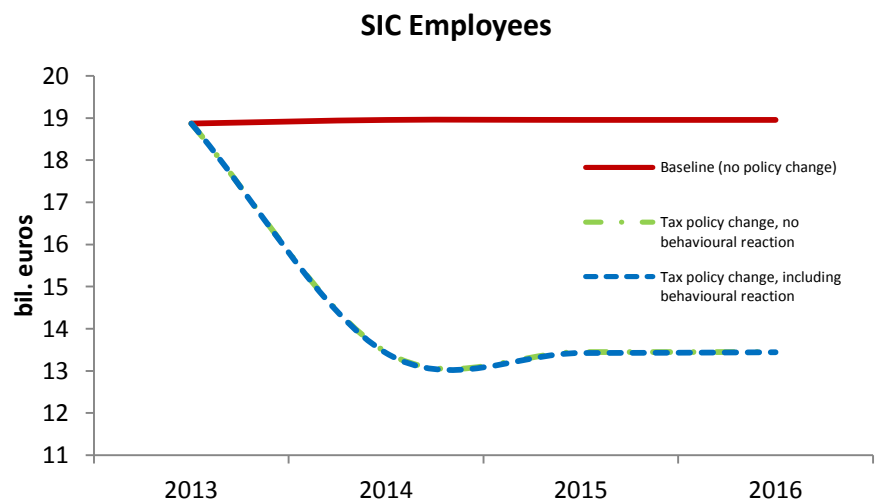
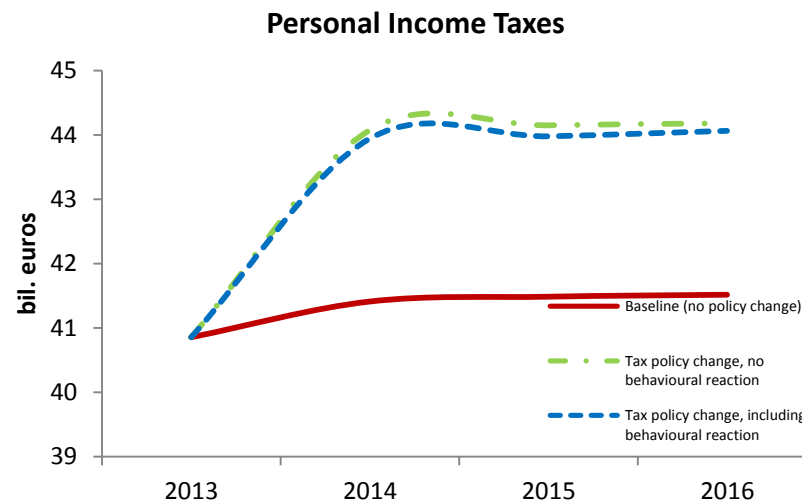
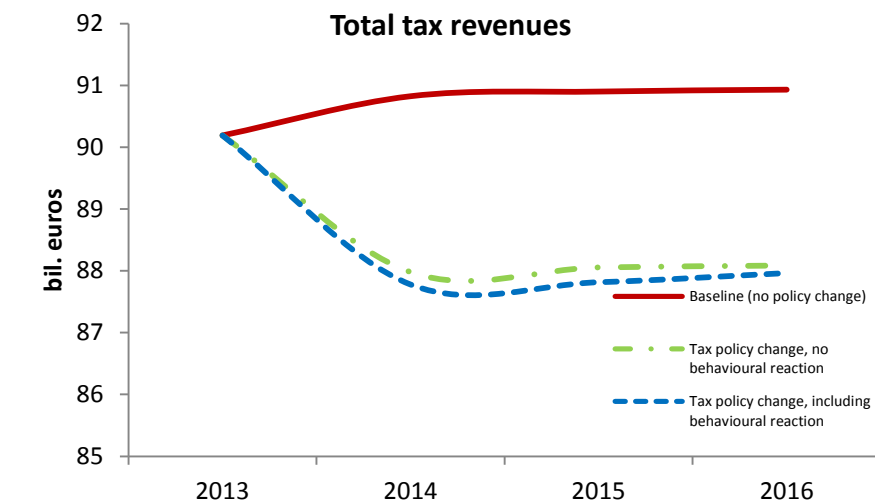
### E.5 Tax revenues impact in EUROMOD incorporating macro feedback on prices, wages and employment – Poland



## E.6 Impact on universal tax credit by income decile – Poland



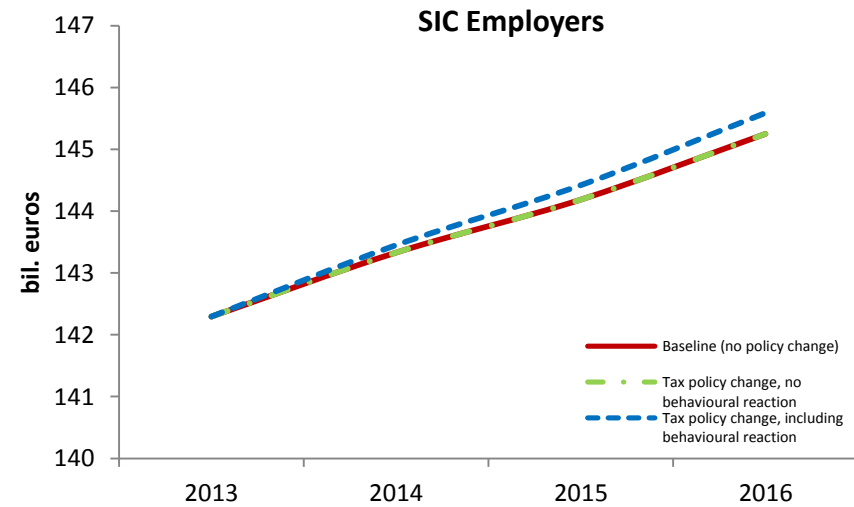
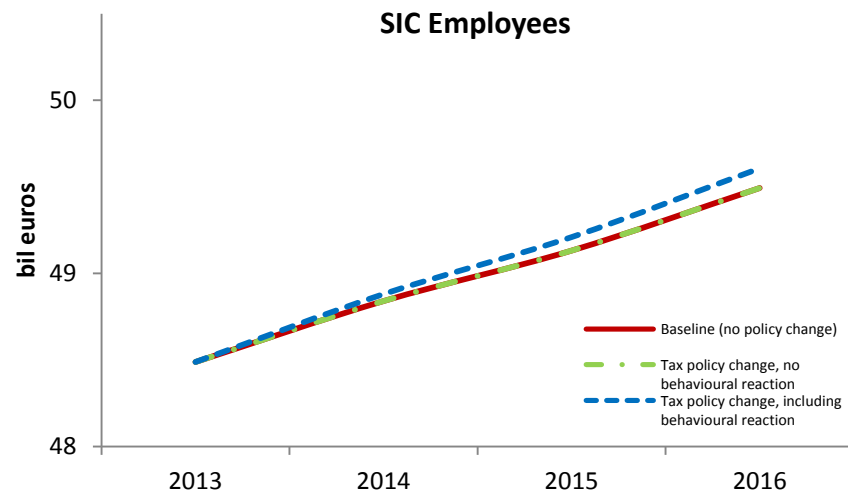
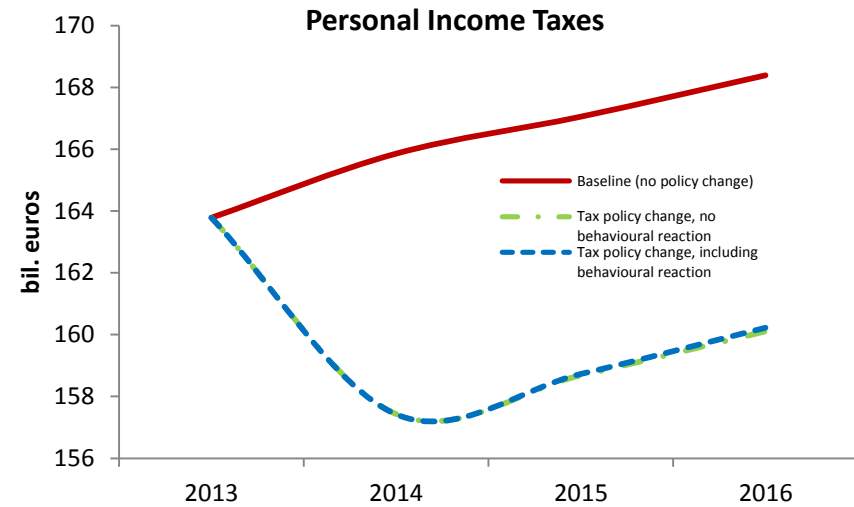
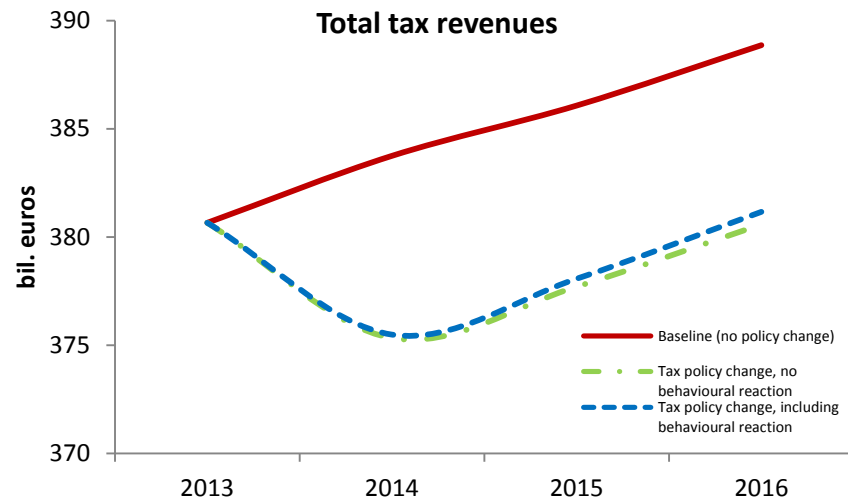
## E.7 Tax revenues impact in EUROMOD incorporating macro feedback on prices, wages and employment – Belgium



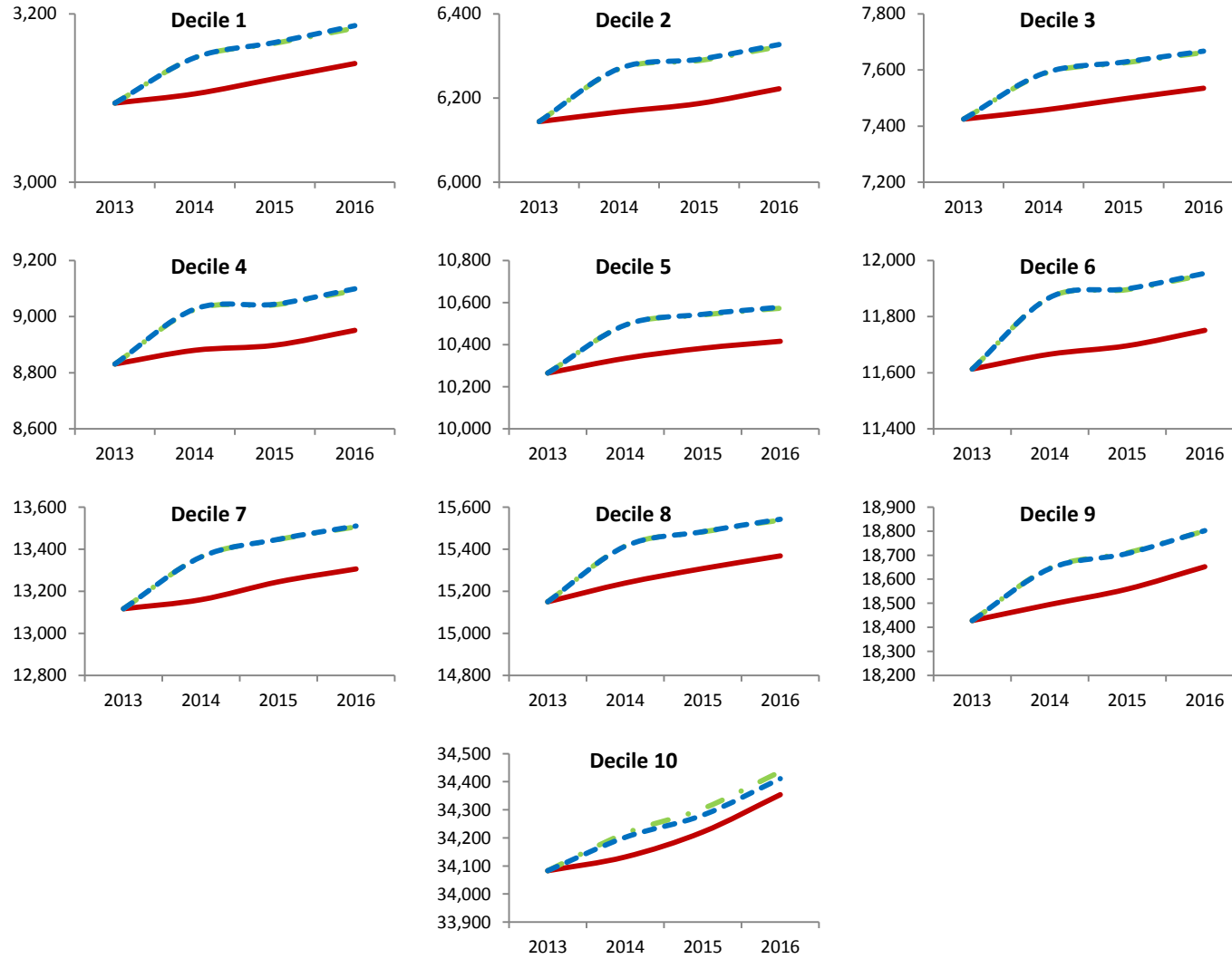
### E.8 Impact on disposable income by income decile – Belgium



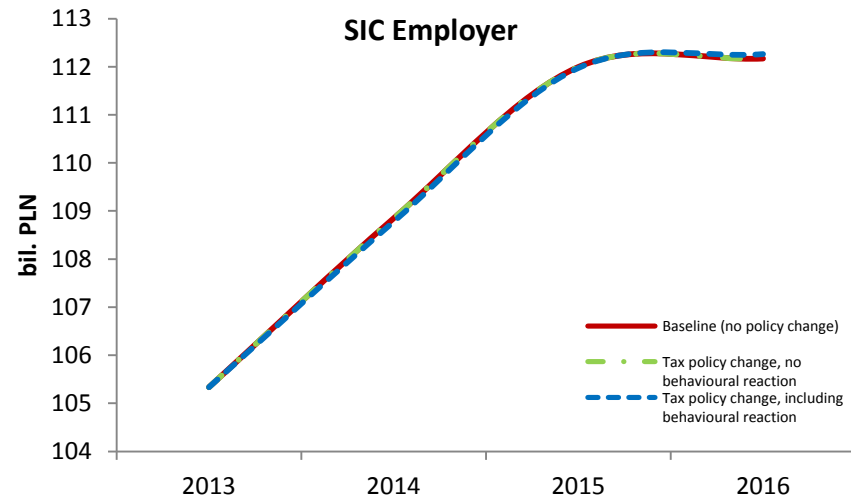
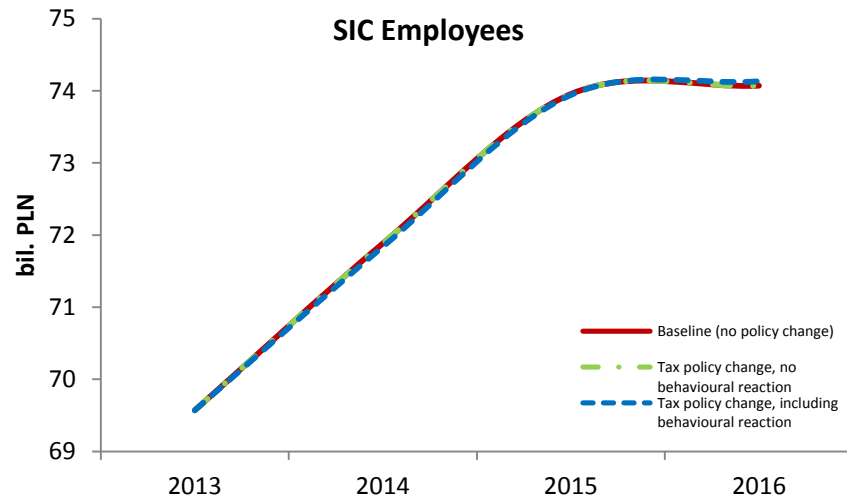
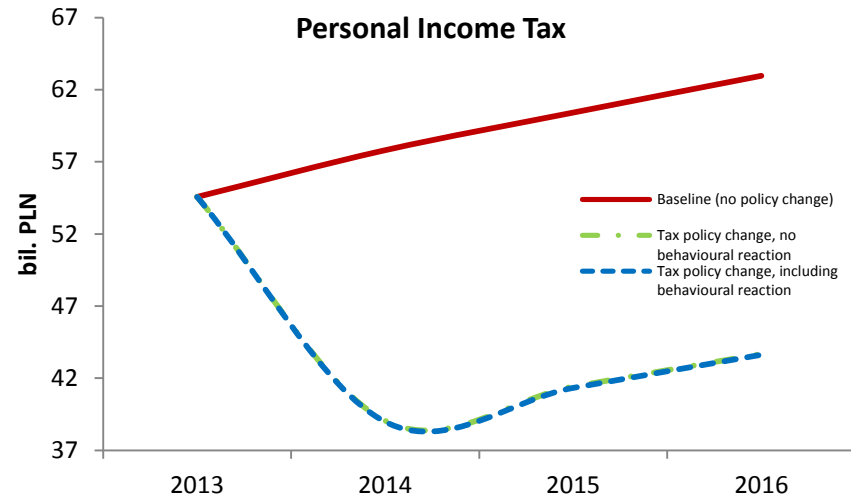
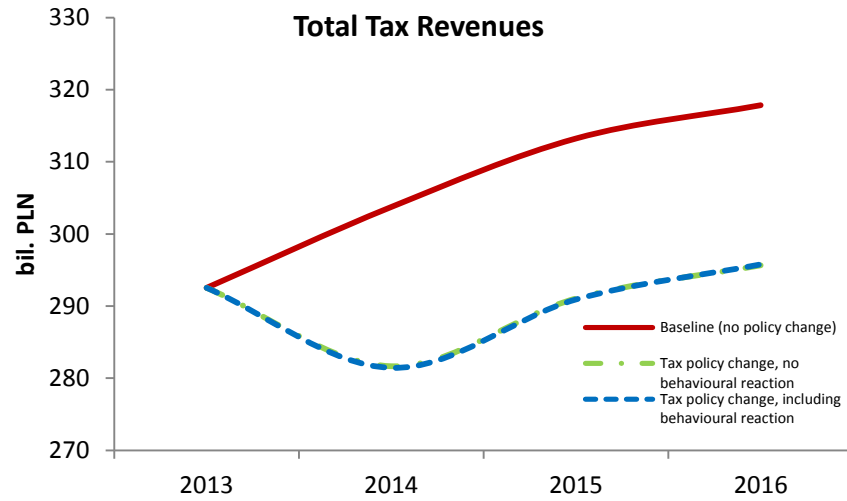
### E.9 Tax revenues impact in EUROMOD incorporating macro feedback on prices, wages and employment – Italy



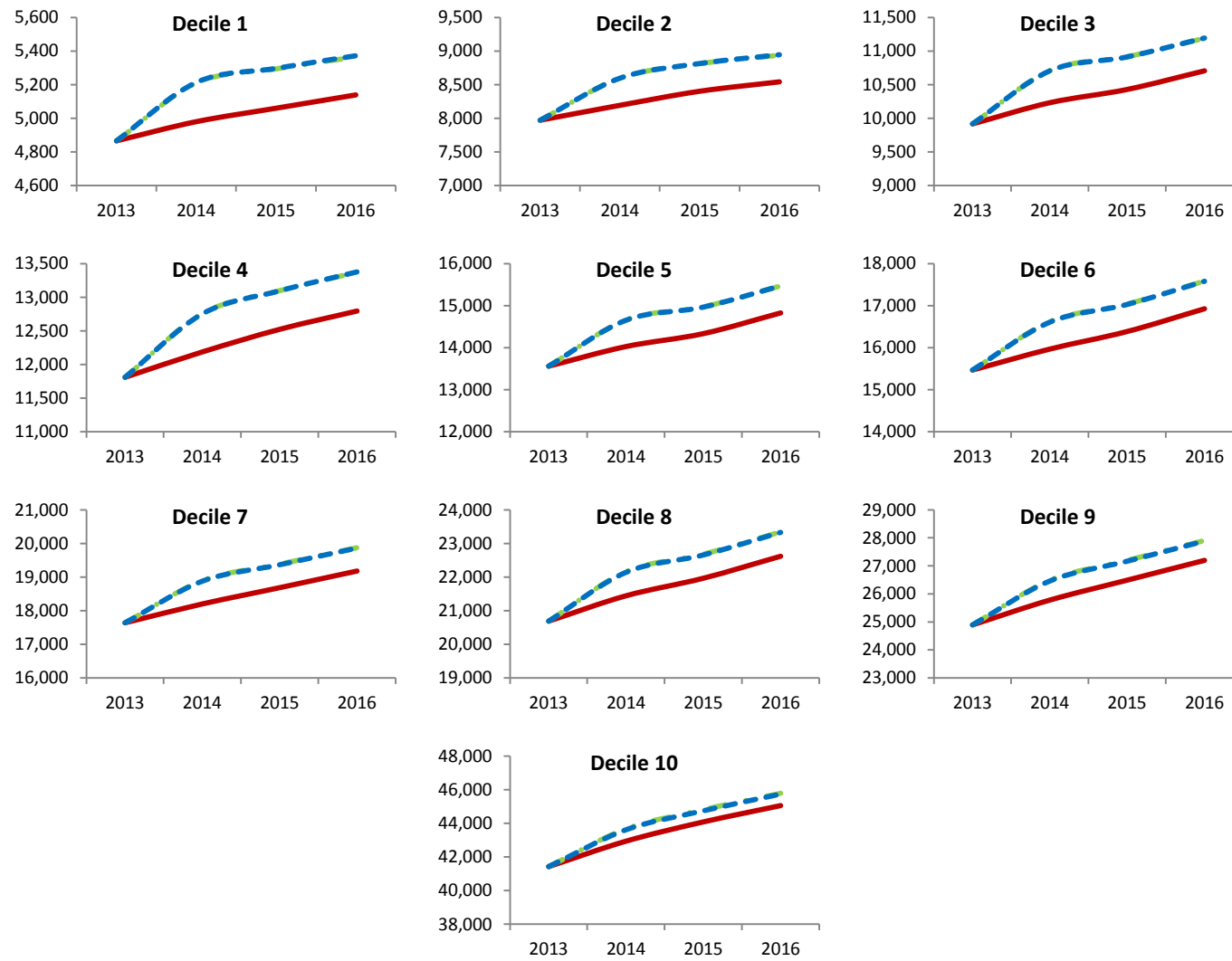
### E.10 Impact on disposable income by income decile – Italy



### E.11 Tax revenues impact in EUROMOD incorporating macro feedback on prices, wages and employment – Poland



### E.12 Impact on disposable income by income decile – Poland





## **List of abbreviations and definitions**

CES – Constant Elasticity of Substitution

ISCED – International Standard Classification of Education

## List of figures

Figure 1: Dynamic scoring methodological steps

Figure 2: Elasticity Estimates (by skill group)

Figure 3: Elasticity Estimates (by margin)

Figure 4: Fiscal policy shocks (pp differences)

Figure 5: Partial equilibrium view of the wage-setting mechanism in QUEST

## List of tables

Table 1: Calibration of labour supply elasticity parameter in QUEST

Table 2: Calibration of non-participation rates in QUEST

Table 3: Macro impact of the tax reforms (annualized % deviation from baseline) on the variables of interest

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