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Dynamic Scoring of Tax Reforms in the EU

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Dynamic scoring of tax reforms in the EU¹

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Abstract

In this paper, we present a dynamic scoring analysis of tax reforms for European countries, accounting for the feedback effects resulting from the adjustment in labour supply and economy-wide reaction to tax policy changes. We combine the microsimulation model EUROMOD incorporating 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 by calibrating QUEST with parameters calculated using EUROMOD such as the elasticity of labour supply at the intensive and extensive margin, the gross wages, participation rates and implicit tax rate on labour income by skill categories. 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 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/micro-dimension is embedded into the macroeconomic model. In this particular set-up, we do not find evidence of strong second-round effects, and the fiscal and distributional effects of the reforms tend to overlap in both scenarios. We attribute these results to existing rigidities in labour and product markets.

¹ Preliminary draft. Do not cite without authors' permission. The view expressed in this paper are of the authors only and do not necessarily reflect those of the European Commission.

Executive Summary

The analysis of discretionary tax policies plays a key role in EU fiscal policy monitoring, in particular in order to determine the cyclically adjusted fiscal balances which are used to assess the national fiscal policy stance. In order to do so the European Commission services traditionally use tax revenues elasticities and output gap estimations. National estimates on the impact of discretionary tax measures must also be provided by the Member States when submitting their Stability and Convergence Programmes which are then assessed by the European Commission services. Recently the European Commission has also started to collect data from on estimates of the impact of discretionary tax measures relying on the Member States' own assessment and providing information at a more disaggregated level. While useful and informative these different sources of estimates suffer from a number of drawbacks. On the one hand, while the macro approach for measuring the impact of tax policy reforms brings a coherent and common approach to all EU countries, it provides only a broad approximation given in particular that the elasticities of tax revenues are fixed and concern broad tax categories while output gap estimates in real-time is are subject to uncertainty, the more so during large swings in the business cycle. On the other hand, the information provided by the EU Member States to the European Commission services has the advantage of providing more precise estimates. However these estimates are hardly comparable across countries since Member States use their own estimation methods different definition of baseline scenarios and methods 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.

In this paper we propose a dynamic scoring approach to quantify the impact of tax reforms in the EU by factoring-in the macroeconomic feedback and behavioural reaction to these reforms. Dynamic scoring has been little developed in the EU, the more so in a comparable manner across EU countries. Yet, such tool would prove very relevant for assessing the impact of discretionary tax measures in order to determine the true fiscal policy stance. The motivation of our paper is twofold. First, we aim at contributing to the literature quantifying the effects of tax policy reforms through dynamic scoring in multi-country framework. In order to do so we combine the microsimulation model EUROMOD extended to account for the labour supply adjustment with the DSGE model QUEST of the European Commission in order to estimate the macroeconomic feedback of these reforms. We ensure that both models are consistent in terms of labour supply modelling and discuss in detail aggregation and tax incidence issues. In particular we show how the macro-model QUEST can be calibrated using the labour supply elasticities estimated from the labour supply model and that both models are consistent in the analysis of labour supply reaction to tax changes. Second, we aim at developing a 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.

Our analysis suggests that dynamic scoring can inform about the fiscal and equity impact of tax reforms using a model-based approach and thereby fill an important gap in EU fiscal monitoring. In particular the use of a microsimulation model allows to replicate with precision the change in tax code entailed by a given reform proposal. The EUROMOD microsimulation model used here allows

us to account for the interaction between tax and social benefits which is especially relevant in the EU in particular regarding incentives on labour supply. The use of the macroeconomic model QUEST allows us to account for the macroeconomic feedback, including the interaction with other EU economies which, in the context of integrated economies as is the case in the EU, is particularly warranted. Our results suggest that accounting for behavioural reaction and macroeconomic feedback to tax policy changes would in many instances not lead to substantially different assessment even in cases where these reforms could be considered as significant. We attribute this to the existence of rigidities in labour and product markets which limits the capacity of individuals to effectively alter their working effort and of firms to alter their pricing policy in the macroeconomic model.

1. Introduction

In this paper we present a dynamic scoring analysis which aims at measuring the second-round effects resulting from tax reforms in the European Union. Dynamic scoring techniques have been used to compare the impact of alternative fiscal policy reforms in order to account for 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. 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 literature quantifying the effects of tax policy reforms through dynamic scoring in multi-country framework. In order to do so we combine a microsimulation model extended to account for labour supply adjustment with a the DSGE model of the European Commission, the QUEST model (see Ratto et al, 2009). We ensure that both models are consistent in terms of labour supply modelling and discuss in detail aggregation and tax incidence issues. In particular we show how the macro-model QUEST can be calibrated using the labour supply elasticities estimated from the EUROMOD model and that both model are consistent in the analysis of labour supply reaction to tax changes. Second, we aim at developing a 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. Our analysis suggests that dynamic scoring can inform about the fiscal and equity impact of tax reforms using a model-based approach and thereby fill an important gap in EU fiscal monitoring. We find however that accounting for behavioural reaction and macroeconomic feedback to tax policy changes would in many instances not lead to substantially different assessments even in cases where these reforms could be considered as significant. We attribute this to the existence of rigidities in labour and product markets which limits the capacity of individuals to effectively alter their working effort and of firms to alter their pricing policy in the macroeconomic model.

In our analysis we combine the mechanical effects of the tax reform on revenues and disposable income, with second-round micro and macroeconomic effects. In particular, we obtain the microeconomic effects of tax reforms using a discrete choice model estimated in combination with the EUROMOD microsimulation model. We estimate a multinomial logit labour supply model, as in 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.² The macroeconomic

² See Sutherland (2001) and Sutherland and Figari (2007) for details on the EUROMOD model.

effects are obtained by simulating the tax reforms of interest with the European Commission New-Keynesian model, QUEST.³ We illustrate our results considering three different countries, and three different kinds of reforms to the tax system: (i) a reduction in social security contributions in Belgium, (ii) a working tax credit in Italy, and (iii) an increase in the universal tax allowance in Poland. Overall, these different reforms result in tax cuts on labour income. 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. 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 which is absent from the labour supply model. The macroeconomic projections correspond to the impulse-responses of the economic variables to the fiscal policy shocks representing the trajectory of the economy to return to its steady state. The reforms considered in this paper all tend to lower tax revenues with the effect that government budgets run into a deficit. We abstain from any (automatic or discrete) policy compensation of the tax cut to control the debt (e.g. through a debt stabilisation rule) and only consider the behaviour of households and firms. Finally, the last step of the dynamic scoring exercise is the introduction of macroeconomic trajectories in EUROMOD. In this step, we pick up the trajectories of employment to change the composition of the population in terms of employed and unemployed in the micro data, and the trajectories of wages and final goods prices to define the uprating factors to adjust price and income variables in EUROMOD over a three-year period.

In our setting, we find no evidence self-financing of the tax cuts. In fact, the labour market response in QUEST is extremely mild, and the decrease on the tax burden of employees end up having a negative effect on gross wages, while employment increases. The tax cuts are partially appropriated by firms, which are willing to hire more workers, but at a lower gross wage rate. 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 rest of the paper is organized as follows. Section 2 describes the EU policy context in which our analysis takes place together with a 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 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. In Section 5 we analyse using our approach and considering hypothetical 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

³ See Ratto et al (2009) for details on the QUEST III model.

(2006) provide a good discussion of the effects of tax cuts by considering two extreme assumptions: 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 below in Section 3). 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 (although these other effects are also accounted for in the macro-model used here).

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 in 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 European Commission needs to analyse the way fiscal and structural reforms can affect national budgets and Member States' economic performance as well. 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). In order to do so the European Commission services use tax revenues elasticities and output gap estimations in order to assess the fiscal impact of discretionary tax reforms, see in particular Mourre et al. (2014) and Price et al.(2014). Estimates on the impact of discretionary tax measures must also be provided by the Member States when submitting their Stability and Convergence Programmes which are then assessed by the European Commission. Recently the European Commission has also started to collect data from 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, these data emanate 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.

More 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 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).⁴ 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 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 used 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 in order 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 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 are consistent, which is actually the case here in particular given the general (and flexible) modelling of labour supply adopted at the micro-level.

⁴ 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 labour supply model

To estimate the labour supply responses to tax reforms, we estimate discrete choice models for each country. 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 – its compelling advantage being that it offers 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.^{5,6} 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.⁷ 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 likelihood estimation. As is standard in the literature, we estimate single men, single women, and

⁵ See van Soest (1995) or Hoynes (1996) among others.

⁶ 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).

⁷ 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).

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 1 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).⁸ 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. EUROMOD is a tax-benefit calculator, intended to provide a framework to simulate direct taxes, social insurance contributions, and social and family transfers. 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. Sutherland and Figari (2013) provide an overview of the recent version of EUROMOD.

In this study, we focus on hypothetical 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 system is 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. We denote these tax-benefit calculations by function $d(\cdot)$, as defined (2.1.3). 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.

⁸ See van Soest (1995) and Blundell et al. (2000).

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.⁹

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 (Ratto et al, 2009), to include different skilled workers, and hereafter referred simply as QUEST. 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. Here we will focus our explanation on the description of the labour market setting and the workings of the tax incidence in QUEST.

3.4 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, and following Fullerton and Metcalf (2002) analysis of tax incidence, we consider that 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):

$$NW = (1 - t_w)W \tag{1}$$

⁹ 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).

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

$$TC = (1 + t_{er})W \quad (2)$$

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 statutory 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:

$$\varepsilon_{LS} = \frac{dL_s/L_s}{dNW/NW} = \frac{dL_s/L_s}{d[(1-t_w)W]/[(1-t_w)W]} \cong \frac{\widehat{L_s}}{\widehat{W} - \widehat{t_w}}, \quad (3)$$

where the symbol \wedge represents percent changes. The changes in labour supply will depend on the changes on gross wages, taxes and on the elasticity parameter as follows:

$$\widehat{L_s} = (\widehat{W} - \widehat{t_w})\varepsilon_{LS} \quad (4)$$

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

$$\varepsilon_{LD} = \frac{dL_d/L_d}{dTC/TC} = \frac{dL_d/L_d}{d[(1+t_{er})W]/[(1+t_{er})W]} \cong \frac{\widehat{L_d}}{\widehat{W} + \widehat{t_{er}}} \quad (5)$$

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

$$\widehat{L_d} = (\widehat{W} + \widehat{t_{er}})\varepsilon_{LD} \quad (6)$$

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

$$\widehat{L_s} = \widehat{L_d} . \quad (7)$$

Substituting (4) and (6) into (7), we find that, in order to reach the new equilibrium, changes in gross wages will be given by the following expression:

$$\widehat{W} = \frac{\varepsilon_{LS}}{\varepsilon_{LS} - \varepsilon_{LD}} \widehat{t_w} + \frac{\varepsilon_{LD}}{\varepsilon_{LS} - \varepsilon_{LD}} \widehat{t_{er}} . \quad (8)$$

Since $0 < \varepsilon_{LS} < \infty$ 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} $\widehat{t_w} < 0$. 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 (1). Applying logarithms and differentiating, we obtain:

$$\widehat{NW} = \widehat{W} - \widehat{t_w} . \quad (9)$$

Substituting (8) in (9), we obtain that:

$$\widehat{NW} = \frac{\varepsilon_{LD}}{\varepsilon_{LS} - \varepsilon_{LD}} (\widehat{t}_w + \widehat{t}_{er}) \quad (10)$$

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 (3). Applying logarithms and differentiating, we obtain:

$$\widehat{TC} = \widehat{W} + \widehat{t}_{er} . \quad (11)$$

Substituting (8) in (11), we obtain that:

$$\widehat{TC} = \frac{\varepsilon_{LS}}{\varepsilon_{LS} - \varepsilon_{LD}} (\widehat{t}_w + \widehat{t}_{er}) \quad (12)$$

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, in QUEST tax incidence, 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.

3.5. Aggregation issues

We consider together the micro and macroeconomic perspectives combining two different models. This interaction raises consistency issues with the way agents' heterogeneity is handled in both cases. 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. However, this means that we also need to combine different degrees of heterogeneity and methods of handling this heterogeneity among models. Aggregation issues are intrinsically related to the methodological choices taken in our analysis. In the following, we will focus this discussion on the structural parameters of the DSGE model 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. The questions being addressed here are such as how structural these types of models really are, leading to the Lucas (1976) critique. 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 DSGE model 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.¹⁰ 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 our discrete-choice labour supply 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 the discrete choice model to calibrate the parameter κ 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 microeconomic 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. Although our approach is also potentially subject to the Lucas' critique, it tries to address the upward bias in labour supply elasticity usually found in the DSGE literature. In particular, as suggested by Chetty et al. (2012), the extensive margin of labour supply should be embedded in the calibrated labour supply elasticities, the more so when elasticities differ across sub-group of the labour force. These issues are discussed in more details in the sequel. Other more general issues related to the particular calibration of QUEST performed in this analysis are discussed in detail below.

4. Interaction between the micro and macro models

We now turn to the sequence of running the microsimulation model (embedding the labour supply reaction to tax change) and the DSGE model QUEST. In order to start the optimization procedure in QUEST we match the gross incomes, for the three skill groups to the values obtained in the microeconomic labour supply model. Then after simulating the tax reform of interest, we feed the macro trajectory of employment, prices and wages back into the microsimulation model for time periods $t+1$, $t+2$ and $t+3$. 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 one.¹¹ Savard 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

¹⁰ 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>.

¹¹ Savard (2003) aims at analysing poverty and inequality problems in a setting that reconciles the microeconomic behaviour with the macroeconomic aggregates, such prices, factor remunerations, unemployment and consumption/expenditure.

two models. This may be a limitation of our analysis, which can be softened by calibrating parameters such as labour supply elasticities, the nonparticipation rate (*NPART*) and, the unemployment replacement rate (benefit rate, *b*) in QUEST, according to these same parameters obtained from the microeconomic model. Furthermore, Savard (2003) also note that the main idea underlying the interaction between the micro and the macroeconomic models is exactly the different contributions/perspectives that they add to the analysis. 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 both 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. This point is treated in details in the next section. The detailed description of the full sequence running the microsimulation model (embedding the labour supply reaction to tax change) and the DSGE model QUEST is presented in Section 3.

4.1 Labour market modelling

The labour market plays arguably a key role in linking the micro and macro models in our analysis. Here we follow the analysis of Magnani and Mercenier (2007) of a case of exact aggregation between a heterogeneous discrete-choice agents and a computable general equilibrium model, which to some extent can be seen as very simple versions of the micro and macro models we use in our dynamic scoring analysis. They describe an exact aggregation of the results of a discrete choice model and their correspondence in 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).

In our particular case, both the micro and macroeconomic models have more complex environments than the example in Magnani and Mercenier (2007). However, our intention here is not to prove that aggregation of heterogeneous households in both macro and micro models lead to exactly the same optimal/equilibrium conditions. Our aim is rather to compare the optimal labour supply produced in the micro and macroeconomic settings, in terms of how the decision is modelled, the functional forms used and finally the structural parameters involved, following the analysis in Magnani and Mercenier (2007). In this way, we can assess the consistency of between our micro and macroeconomic models, and, importantly, the limitations of our analysis.

Let us focus first on the modelling of the labour supply side of the labour market from the microeconomic perspective and let us consider the stochastic utility function defined in (see Equation). For simplicity of the analysis, let us define this utility function for one individual. In this way, assume that for each of the j alternatives of working hours of the setting $\{0,20,40,60\}$, individual i derives the following stochastic utility function:

$$V_{ij} = U_{ij}(C_{ij}, H_{ij}, \cdot) + \epsilon_{ij} \quad (13)$$

where ϵ_{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:

$$\begin{aligned} P_{ij} &= \text{prob}[V_{ij} \geq V_{ik}, \forall k \in \{0,20,40,60\}, k \neq j] \\ &= \text{prob}[U_{ij}(C_{ij}, H_{ij}, \cdot) + \epsilon_{ij} \geq U_{ik}(C_{ik}, H_{ik}, \cdot) + \epsilon_{ik}, \forall k \in \{0,20,40,60\}, k \neq j] \\ &= \text{prob}[U_{ij}(C_{ij}, H_{ij}, \cdot) - U_{ik}(C_{ik}, H_{ik}, \cdot) \geq \epsilon_{ik} - \epsilon_{ij}, \forall k \in \{0,20,40,60\}, k \neq j] \\ &= \text{prob}[\epsilon_{ik} - \epsilon_{ij} \leq U_{ij}(C_{ij}, H_{ij}, \cdot) - U_{ik}(C_{ik}, H_{ik}, \cdot), \forall k \in \{0,20,40,60\}, k \neq j] \\ &= F(\epsilon_{ik} - \epsilon_{ij}) \end{aligned} \quad (14)$$

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

$$F(\epsilon_{i0}, \epsilon_{i20}, \epsilon_{i40}, \epsilon_{i60}) = \exp[-H(e^{-\epsilon_{i0}}, e^{-\epsilon_{i20}}, e^{-\epsilon_{i40}}, e^{-\epsilon_{i60}})] \quad (15)$$

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

$$H(\epsilon_{i0}, \epsilon_{i20}, \epsilon_{i40}, \epsilon_{i60}) = \sum_{s \in \{0,20,40,60\}} \epsilon_{is}^{1/\mu} \quad (16)$$

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, as showed below. Assuming (16) then:

$$H(e^{-\epsilon_{i0}}, e^{-\epsilon_{i20}}, e^{-\epsilon_{i40}}, e^{-\epsilon_{i60}}) = \sum_{s \in \{0,20,40,60\}} (e^{-\epsilon_{is}})^{1/\mu} = \sum_{s \in \{0,20,40,60\}} e^{-(\epsilon_{is}/\mu)} \quad (17)$$

and F assumes the following form:

$$F(\epsilon_{i0}, \epsilon_{i20}, \epsilon_{i40}, \epsilon_{i60}) = \exp \left[- \sum_{s \in \{0,20,40,60\}} e^{-(\epsilon_{is}/\mu)} \right] = \prod_{s \in \{0,20,40,60\}} \exp \left[-e^{-(\epsilon_{is}/\mu)} \right] \quad (18)$$

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

$$P_{ij} = \mu \frac{\partial \ln H(e^{U_{i0}}, e^{U_{i20}}, e^{U_{i40}}, e^{U_{i60}})}{\partial U_{ij}} \quad (19)$$

where μ is the dispersion parameter of the extreme value distribution. The probability we are looking for can be obtained by substituting (17) in (19) to obtain:

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

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

$$P_{ij} = \frac{e^{U_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \quad (21)$$

Note that the expression (21) compares to expression A.1.5 in Appendix 1.¹² Then, the expected number of hours supplied by individual i will be given by:

$$L_i = \sum_{j \in \{0,20,40,60\}} P_{ij} * j = \sum_{j \in \{0,20,40,60\}} \left(\frac{e^{U_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \right) * j = \frac{\sum_{j \in \{0,20,40,60\}} j * e^{U_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \quad (22)$$

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:

$$L = \sum_{i=1}^N L_i = \sum_i^N \left[\frac{\sum_{j \in \{0,20,40,60\}} j * e^{U_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \right] \quad (23)$$

Note that equation (23) 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:

$$L_{j=0} = P_{i0} * N = \left(\frac{e^{U_{i0}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \right) * N \quad (24)$$

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

$$L_{j \neq 0} = (1 - P_{i0}) * N = \left(1 - \frac{e^{U_{i0}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \right) * N = N - L_{j=0} \quad (25)$$

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

$$L_j = P_{ij} * N = \left(\frac{e^{U_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{U_{is}}} \right) * N \quad (26)$$

We turn now to the macroeconomic setting. In QUEST the labour market is populated by workers, while in the macro setting firms are also accounted for. 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

¹² And with expression (1) in Magnani and Mercenier (2007), and (7) in Bargain, Orsini, and Peichl (2014).

this way, and abstracting from other general equilibrium effects, the referred system is presented below (and graphically sketched in more detail below):¹³

$$\left\{ \begin{array}{l} \frac{V_{1-L,h,s,t}}{U_{C,h,s,t}} \frac{1}{\eta_{s,t}} = \frac{W_{s,t}(1-t_{w,s,t}-b)}{P_{C,t}(1+t_{C,t})} \\ P_{j,t} \frac{\partial Y_{j,t}}{\partial L_{j,s,t}} \eta_{j,t} = (1+t_{er,s,t}) W_{s,t} + \frac{\partial \Gamma^L(L_{j,L,t}, L_{j,M,t}, L_{j,H,t})}{\partial L_{j,s,t}} \end{array} \right. \text{ for } s \in \{H, M, L\} \quad (27)$$

where the first equation of the system (equation B.1.7 in Appendix B) results from the combination between the first order conditions with respect to consumption and labour – i.e. is the intra-temporal optimality condition – resulting from the household problem, and the second equation of the system results from maximizing firms profits with respect to labour (equation B.2..5). From this system 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. In this way, and in the context of this dynamic scoring exercise, 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.¹⁴ Considering the functional form of the household utility function in QUEST, given by equations B.1.2 and B.1.3 in Appendix B, for skill group $s \in \{H, M, L\}$, we have that:

$$V_{1-L,h,s,t} = \frac{\omega_s}{(1-L_{i,s,t})^\kappa}, s \in \{H, M, L\} \quad (28)$$

and,

$$U_{C,h,s,t} = \frac{1-habc}{C_{i,t}-habcC_{t-1}}, s \in \{H, M, L\} \quad (29)$$

Then, substituting (2.3.16) and (2.3.17) in (2.2.7), we obtain the expression for the labour supply function in QUEST:

$$L_{i,s,t} = 1 - \left[\frac{\omega_s}{\eta_{s,t}(1-habc)} \frac{P_{C,t}(1+t_{C,t})(C_{i,t}-habcC_{t-1})}{W_{s,t}(1-t_{W,s,t}-b)} \right]^{1/\kappa} \Leftrightarrow L_{i,s,t} = 1 - \left[\frac{\omega_s}{\eta_{s,t}} \frac{1}{W_{s,t}(1-t_{W,s,t}-b)} \frac{P_{C,t}(1+t_{C,t})}{U_{C,h,s,t}} \right]^{1/\kappa} \quad (30)$$

¹³ 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.

¹⁴ 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.

If we now consider that there are N identical households on the skill group $s \in \{H, M, L\}$ we can rewrite (30) as follows:

$$L_{s,t} = N \left(1 - \left[\frac{\omega_s}{\eta_{s,t}} \frac{1}{W_{s,t}(1-t_{W,s,t}-b)} \frac{P_{c,t}(1+t_{c,t})}{U_{c,h,s,t}} \right]^{1/\kappa} \right) \quad (31)$$

Expression (31) can be compared with expression (25), 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. This ensures that both the micro and macro models are theoretically consistent. To see this better, we can write expression (31) in the following terms:

$$L_{s,t} = N(1 - g(X_t; T_t; \Omega)) \quad (32)$$

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, Ω , 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 (25) as follows:

$$L_{j \neq 0} = N(1 - F(U_{ij}; \Theta)) \quad (33)$$

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 Θ . However, while expression (31) 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 (25) denotes the expected number of individuals working in the economy – extensive margin. Clearly they are not the same measure, and, in this way, we cannot have quantitative convergence in the sense of Savard (2003). Furthermore, notice that, in QUEST, unemployment is obtained endogenously and is equal to:

$$UNEMPL = 1 - NPART_{L,t} - L_{L,t} \quad (34)$$

where $NPART$ is the non-participation rate.

Note finally that 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 (24) in the discrete choice model.

4.2 Labour market 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, in general. Moreover, as we have discussed before, 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. 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 κ . This parameter relates the Frisch elasticity to the intertemporal 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 31) with respect to the wage, maintaining the marginal utility of consumption constant. In this way, we can define the Frisch elasticity as follows:

$$\varepsilon_{L,W}^F = \frac{\partial L_{s,t} / L_{s,t}}{\partial W_{s,t} / W_{s,t}} \Leftrightarrow \varepsilon_{L,W}^F = \frac{1}{\kappa} \left(\frac{N - L_{s,t}}{L_{s,t}} \right) \quad (35)$$

The elasticity in (33) suggests a positive relationship between wages and labour supply which depends 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 wages. This is known as the intertemporal elasticity of substitution, ε^{IES} . The idea is to find a 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 obtain this elasticity, we need to find an intertemporal labour supply function, where we can relate the path of labour supply with the path of wages. For that, 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.1.7) and write it one period ahead, as follows:

$$\frac{V_{1-L,h,s,t+1}}{U_{C,h,s,t+1}} \frac{1}{\eta_{s,t+1}} = \frac{W_{s,t+1}(1-t_{W,s,t+1}-b)}{P_{c,t+1}(1+t_{c,t+1})} \quad (36)$$

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

$$L_{s,t+1} = N \left(1 - \left[\frac{\omega_s}{\eta_{s,t+1}} \frac{1}{W_{s,t+1}(1-t_{W,s,t+1}-b)} \frac{P_{c,t}(1+t_{c,t+1})}{U_{C,h,s,t+1}} \right]^{1/\kappa} \right) \quad (37)$$

We can now substitute in (37) the marginal utility of consumption $U_{C,h,s,t+1}$ by its expression one period ahead:

$$L_{s,t+1} = N \left(1 - \left[\frac{\omega_s}{\eta_{s,t+1}} \frac{1}{W_{s,t+1}(1-t_{W,s,t+1}-b)} \frac{P_{c,t}(1+t_{c,t+1})}{1-habc} (C_{i,t+1} - habcC_t) \right]^{1/\kappa} \right) \quad (38)$$

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 w.r.t consumption and bonds, i.e. equations (B.1.5.a) and (B.1.5.b) of Appendix B, respectively of the household problem, and it explains the path of consumption over time. In this way, we obtain an expression for the Lagrangian multiplier, $\lambda_{i,t}$:

$$\lambda_{i,t} = \frac{P_t}{P_{c,t}} \frac{U_{c,i,t}}{1+t_{c,t}} \quad (39)$$

And writing (39) one period ahead, we get:

$$\lambda_{i,t+1} = \frac{P_{t+1}}{P_{c,t+1}} \frac{U_{c,i,t+1}}{1+t_{c,t+1}} \quad (40)$$

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 (equation B.1.5.b I Appendix B) to obtain the Euler equation:

$$\frac{U_{c,i,t}}{P_{c,t}(1+t_{c,t})} \frac{1}{\beta(1+i_t)} = E_t \left[\frac{U_{c,i,t+1}}{P_{c,t+1}(1+t_{c,t+1})} \right] \quad (41)$$

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:

$$E_t [P_{c,t+1}(1+t_{c,t+1})(C_{i,t+1} - habcC_t)] = \beta(1+i_t)P_{c,t}(1+t_{c,t})(C_{i,t} - habcC_{t-1}) \quad (42)$$

The next step is to include the Euler equation derived in equation (42) in the labour supply function, equation (38) to obtain a relation between the labour supplied tomorrow and consumption today, as follows:

$$L_{s,t+1} = N \left(1 - \left[\frac{\omega_s}{\eta_{s,t+1}} \frac{1}{W_{s,t+1}(1-t_{W,s,t+1}-b)} \frac{\beta(1+i_t)P_{c,t}(1+t_{c,t})(C_{i,t} - habcC_{t-1})}{1-habc} \right]^{1/\kappa} \right) \quad (43)$$

Recurring again to the intra-temporal optimality condition (see equation B.1.7 in Appendix B), and substituting the marginal utilities of leisure and consumption, we find that:

$$P_{c,t}(1+t_{c,t})(C_{i,t} - habcC_{t-1}) = \frac{\eta_{s,t}(1-habc)}{\omega_s} W_{s,t}(1-t_{W,s,t}-b)(1-L_{i,s,t})^\kappa \quad (44)$$

Substituting the previous result in the labour supply equation given by (43), we will obtain finally an expression which includes $L_{s,t+1}$, $L_{i,s,t}$, $W_{s,t+1}$ and $W_{s,t}$. This is shown below.

$$L_{s,t+1} = N \left(1 - \left[\frac{\eta_{s,t}}{\eta_{s,t+1}} \frac{W_{s,t}(1-t_{W,s,t}-b)}{W_{s,t+1}(1-t_{W,s,t+1}-b)} \beta(1+i_t)(1-L_{i,s,t})^\kappa \right]^{1/\kappa} \right) \quad (45)$$

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:

$$\frac{1-L_{i,s,t+1}}{1-L_{i,s,t}} = \left[\beta(1+i_t) \frac{\eta_{s,t}}{\eta_{s,t+1}} \frac{1-t_{W,s,t}-b}{1-t_{W,s,t+1}-b} \right]^{1/\kappa} \left(\frac{W_{s,t+1}}{W_{s,t}} \right)^{-1/\kappa} \quad (46)$$

Similarly to the Euler equation, equation (46) represents the intertemporal 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 (46) as follows:

$$(1-\widehat{L}_{i,s}) = \left[\beta(1+i_t) \frac{\eta_{s,t}}{\eta_{s,t+1}} \frac{1-t_{W,s,t}-b}{1-t_{W,s,t+1}-b} \right]^{1/\kappa} (\widehat{W}_s)^{-1/\kappa} \quad (47)$$

It is now straightforward to compute the elasticity of intertemporal substitution for leisure since the results are very easily extrapolated in terms of labour supply. In order to do this we simply apply logarithms to equation (47) and then compute the derivative of the $\ln(1-\widehat{L}_{i,s})$ with respect to the $\ln(\widehat{W}_s)$. In this way we obtain the following expression:

$$\ln(1-\widehat{L}_{i,s}) = \frac{1}{\kappa} \ln \left[\beta(1+i_t) \frac{\eta_{s,t}}{\eta_{s,t+1}} \frac{1-t_{W,s,t}-b}{1-t_{W,s,t+1}-b} \right] - \frac{1}{\kappa} \ln(\widehat{W}_{s,t}) \quad (48)$$

and

$$\frac{d\ln(1-\widehat{L}_{i,s})}{d\ln(\widehat{W}_{s,t})} = -\frac{1}{\kappa} \Leftrightarrow \frac{d(1-\widehat{L}_{i,s})/d(1-\widehat{L}_{i,s})}{d(\widehat{W}_{s,t})/d(\widehat{W}_{s,t})} = -\frac{1}{\kappa} \Leftrightarrow \varepsilon_{1-L_{i,s}}^{IES} = -\frac{1}{\kappa} \quad (49)$$

As we can observe from expression (49), parameter κ guides the elasticity of intertemporal 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 intertemporal elasticity of substitution depends on the parameter κ . In this way, we can establish the following relation between the two elasticities:

$$\varepsilon_{L,W}^F = -\varepsilon_{1-L_{i,s}}^{IES} \left(\frac{N-L_{s,t}}{L_{s,t}} \right) \quad (50)$$

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 (22) the expected hours per household i :

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

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:

$$\tilde{L}_i = \frac{\sum_{j \in \{0,20,40,60\}} j * e^{\tilde{U}_{ij}}}{\sum_{s \in \{0,20,40,60\}} e^{\tilde{U}_{is}}} = \sum_{j \in \{0,20,40,60\}} \tilde{P}_{ij} * j. \quad (51)$$

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

$$\varepsilon_{L_i, w} = \frac{\frac{\partial L_i}{\partial w_i} / L_i}{(\tilde{L}_i - L_i) / L_i} = \frac{\partial L_i / \partial w_i}{(\tilde{w}_i - w_i) / w_i} \quad (52)$$

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) and an 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.¹⁵

Comparing the elasticities defined both in the micro and in macroeconomic settings, we conclude that, in fact, the elasticity defined in (52) is the micro-equivalent to the elasticity derived in (33), 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 κ in QUEST can be obtained from the following expression:

$$\kappa = \frac{1}{\varepsilon_{L,W}^F} \frac{N - L_{s,t}}{L_{s,t}} \quad (53)$$

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

¹⁵ 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.

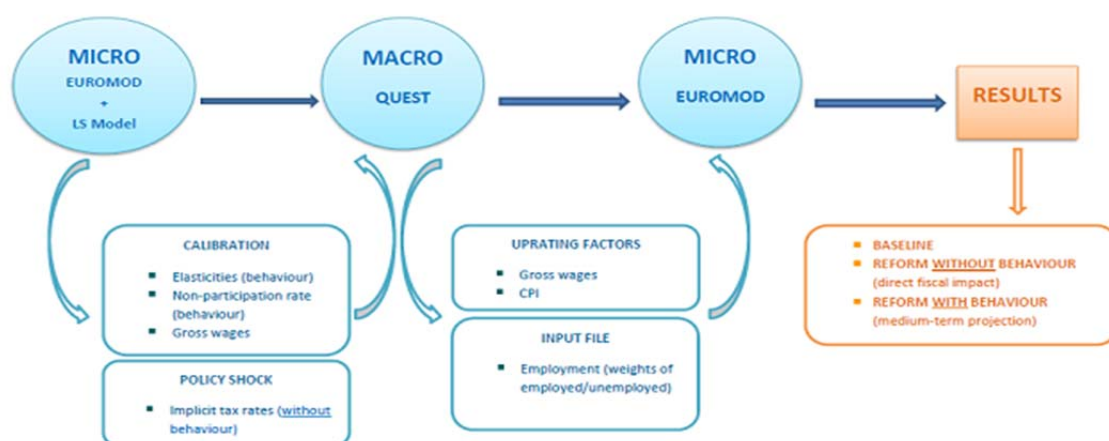
5. Illustration: hypothetical tax reforms in Belgium, Italy and Poland

To illustrate the usefulness of our methodology, we analyse the potential effects of a series of hypothetical tax reforms implemented in three countries: Belgium, Italy, and Poland.¹⁶ 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 can be 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 expected 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

¹⁶ 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. In what follows we describe in detail these methodological steps.

5.1. First step: Labour market characterization and policy shocks

As referred previously, we start from the microeconomic framework to estimate the labour supply elasticities and the expected voluntary unemployed 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 voluntary unemployment rate, we use version G3.0 of the EUROMOD microsimulation model, together with the datasets based on the 2012 version of EU-SILC.¹⁷ EUROMOD is then linked with the labour supply discrete choice model described in previous sections. For the simulation of the tax reforms, we choose 2013 tax-benefit rules as the baseline. This is the most recent policy year that can be simulated with EUROMOD at the time of writing this paper. We predict labour supply based on the estimated labour supply model both for the baseline and the reform scenario. Uprating 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. 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. From here, and now 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 κ 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 each of 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

¹⁷ 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.

of the elasticity (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.¹⁸

Figure 2. Elasticity Estimates (by skill group)

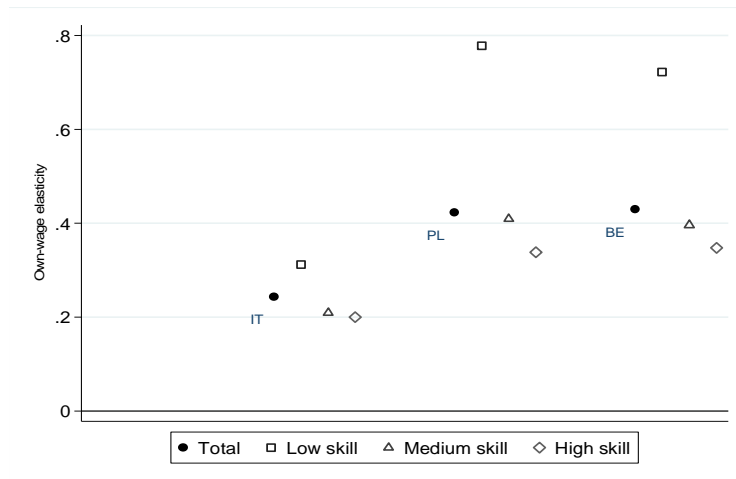


Figure 3. Elasticity Estimates (by margin)

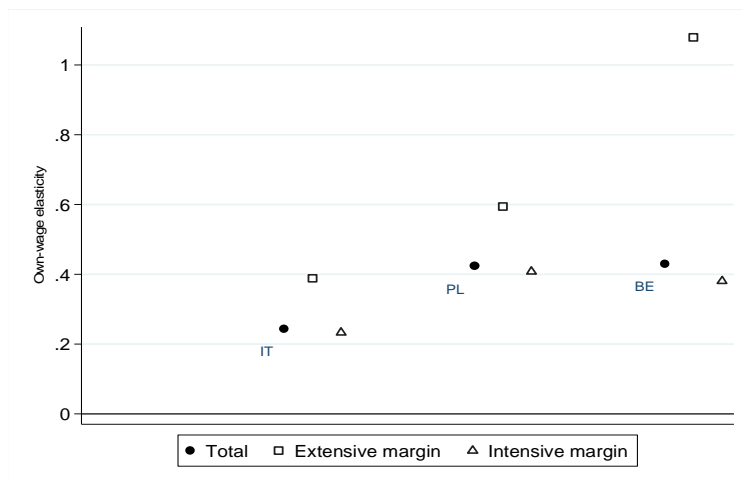


Table 1 below shows the figures for the elasticities, by skill level, and the correspondent value for parameter κ , by skill level, in QUEST, which was obtained using equation expression (2.3.39) derived previously, where the population and employment figures came from the sample of active individuals used in the estimation process.

¹⁸ For a detailed analysis on elasticities see Chetty et al (2012), and Chetty (2012).

Table 1. Calibration of labour supply elasticity parameter in QUEST

Countries	Elasticities			Parameter κ		
	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 (2.3.12) 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 (2.3.20).

Table 2. Nonparticipation rates

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:

$$itr_s = \frac{\sum_i w_i * PIT_i + SIC_{EE} + SIC_{ER}}{Gross\ Wages + SIC_{ER}}, s \in \{H, M, L\} \quad (54)$$

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

$$w_i = \frac{Gross\ wages_i}{Total\ taxable\ income_i} \quad (55)$$

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

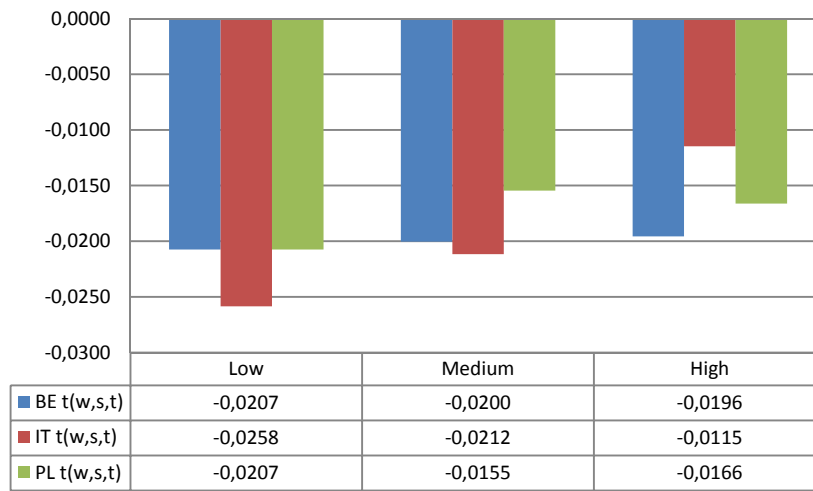
$$itr_{EE,s} = \frac{\sum_i w_i * PIT_i + SIC_{EE}}{Gross\ Wages + SIC_{ER}}, s \in \{H, M, L\} \quad (56)$$

$$itr_{ER,s} = \frac{SIC_{ER}}{Gross\ Wages + SIC_{ER}}, s \in \{H, M, L\} \quad (57)$$

In this way, we need to compute expression (56) in the baseline and the reform scenarios for each country. Then 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 $itr_{ER,s}$ 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

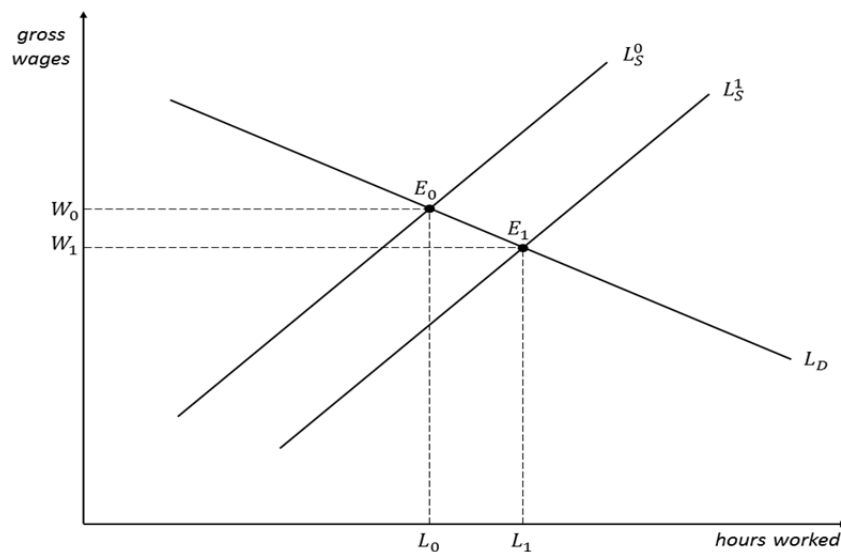
In this exercise, QUEST was calibrated for the following three regions: the country of interest (i.e., respectively Italy, Belgium and Poland), the euro area and the rest of the world. As explained in the previous section, we have calibrated the parameter κ and the nonparticipation rate, $NPART$, with the figures obtained from the discrete choice econometric model¹⁹. The changes in the implicit tax rates on labour paid by employees for each of the three countries of interest are introduced as

¹⁹ 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.

permanent policy shocks in QUEST. For that we have also set off the debt-stabilization rule in equation (B.3.4) 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 (graphs C.1 to C.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 3 below illustrates the basic wage setting mechanism in the model illustrating in particular the role played by tax incidence. In order to explain the mechanisms at play and abstracting from other general equilibrium effects, we can describe the wage setting mechanisms as in Figure 3 below.

Figure 3. Partial equilibrium view of the wage-setting mechanism in QUEST



In Figure 3, L_D is the labour demand function and corresponds to equation (B.2.5), assuming Y , K and $ucap$, are constant and no adjustment costs, for simplicity. L_S is the labour supply function, equivalent of equation (B.1.7), 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 2.2. 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 $\widehat{\tau}_w < 0$ and $\widehat{\tau}_{er} = 0$, then from equation (8) gross wages should go down, i.e. $\widehat{W} < 0$. In the same way, and now from equation (10), we should expect the net wages to rise in the new equilibrium. Note that $(\widehat{\tau}_w + \widehat{\tau}_{er}) < 0$, for all the countries and, according to equation (10), 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 (12), we should expect it to decrease. Equation (12) implies a positive relationship between the change in total taxes on labour income and the total compensation. In our case, $(\widehat{\tau}_w + \widehat{\tau}_{er}) < 0$. So, the total compensation of employees will decrease to reach in the new equilibrium. Again this is shown in the impulse response functions of the total compensation of employees, for the three countries, in the Appendix. The final macro impact on the variables of interest from the tax reforms is finally 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
GDP	0.101	0.239	0.385	0.154	0.191	0.235	0.113	0.218	0.289
Price level	-0.033	-0.076	-0.096	-0.002	-0.075	-0.113	-0.065	-0.182	-0.275
Real consumption	0.166	0.158	0.179	0.352	0.351	0.385	0.145	0.194	0.215
Employment									
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
Gross real wage									
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
Net gross real wage									
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
Total compensation of employees									
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

Source: based on QUEST simulations.

Notice that the changes across periods on the different variables are very small. This can be mainly attributed to the sluggishness embedded in QUEST through the different frictions included in the model.

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 DSGE 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 section, since the macroeconomic trajectories imply very small 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 too.

We analyse both scenarios over the period t_0 to t_3 and compare the variation in tax revenues, contributions, and disposable income against the baseline. Out of the two scenarios, the implementation of the reforms under the second scenario (i.e. 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).²⁰ Assessing the fiscal and equity impact of the same tax reforms under the first scenario (i.e. the one embedding the second-round effects) is done by amending the uprating factors according to the macroeconomic feedback provided by the QUEST model. 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;

²⁰ The European Commission macroeconomic forecast are publicly available in the AMECO database, http://ec.europa.eu/economy_finance/db_indicators/ameco/index_en.htm.

- iii) 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 D. Graphs D1 to D6 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 7-12 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 D1 to D6 depicting the dynamic scoring results by specific tax categories we observe that:

- i. *In Belgium* – as expected, Graph D1 shows that the employee social insurance contributions decrease both in presence and absence of second-round effects when considering the change in pension insurance or 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 billions 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 D2), we observe this same pattern, with the positive effects on employment balancing the negative ones on gross wages. It is important to note that D2 depicts the evolutions in the average social insurance contribution per employee and income decile such that the differences between Graph D1 and D2 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 higher in the second-round effect scenario (see Graph D3). 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. 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 proceeds increases. This shows some evidence of a self-financing tax cuts although to a very modest extent. In order to see this 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 D4), we observe that when considering the behaviour effects, the tax credit generates 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 last two deciles. These 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 D6). 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 D7), 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 D7 to D12 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 D7). 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. 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 D8). The effect seems regressive for lower deciles benefiting 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 the decrease of gross wages.
- ii. *In Italy* – as expected, the introduction of the in-work tax credit induces a fall in the personal income tax revenues (see Graph D9). Given the very small fall in gross wages, 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, as noticed earlier (see Graph D10). Since the drop in gross wages is extremely small 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 D11). 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.

6. Conclusion

We propose an approach for dynamic scoring the impact of tax reforms in EU Member States. 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 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. The use of dynamic scoring method to analyse the impact reforms in the EU is especially warranted given the need to quantify the impact of discretionary tax reforms on public budgets and households' disposable income. In this dynamic scoring exercise, we have quantified the effects of hypothetical 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. 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 result could be due to the rigidities included in the macroeconomic setting that generates very small effects in terms of wages and employment effects. Future research shall aim at analysing the joint impact of structural reforms tackling these rigidities with tax reforms aimed at promoting job and investment in the EU.

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Appendix

A. Labour supply model

B. The DSGE QUEST model

C. Labour market impulse responses

D. Budgetary and redistributive effects of the reforms

Appendix A. Labour supply model

As Bargain, Orsini, and Peichl (2014), we opt for a flexible discrete choice model.²¹ In our baseline, we specify consumption-leisure preferences using a quadratic utility function with fixed costs.²² The deterministic part of utility of a couple i at each discrete choice $j = 1, \dots, J$ can be written as:

$$U_{ij} = \alpha_{ci}C_{ij} + \alpha_{cc}C_{ij}^2 + \alpha_{hfi}H_{ij}^f + \alpha_{hmi}H_{ij}^m + \alpha_{hff}(H_{ij}^f)^2 + \alpha_{hmm}(H_{ij}^m)^2 \\ + \alpha_{chf}C_{ij}H_{ij}^f + \alpha_{chm}C_{ij}H_{ij}^m + \alpha_{hmf}H_{ij}^fH_{ij}^m - \eta_j^f \cdot 1(H_{ij}^f > 0) - \eta_j^m \cdot 1(H_{ij}^m > 0) \quad (\text{A.1.1})$$

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:

$$\begin{aligned} \alpha_{ci} &= \alpha_c^0 + Z_i^c \alpha_c + u_i \\ \alpha_{hfi} &= \alpha_{hf}^0 + Z_i^f \alpha_{hf} \\ \alpha_{hmi} &= \alpha_{hm}^0 + Z_i^m \alpha_{hm}, \end{aligned} \quad (\text{A.1.2})$$

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 α_{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.²³ 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 η_j^k for $k = f, m$, are non-zero for positive hours choices.²⁴ In general, the approach is flexible and allows imposing few constraints²⁵. 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.²⁶ For each labour supply choice j , disposable income is calculated as a function

$$C_{ij} = d(w_i^f H_{ij}^f, w_i^m H_{ij}^m, y_i, X_i) \quad (\text{A.1.3})$$

²¹ 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).

²² 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).

²³ 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).

²⁴ 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.

²⁵ See Bargain, Orsini, and Peichl (2014) and van Soest (1995).

²⁶ 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 α_{ci} .

of female and male earnings, 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 elasticities²⁷. 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 (2.1.3) using the tax-benefit calculator EUROMOD, which we present in the next section. 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.²⁸ 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 observations²⁹. As the model is stochastic in nature, the full specification of the labour supply model is obtained after including i.i.d. error terms ϵ_{ij} for each choice $j = 1, \dots, J$. That is, total utility at each alternative is

$$V_{ij} = U_{ij} + \epsilon_{ij}, \quad (\text{A.1.4})$$

with the observable part of utility U_{ij} being defined as above in (2.1.1). 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 an explicit analytical solution³⁰:

$$p_{ij} = \frac{e^{U_{ij}}}{\sum_{k=1}^J e^{U_{ik}}}. \quad (\text{A.1.5})$$

²⁷ Hicksian elasticities can be obtained by additionally estimating income elasticities and using the Slutsky decomposition.

²⁸ 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).

²⁹ 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).

³⁰ See McFadden (1974) or Creedy and Kalb (2006).

Appendix B. Details on the QUEST model

B.1 Households

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 ε 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 ($i_{K,t}$). Hence, non-liquidity constrained households face the following Lagrangian

$$\begin{aligned} \max_{\left\{ \begin{array}{l} C_{i,t}, L_{i,z,t}, B_{i,t} \\ J_{i,t}, K_{i,t} \end{array} \right\}_{t=0}^{\infty}} V_{i,0} = & E_0 \sum_{t=0}^{\infty} \beta^t \left(U(C_{i,t}) + \sum_z V(1-L_{i,z,t}) \right) \\ & - E_0 \sum_{t=0}^{\infty} \lambda_{i,t} \frac{\beta^t}{P_t} \left(\begin{aligned} & (1+t_{C,t})P_{C,t}C_{i,t} + B_{i,t} + P_{I,t}(J_{i,t} + \Gamma^J(J_{i,t})) - (1+i_{t-1})B_{i,t-1} \\ & - \sum_z (1-t_{W,z,t})W_{z,t}L_{i,z,t} - bW_{z,t}(1-NPART_{i,z,t} - L_{i,z,t}) \\ & - (1-t_K)(i_{K,t-1} - rp_K)P_{I,t-1}K_{i,t-1} - t_K\delta_K P_{I,t-1}K_{i,t-1} \\ & - TR_{i,t} - PR_{fin,i,t} \end{aligned} \right) \\ & - E_0 \sum_{t=0}^{\infty} \lambda_{i,t} \xi_{i,t} \beta^t (K_{i,t} - J_{i,t} - (1-\delta_K)K_{i,t-1}) \end{aligned} \quad (B.1.1)$$

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, as follows:

$$U(C_{i,t}) = (1 - habc) \log(C_{i,t} - habcC_{i-1}) \quad (\text{B.1.2})$$

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

$$V(1 - L_{i,s,t}) = \frac{\omega_s}{1 - \kappa} (1 - L_{i,s,t})^{1 - \kappa}, \quad s \in \{L, M, H\} \quad (\text{B.1.3})$$

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

$$\Gamma_J(J_{i,t}) = \frac{\gamma_K}{2} \frac{(J_{i,t})^2}{K_{i,t-1}} + \frac{\gamma_I}{2} (\Delta J_{i,t})^2. \quad (\text{B.1.4})$$

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

$$\frac{\partial V_0}{\partial C_{i,t}} \Rightarrow U_{C,i,t} - \lambda_{i,t} (1 + t_{C,t}) \frac{P_{C,t}}{P_t} = 0 \quad (\text{B.1.5a})$$

$$\frac{\partial V_0}{\partial B_{i,t}} \Rightarrow -\lambda_{i,t} + E_t \left(\lambda_{i,t+1} \beta (1 + i_t) \frac{P_t}{P_{t+1}} \right) = 0 \quad (\text{B.1.5b})$$

$$\frac{\partial V_0}{\partial K_{i,t}} \Rightarrow E_t \left(\lambda_{i,t+1} \frac{\beta P_{I,t}}{P_{t+1}} ((1 - t_K)(i_{K,t} - r p_K) + t_K \delta_K) \right) - \lambda_{i,t} \xi_{i,t} + E_t (\lambda_{i,t+1} \xi_{i,t+1} \beta (1 - \delta_K)) = 0 \quad (\text{B.1.5c})$$

$$\frac{\partial V_0}{\partial J_{i,t}} \Rightarrow - \left(1 + \gamma_K \left(\frac{J_{i,t}}{K_{i,t-1}} \right) + \gamma_I \Delta J_{i,t} \right) + E_t \left(\frac{1}{1 + i_t} \frac{P_{I,t+1}}{P_{I,t}} \gamma_I \Delta J_{i,t+1} \right) + \xi_{i,t} \frac{P_t}{P_{I,t}} = 0 \quad (\text{B.1.5d})$$

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:

$$(1 + t_{C,t}) P_{C,t} C_{L,t} = (1 - t_{w,L,t}) W_{L,t} L_{L,t} + b W_{L,t} (1 - NPART_{L,t} - L_{L,t}) + TR_{L,t} \quad (\text{B.1.6})$$

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 ($1/\eta_{s,t}$) over the reservation wage³¹. The 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

$$\frac{V_{1-L,h,s,t}}{U_{C,h,s,t}} \frac{1}{\eta_{s,t}} = \frac{W_{s,t}(1-t_{w,s,t}-b)}{P_{C,t}(1+t_{C,t})} \text{ for } s \in \{L, M, H\},^{32} \quad (\text{B.1.7})$$

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

$$X_t = \int_0^1 X_{h,t} dh = (1-\varepsilon)X_{i,t} + \varepsilon X_{k,t}. \quad (\text{B.1.8})$$

Hence, aggregate consumption and employment are given by

$$C_t = (1-\varepsilon)C_{i,t} + \varepsilon C_{k,t} \quad (\text{B.1.9})$$

and

$$L_t = (1-\varepsilon)L_{i,t} + \varepsilon L_{k,t}. \quad (\text{B.1.10})$$

B.2 Firms

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

³¹ The mark-up depends on the intra-temporal elasticity of substitution between differentiated labour services within each skill groups (σ_s) and fluctuations in the mark-up arise because of wage adjustment costs and the fact that a fraction $(1-sfw)$ of workers is indexing the growth rate of wages π_w to wage inflation in the previous period $\eta_{s,t} = 1 - 1/\sigma_s - \gamma_W / \sigma_s (\beta(sfw\pi_{W,t+1} - (1-sfw)\pi_{W,t-1}) - \pi_{W,t})$.

³² In order to find the wage equation, consider the problem of representative household i , of a subgroup s of the population given by (2.2.1). 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 (2.2.7), 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.

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:

$$Y_{j,t} = (L_{j,t} - FC_{j,t})^\alpha (u_{j,t} K_{j,t})^{1-\alpha} - FC_{j,t} \quad (\text{B.2.1})$$

with

$$L_{j,t} = \left(\Lambda_L^\frac{1}{\mu} (\chi_L L_{j,L,t})^\frac{\mu-1}{\mu} + \Lambda_M^\frac{1}{\mu} (\chi_M L_{j,M,t})^\frac{\mu-1}{\mu} + \Lambda_H^\frac{1}{\mu} (\chi_H L_{j,H,t})^\frac{\mu-1}{\mu} \right)^\frac{\mu}{\mu-1}, \quad (\text{B.2.2})$$

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 Λ_s is the corresponding share parameter ($s \in \{L, M, H\}$), χ_s is the efficiency unit, and μ 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:

$$PR_{j,t} = P_{j,t} Y_{j,t} - \sum_s (1 + t_{er,s,t}) W_{j,s,t} L_{j,s,t} - i_t^K P_{j,t} K_{j,t} - (\Gamma^P(P_{j,t}) + \Gamma^L(L_{j,L,t}, L_{j,M,t}, L_{j,H,t}) + \Gamma^u(u_{j,t})) \quad (\text{B.2.3})$$

where i_t^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):

$$P_{j,t} = \frac{1}{\eta_{j,t}} MC_{j,t} \quad (\text{B.2.4})$$

where $\eta_{j,t}$ is the inverse price mark-up factor which is defined as a function of the elasticity of substitution (σ^d), changes in inflation (π) and the mark-up shock (ε_{mkp})³³. Skill-specific labour demand can be obtained from the first order condition w.r.t labour:

$$P_{j,t} \frac{\partial Y_{j,t}}{\partial L_{j,s,t}} \eta_{j,t} = (1 + t_{er,s,t}) W_{s,t} + \frac{\partial \Gamma^L(L_{j,L,t}, L_{j,M,t}, L_{j,H,t})}{\partial L_{j,s,t}}, \quad s \in \{L, M, H\}, \quad (\text{B.2.5})$$

³³ 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 γ_P is the corresponding adjustment cost parameter.

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:

$$(1-\alpha)P_{j,t} \frac{\partial Y_{j,t}}{\partial K_{j,t}} \eta_{j,t} = i_{K,t} P_{j,t} \quad (\text{B.2.6})$$

where $P_{j,t}$ 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:

$$(1-\alpha)P_{j,t} \frac{\partial Y_{j,t}}{K_{j,t} ucap_{j,t}} \eta_{j,t} = i_{K,t} P_{j,t} \quad (\text{B.2.7})$$

B.3 Fiscal and monetary policies

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

$$BEN_t = \sum_s bW_{s,t} (1 - NPART_{s,t} - L_{s,t}), s \in \{L, M, H\}. \quad (\text{B.3.1})$$

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

$$R_t^G = t_{C,t} P_{C,t} C_{i,t} + \sum_s (t_{w,s,t} + t_{er,s,t}) W_{s,t} L_{s,t} + t_K i_{K,t-1} P_{I,t-1} K_{i,t-1} - t_K \delta_K P_{I,t-1} K_{i,t-1}. \quad (\text{B.3.2})$$

Government debt (B_t) evolves according to

$$B_t = (1+i_t)B_{t-1} + G_t + IG_t + TR_t + BEN_t - R_t^G. \quad (\text{B.3.3})$$

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

$$\Delta t_{w,t} = \tau_B \left(\frac{B_{t-1}}{Y_{t-1}} - b^T \right) + \tau_{DEF} \Delta \left(\frac{B_t}{Y_t} \right), \quad (\text{B.3.4})$$

where τ_B captures the sensitivity with respect to deviations from b^T , the government debt target, and τ_{DEF} controls the sensitivity of the tax-rule with respect to changes in the debt to output ratio. This budget balance 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:

$$i_t = \gamma_{ilag} i_{t-1} + (1 - \gamma_{ilag}) (r_{EQ} + \pi_{TAR} + \gamma_{inf} (\pi_{C,t} - \pi_{TAR}) + \gamma_{ygap} \hat{y}_t). \quad (B.3.5)$$

The central bank has a constant inflation target (π_{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 γ_{inf} and γ_{ygap} coefficients. There is also some inertia in nominal interest rate setting over the equilibrium real interest rate r_{EQ} determined by γ_{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.

B.4 Trade

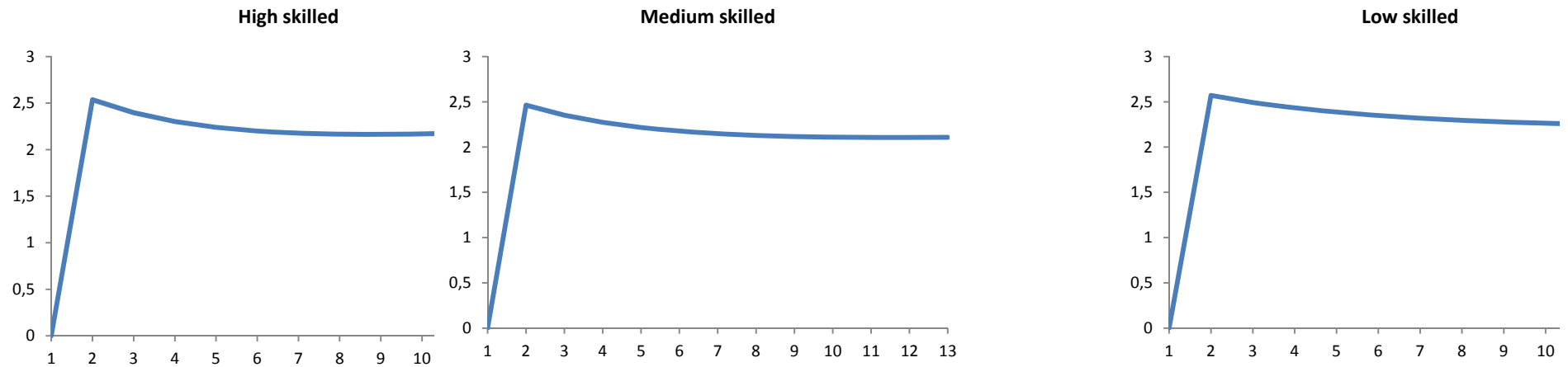
In order to facilitate aggregation, we assume that households, the government and the final goods sector have identical preferences across goods used for private consumption, investment and public expenditure. Let $Z_t \in \{C_t, I_t, G_t, IG_t\}$ be the demand of households, investors or the government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

$$Z_t = \left((1 - \rho)^{\frac{1}{\sigma_{im}}} Z_{d,t}^{\frac{\sigma_{im}-1}{\sigma_{im}}} + \rho^{\frac{1}{\sigma_{im}}} Z_{f,t}^{\frac{\sigma_{im}-1}{\sigma_{im}}} \right)^{\frac{\sigma_{im}}{\sigma_{im}-1}}, \quad (B.4.1)$$

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

Appendix C. Labour market impulse responses

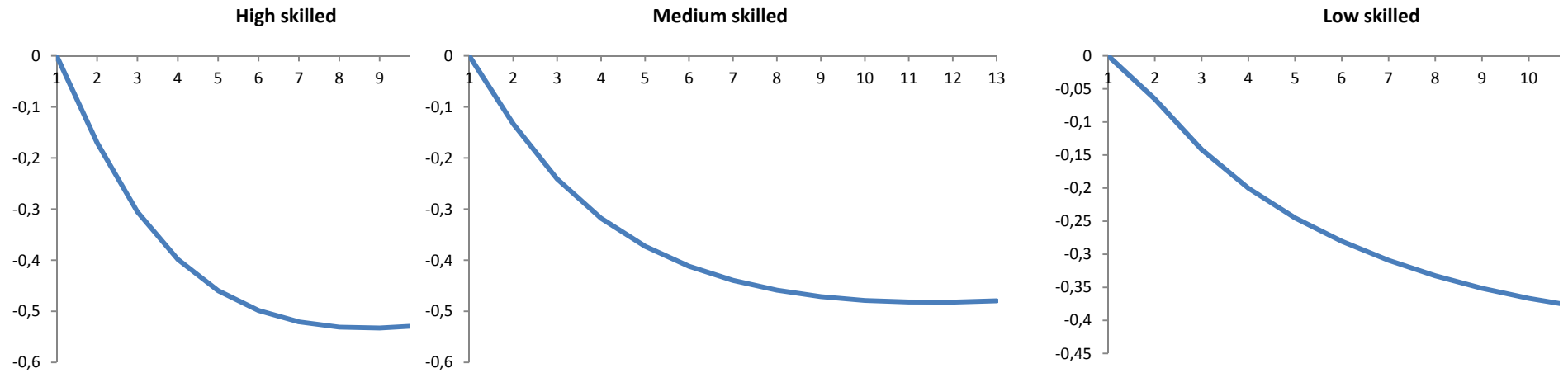
C.1 Net real wage of employees, per skill level (% quarterly change from baseline) – Belgium



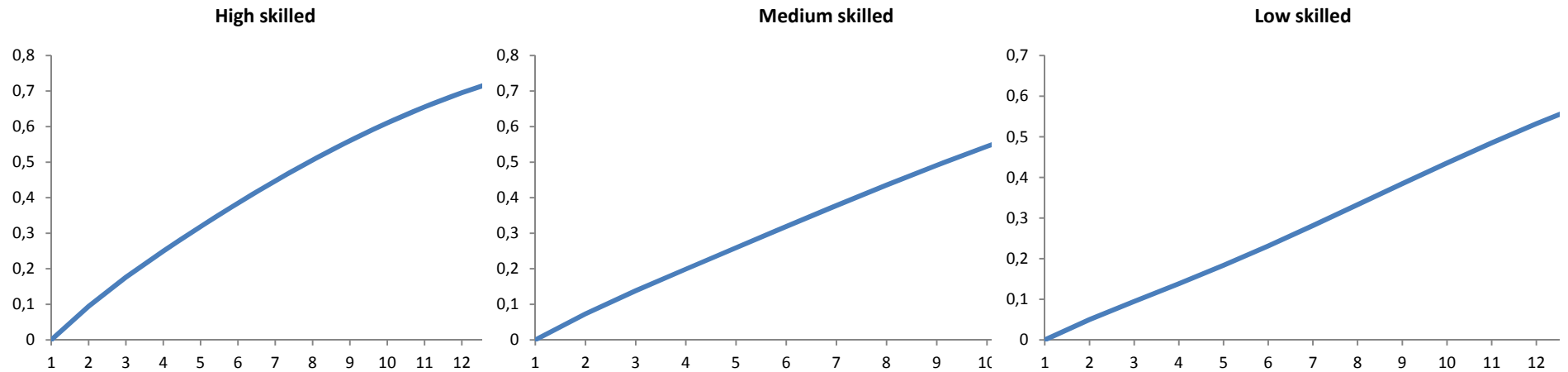
C.2 Total compensation of employees, per skill level (% quarterly change from baseline) – Belgium



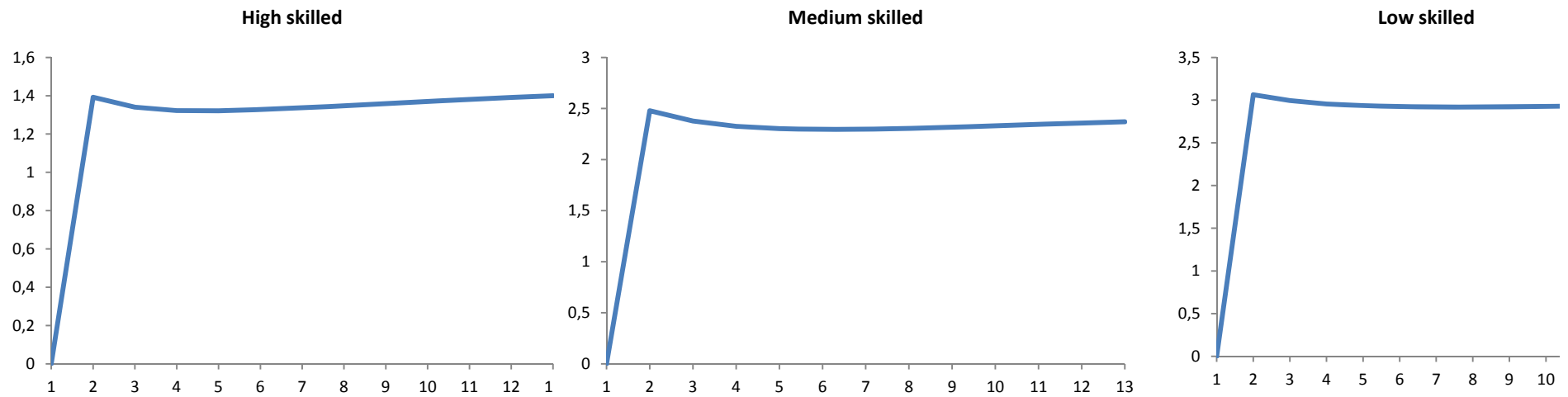
C.3 Gross real wage, per skill level (% quarterly change from baseline) – Belgium



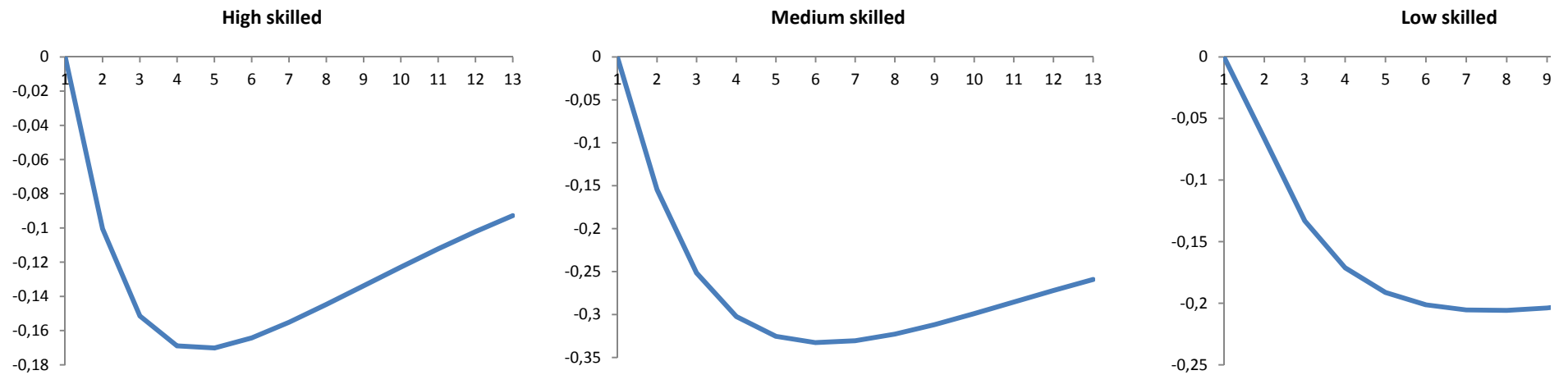
C.4 Employment, per skill level (% quarterly change from baseline) – Belgium



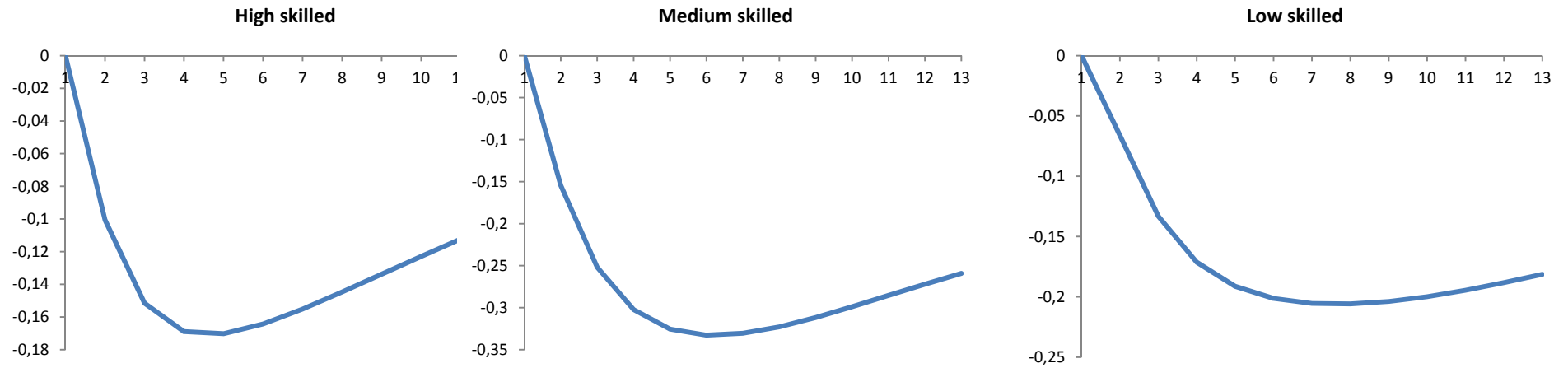
C.5 Net real wage of employees, per skill level (% quarterly change from baseline) – Italy



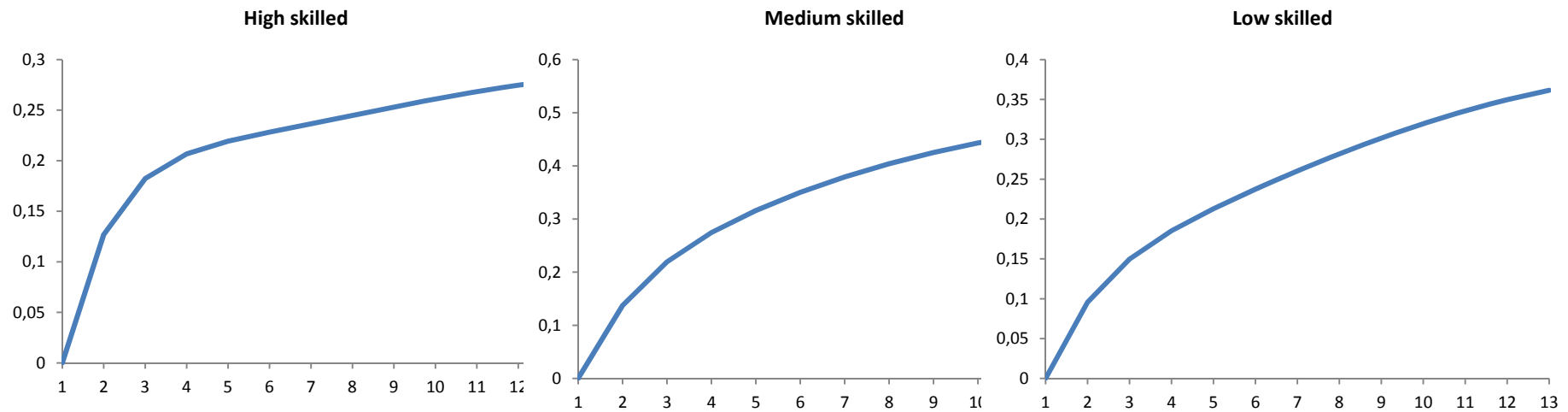
C.6 Total compensation of employees, per skill level (% quarterly change from baseline) – Italy



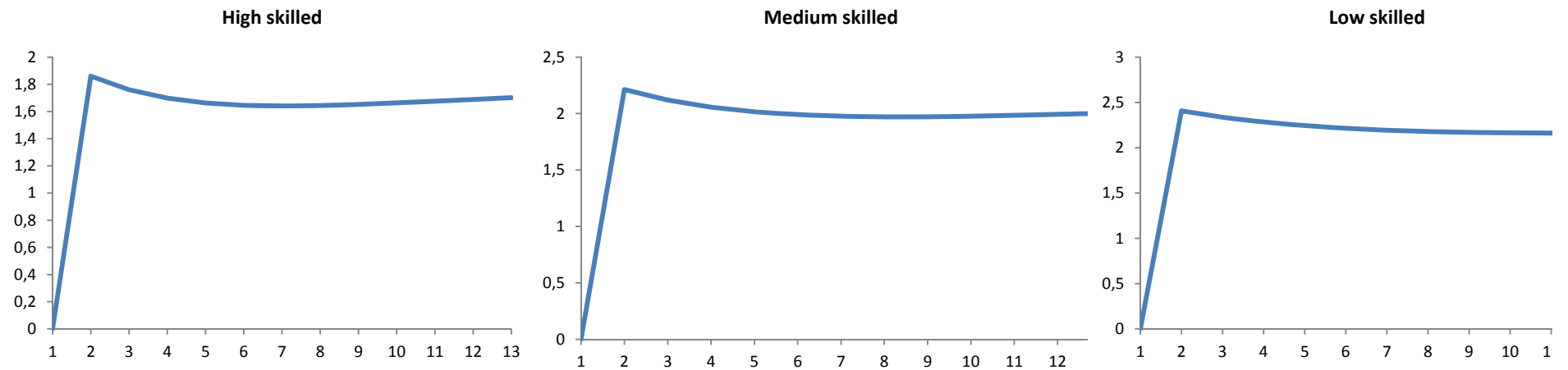
C.7 Gross real wage, per skill level (% quarterly change from baseline) – Italy



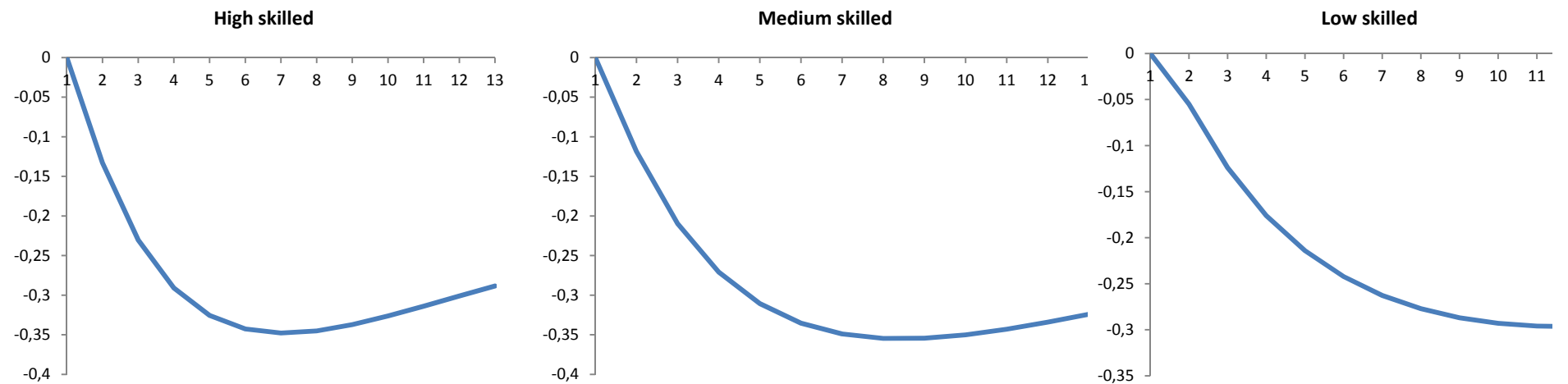
C.8 Employment, per skill level (% quarterly change from baseline) – Italy



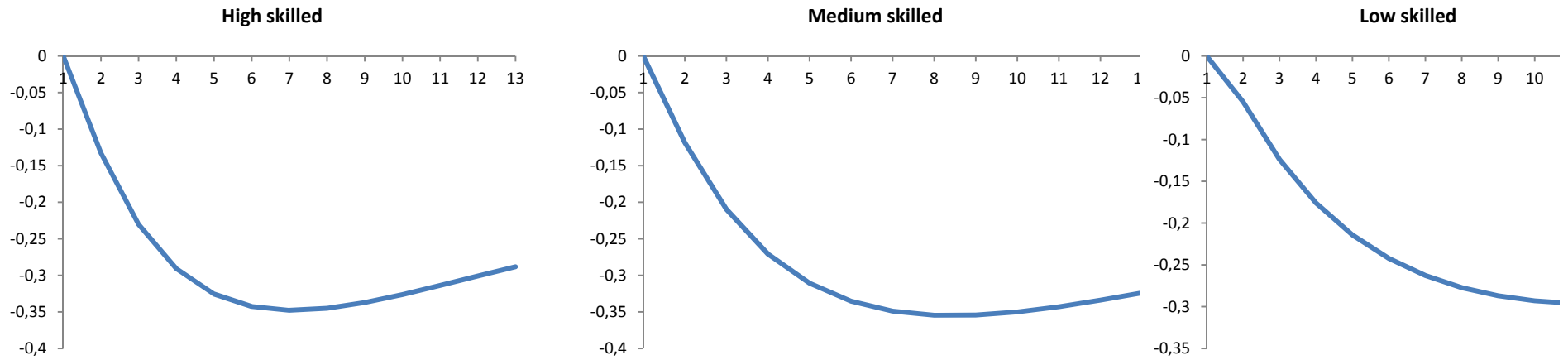
C.9 Net real wage of employees, per skill level (% quarterly change from baseline) – Poland



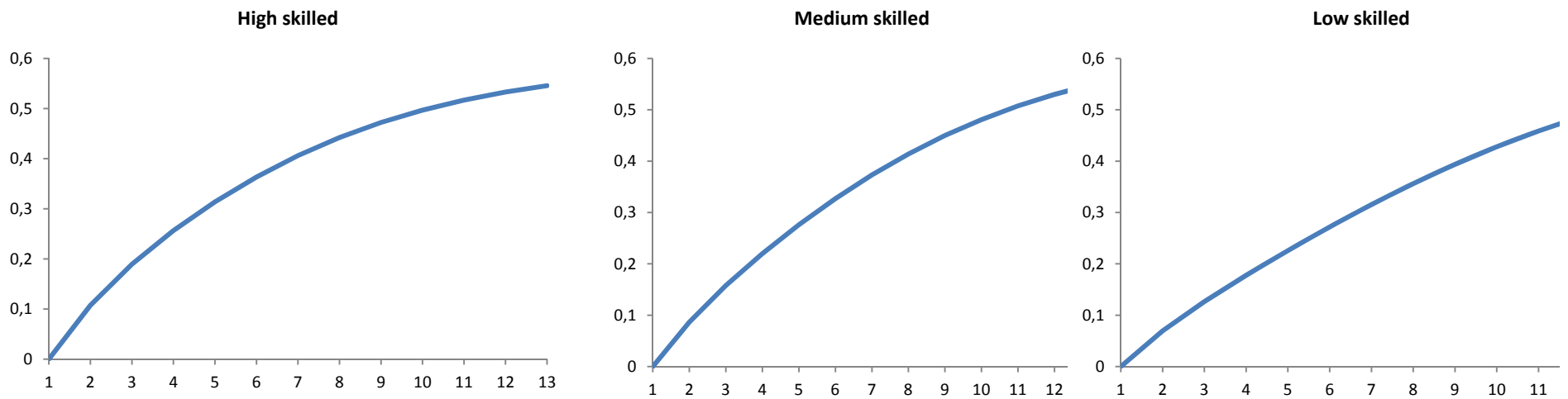
C.10 Total compensation of employees, per skill level (% quarterly change from baseline) – Poland



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

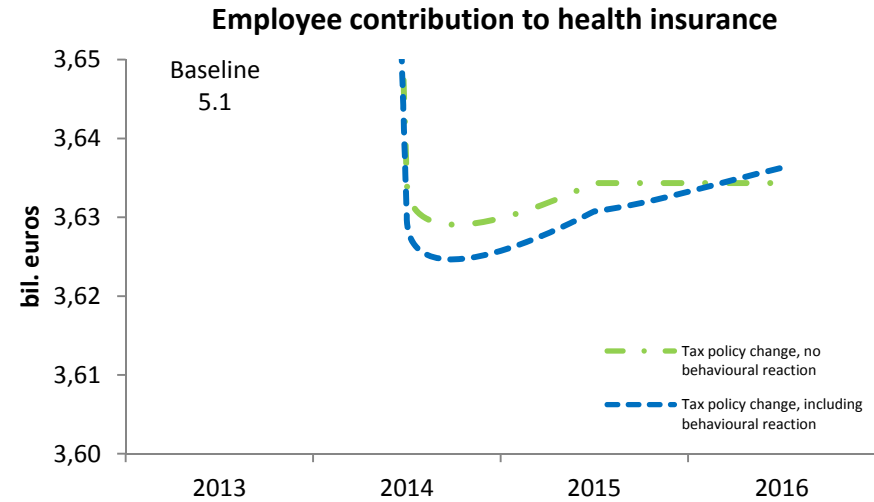
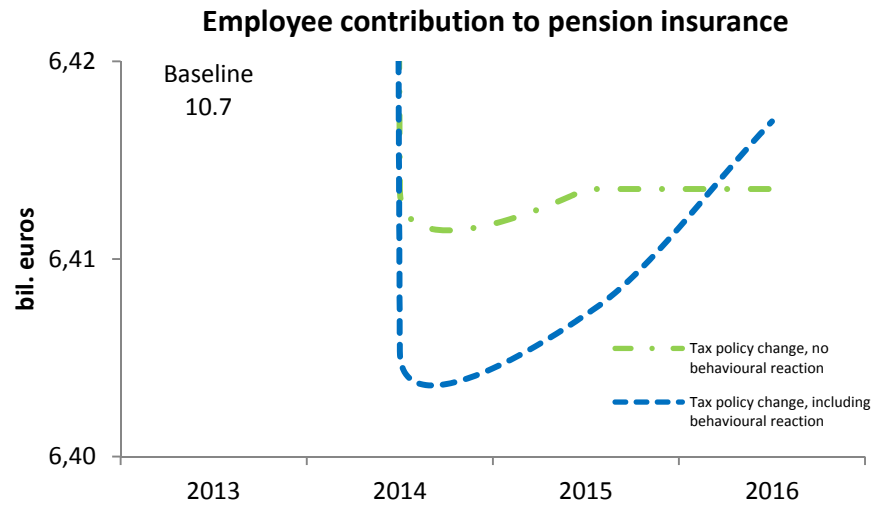


C.12 Employment, per skill level (% quarterly change from baseline) – Poland

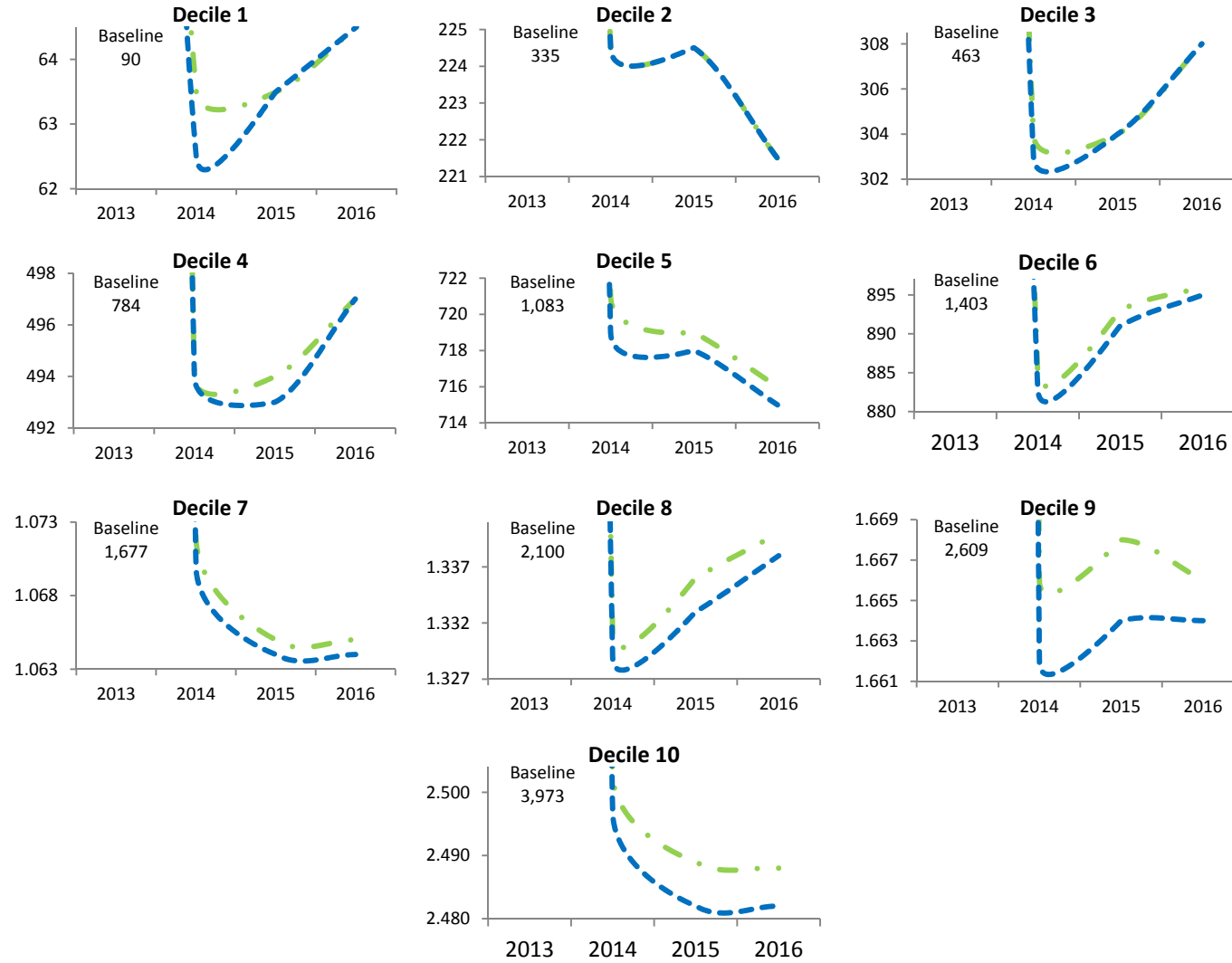


Appendix D. Budgetary and redistributive effects of the reforms

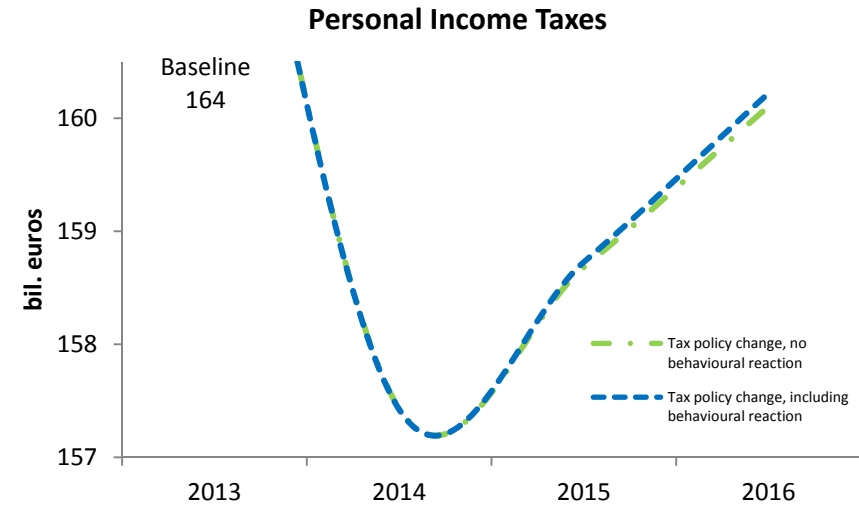
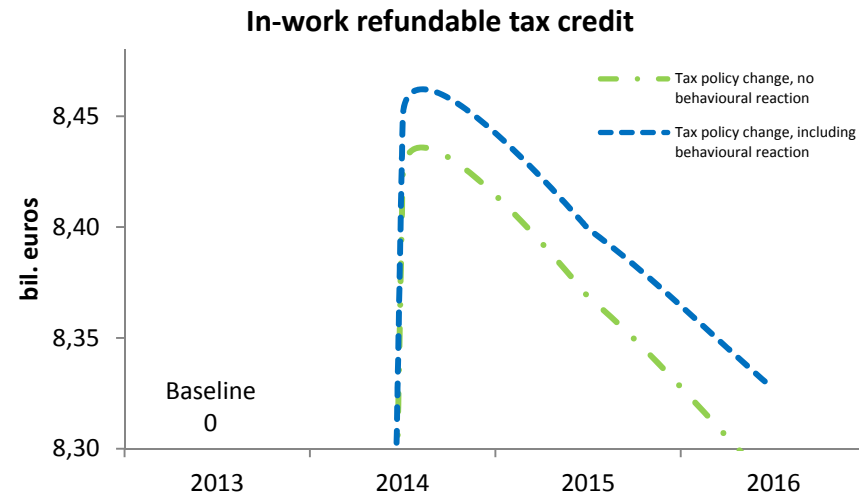
D.1 Employee contribution impact in EUROMOD incorporating macro feedback on prices, wages and employment – Belgium



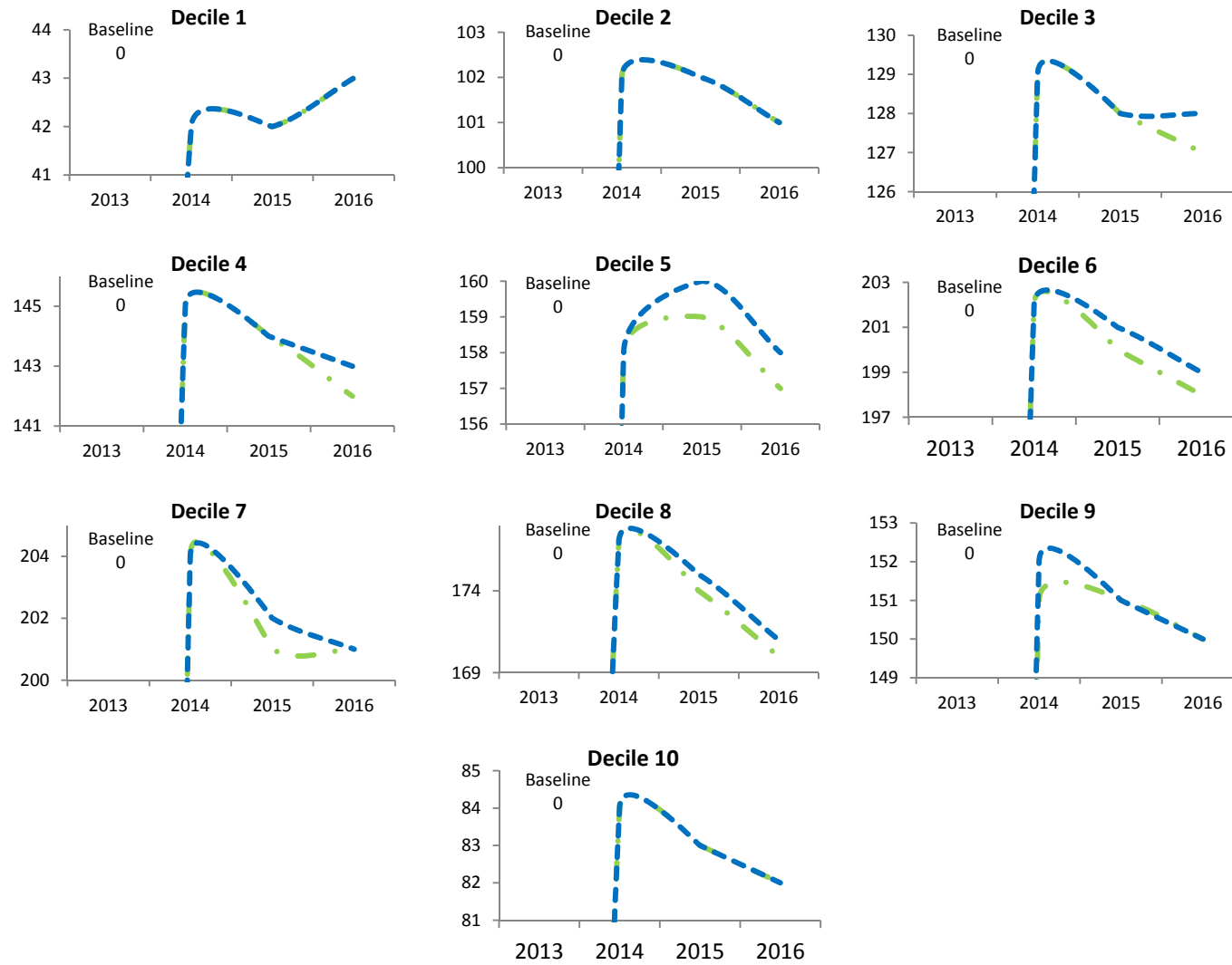
D.2 Impact on employee contribution to pension and health insurance by income decile – Belgium



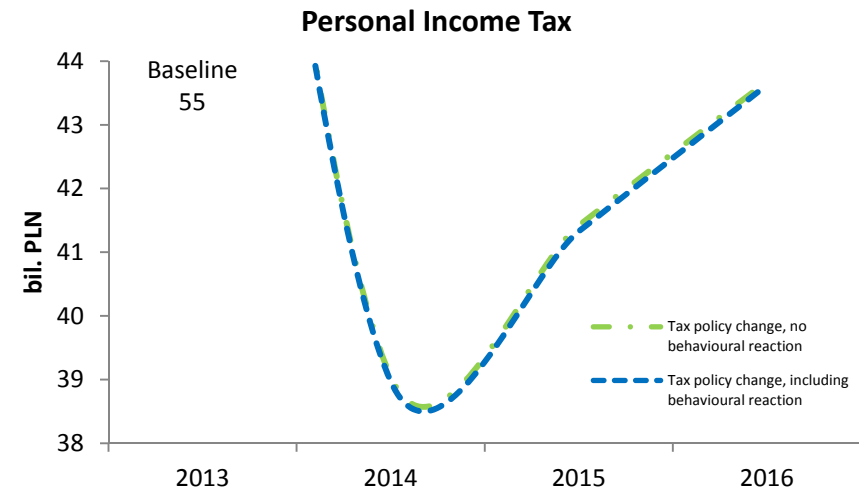
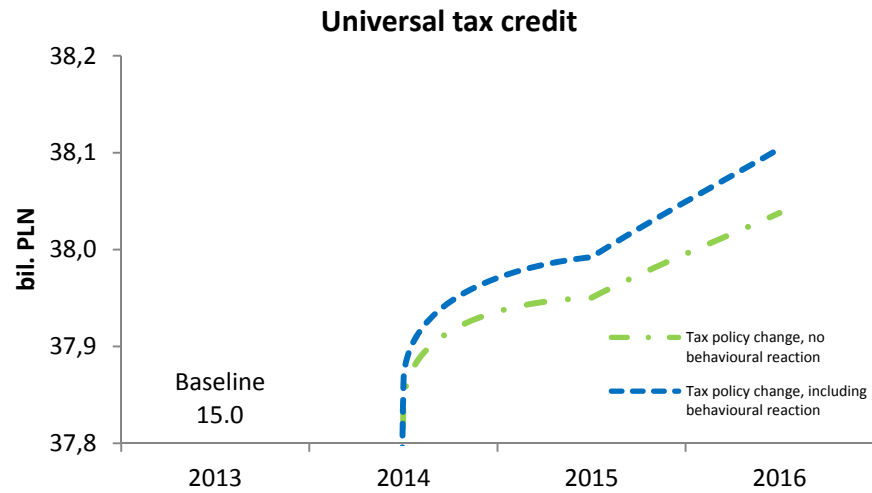
D.3 Tax revenues impact in EUROMOD incorporating macro feedback on prices, wages and employment – Italy



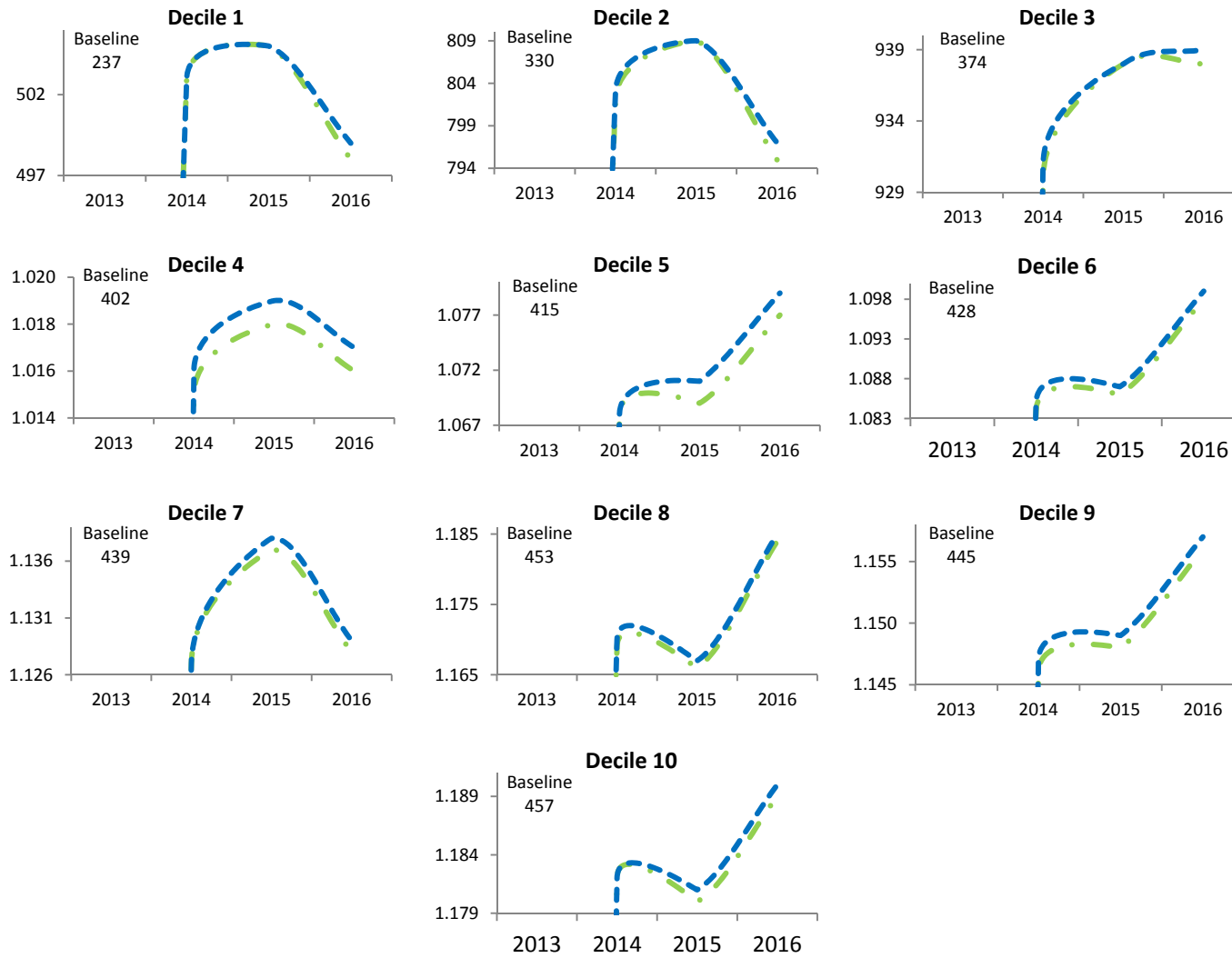
D.4 Impact on in-work refundable tax credit by income decile – Italy



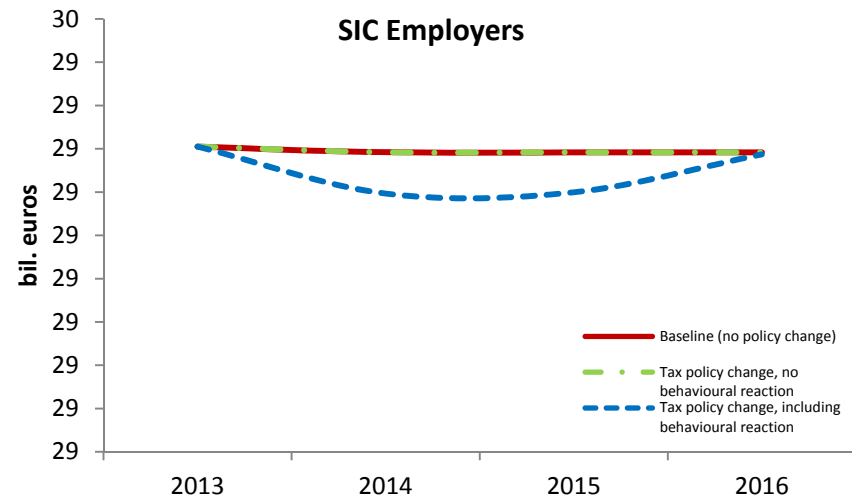
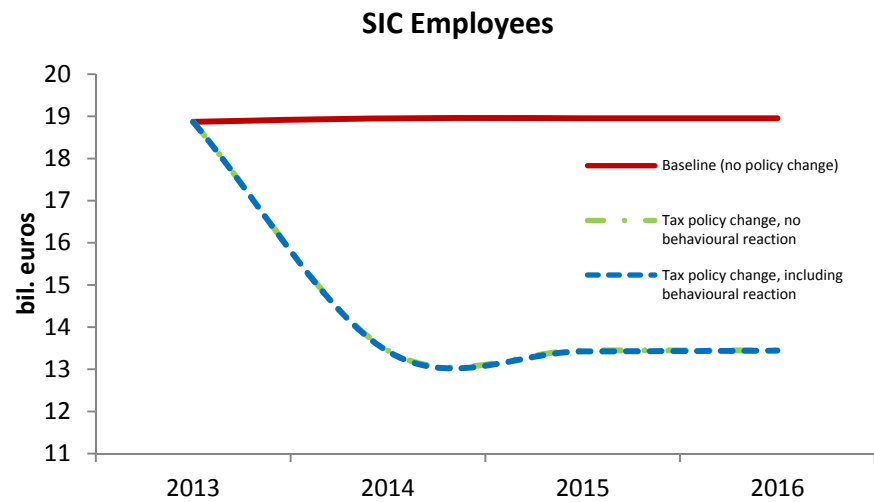
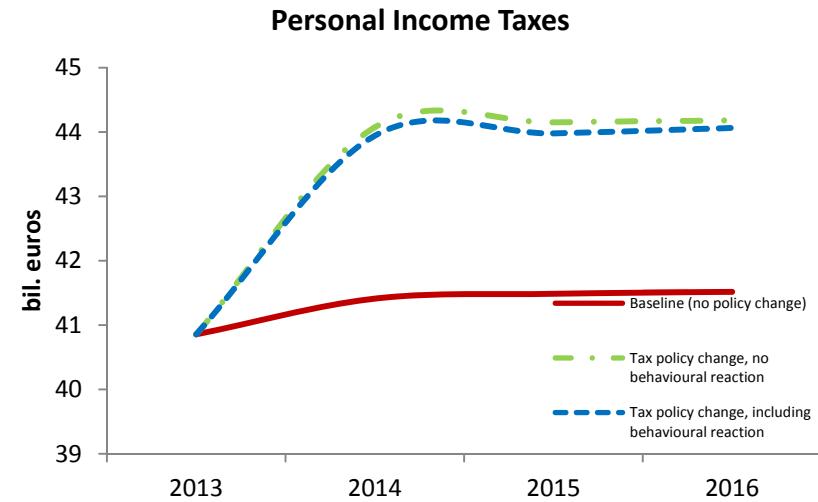
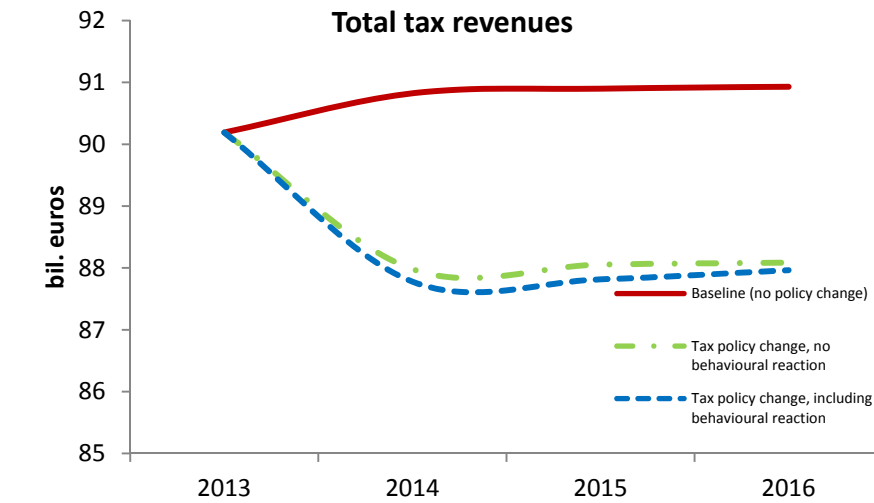
D.5 Tax revenues impact in EUROMOD incorporating macro feedback on prices, wages and employment – Poland



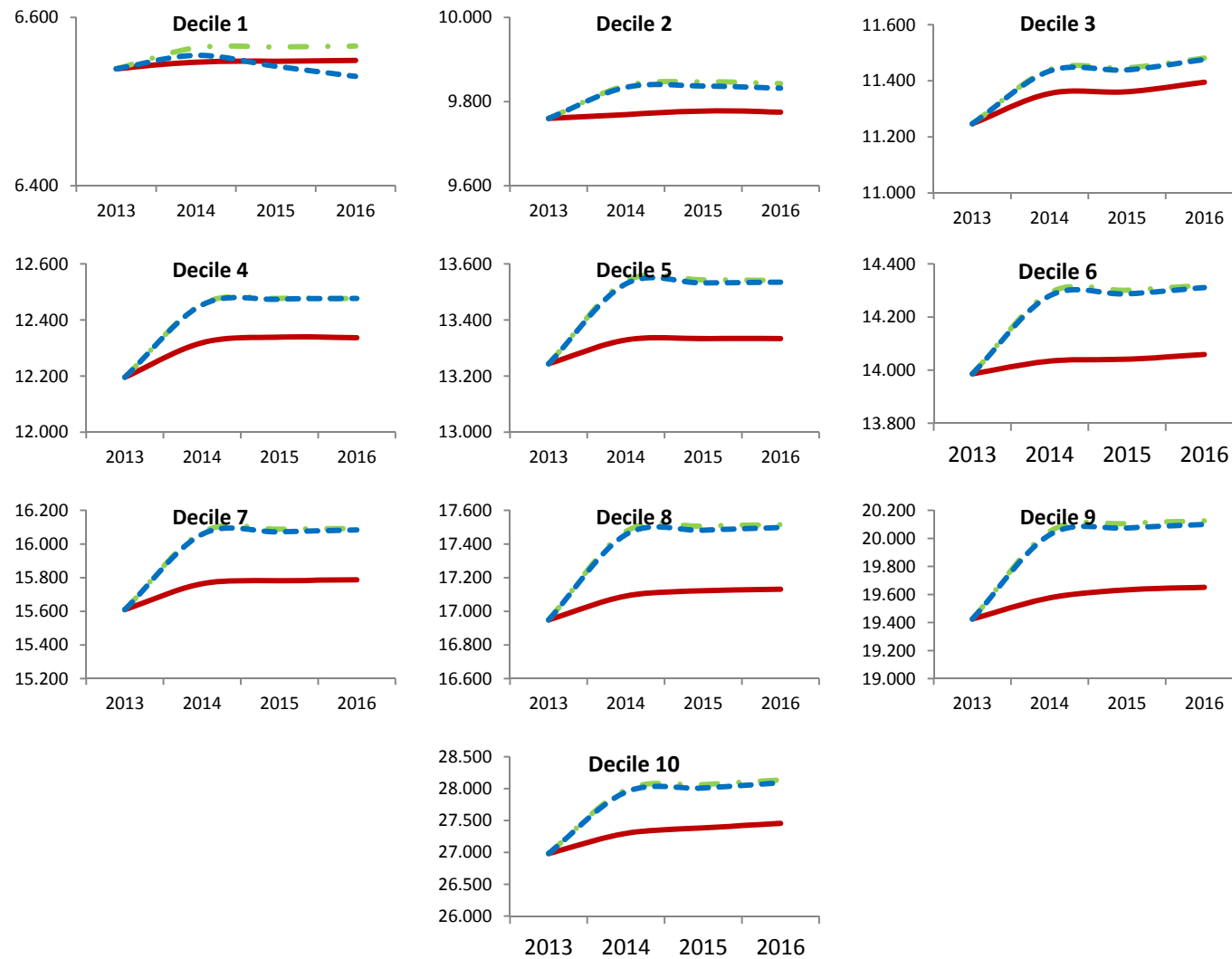
D.6 Impact on universal tax credit by income decile – Poland



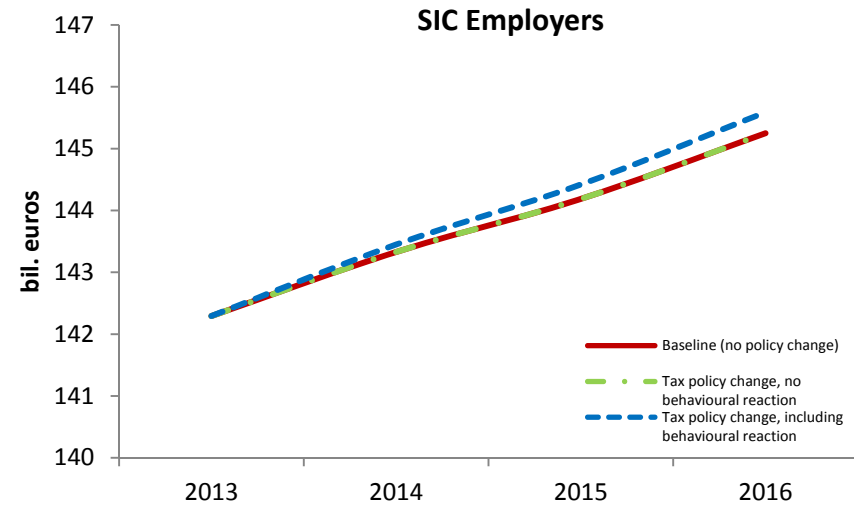
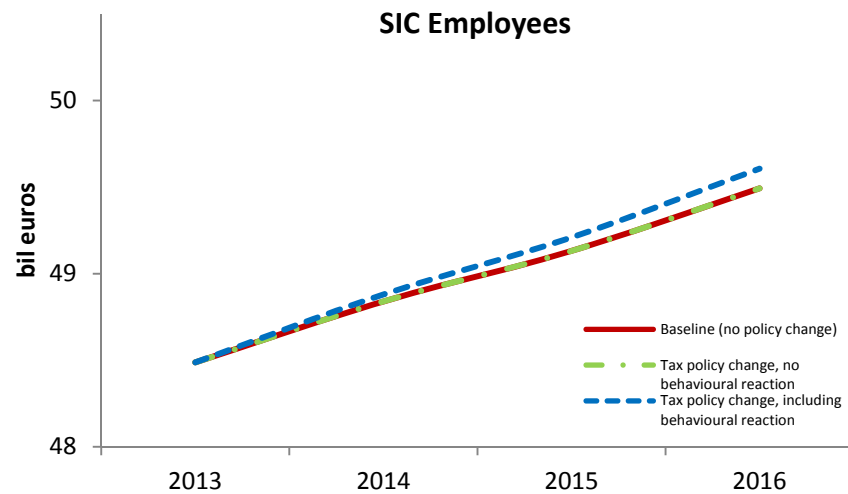
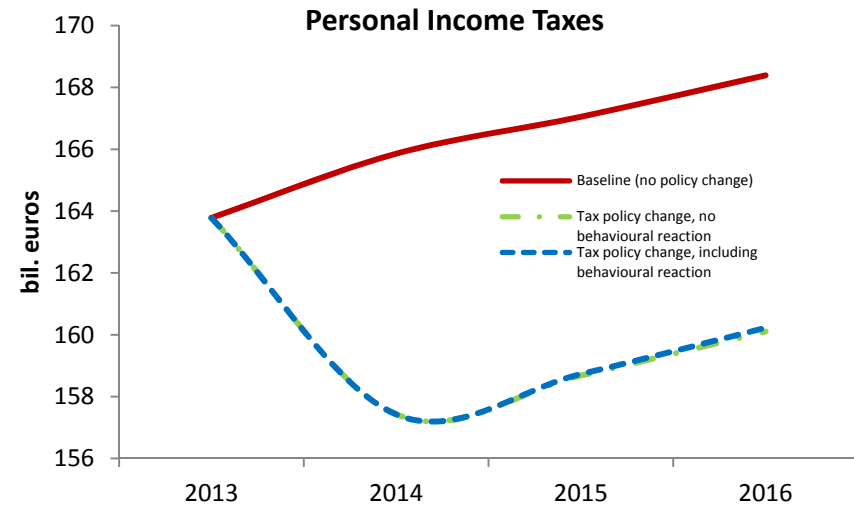
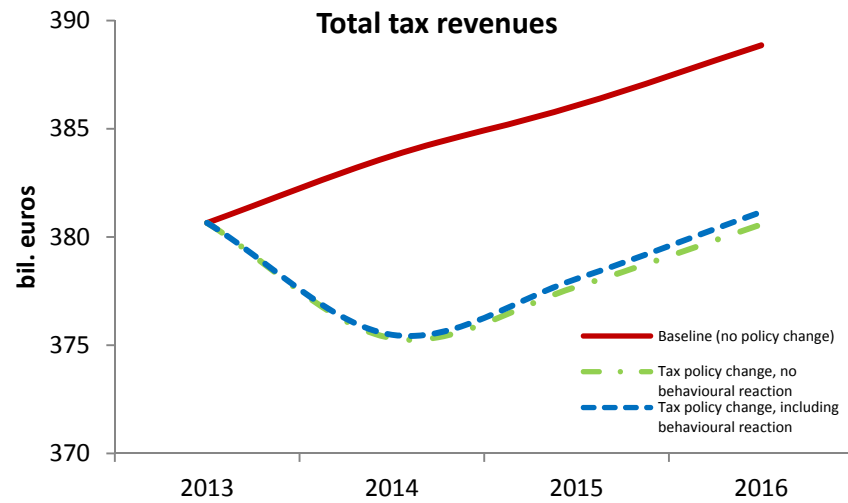
D.7 Tax revenues impact in EUROMOD incorporating macro feedback on prices, wages and employment – Belgium



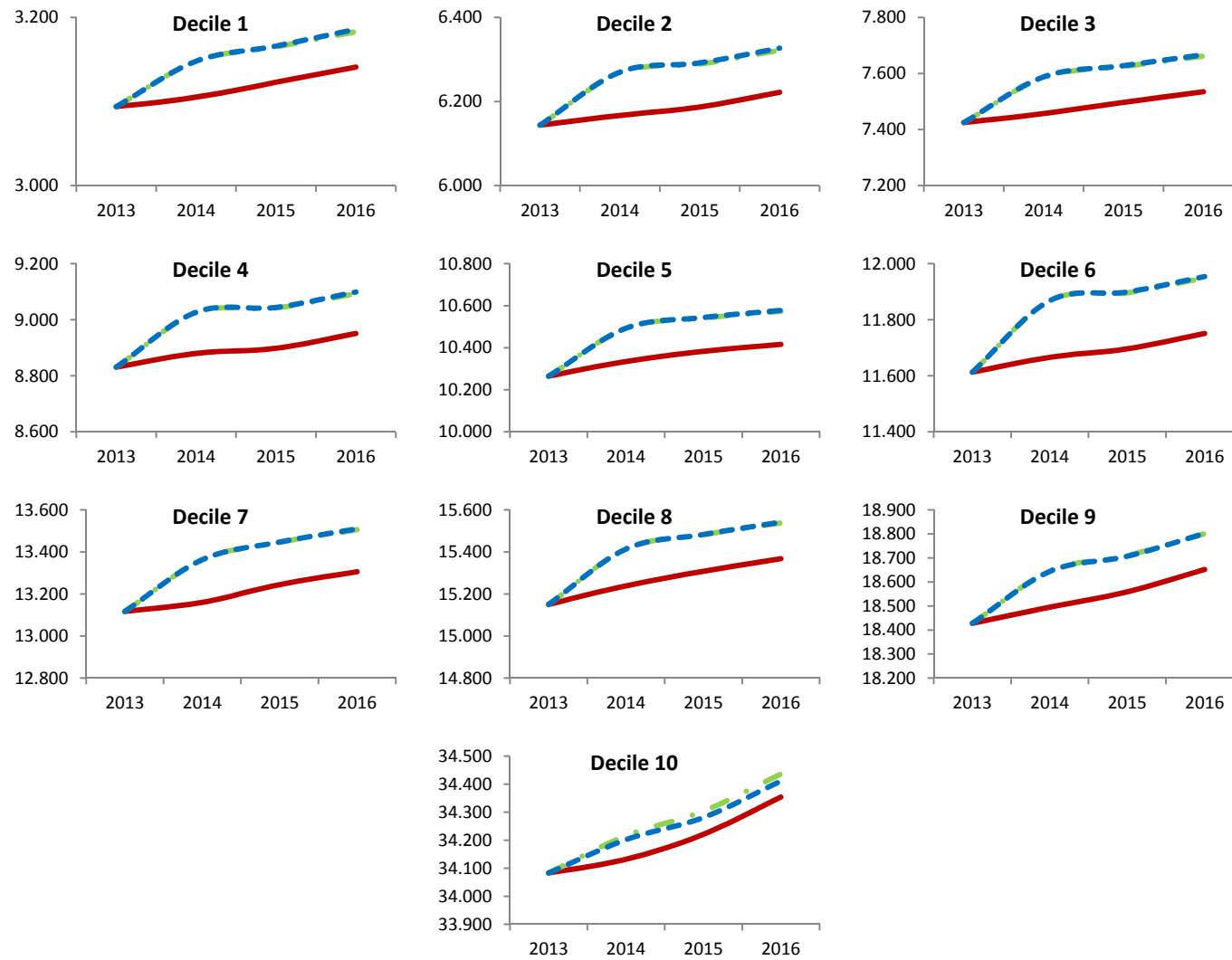
D.8 Impact on disposable income by income decile – Belgium



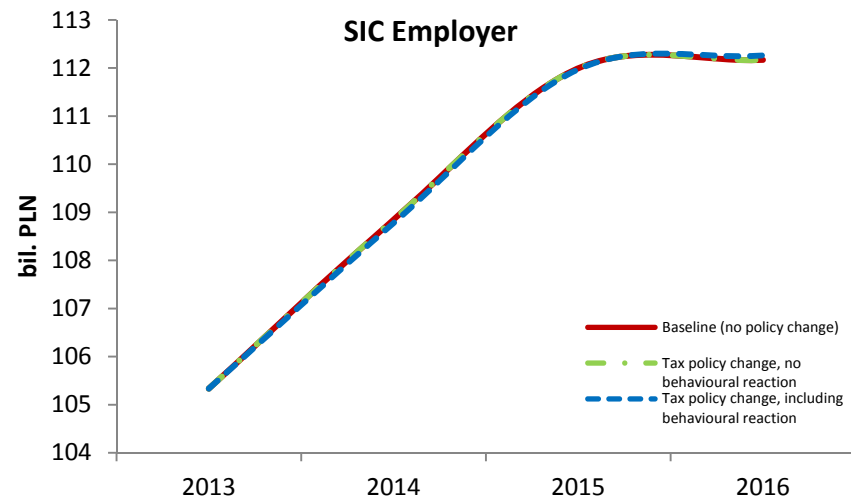
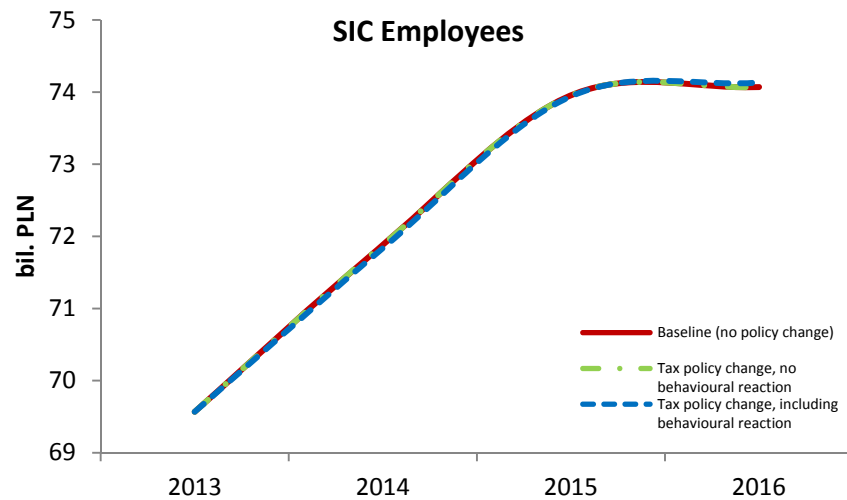
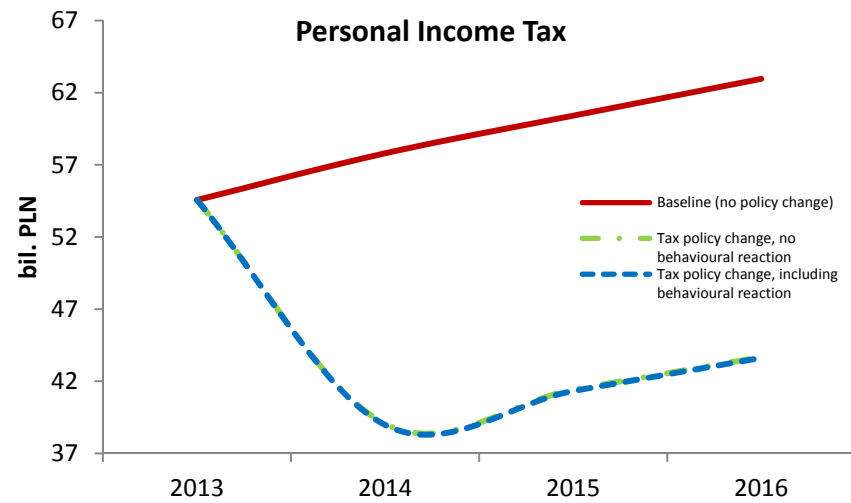
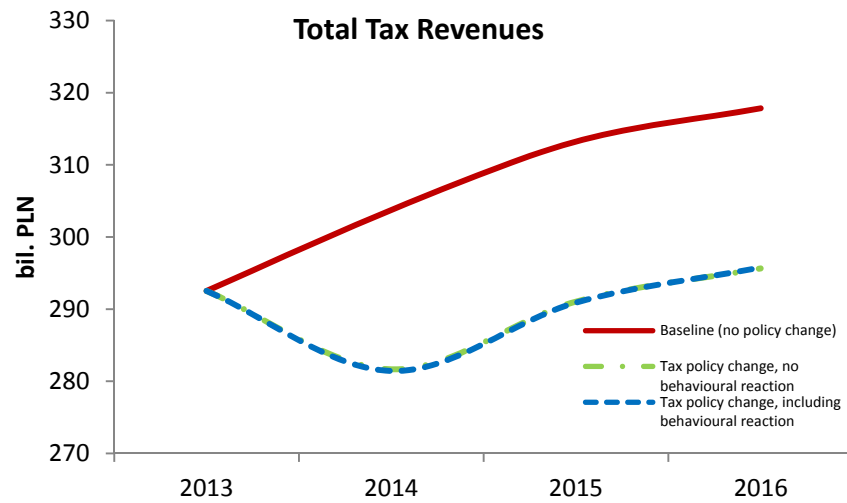
D.9 Tax revenues impact in EUROMOD incorporating macro feedback on prices, wages and employment – Italy



D.10 Impact on disposable income by income decile – Italy



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



D.12 Impact on disposable income by income decile – Poland

