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# Dynamic scoring of tax reforms in the European Union[1]

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## Abstract

In this paper, we present the first dynamic scoring exercise linking a microsimulation and a dynamic general equilibrium model for Europe. We illustrate our novel methodology analysing hypothetical reforms of the social insurance contributions system in Belgium. Our approach takes into account the feedback effects resulting from adjustments and behavioral responses in the labor market and the economy-wide reaction to the tax policy changes, essential for a comprehensive evaluation of the reforms. We find that the self-financing effect

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of a reduction in employers' social insurance contribution is substantially larger than that of a comparable reduction in employees' social insurance contributions.

## 1. Introduction

Assessing the revenue, behavioral and macroeconomic effects of tax reform proposals before their introduction provides important information to feed the political and public debate. The interaction between tax reforms and the induced changes in the economy are multi-faceted. Hence, it is necessary to capture not only the reaction of economic agents to the tax reforms (in particular labor adjustment effects), but also the overall economic effect, including in the factor and product markets. The evaluation of the tax reform effects is known as dynamic scoring.[7] In the US, dynamic scoring analyses are now well established and legally required before significant changes in tax legislation are implemented.[8]

In contrast to the US, dynamic scoring has not been applied in the fiscal governance framework in the European Union (EU) so far. Yet, such analysis would allow an in-depth evaluation of discretionary tax measures and a better assessment of the true fiscal policy stance which remain important issues in the EU (Buti and Van den Noord, 2004). Moreover, in a policy context where the European Commission analyses the fiscal and structural reform

[7] See Adam and Bozio (2009) for a comprehensive assessment of the dynamic scoring exercise.

[8] In the US, dynamic scoring analyses are conducted by the Joint Committee on Taxation (JCT) and the Congressional Budget Office (CBO). The JCT has been responsible for a macroeconomic impact analysis of changes in tax law since 2003. In addition, the CBO has incorporated these macroeconomic feedback effects into their estimates of fiscal effects if revenue effects exceeded $5 billion in any fiscal year. Since 2015, the JCT and the CBO are obliged to provide precise estimates for output and revenue feedback effects of major tax and mandatory spending changes (see Altshuler et al. 2005, Auerbach 2005, Furman 2006, Gravelle 2014, 2015, Holtz-Eakin 2015, and Auerbach and Grinberg 2017 for more details).

policies of every Member State – providing recommendations, and monitoring their implementation according to an annual round of policy dialogue (the so-called European Semester) – the analysis of how fiscal and structural reforms can affect national budgets as well as Member States´ economic performance is required.[9] Accounting for macroeconomic feedback effects of tax reforms is also crucial for the determination of the cyclically adjusted fiscal balance which plays a key role in the European fiscal framework (see in particular Larch and Turrini, 2010).

In this paper, we develop the first dynamic scoring framework for modelling and analysing tax and benefit reforms for all EU countries. A key feature of our dynamic scoring approach is to combine EUROMOD, the microsimulation model for all European Union Member States, with QUEST, the European Commission's dynamic stochastic general equilibrium (DSGE) model used for the analysis of structural reforms (including fiscal ones).[10] By doing so, we are able to precisely model actual tax reforms, since EUROMOD contains all relevant rules of the tax-benefit systems in the EU Member States and allows for the simulation of direct taxes, social insurance contributions and benefits according to actual legislation and hypothetical reform scenarios. This is usually not possible using aggregated macroeconomic models alone, that only differentiate between capital and labor taxes (see e.g. Mankiw and Weinzierl 2006, Leeper and Yang 2008, Trabandt and Uhlig 2011, Strulik and Trimborn 2012).

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[9] For example, recently the European Commission has also started to collect data on estimates of the impact of discretionary tax measures relying on the Member States' own assessment and providing information at a more disaggregated level (see in particular Barrios and Fargnoli, 2010).

[10] See Sutherland (2001) and Sutherland and Figari (2013) for a description of the EUROMOD microsimulation model and Ratto et al. (2009) for details on the QUEST III model.

On the other hand, microsimulation models do not take into account agents' reactions to policy changes, and hence ignore how tax reforms endogenously affect prices and quantities as well as monetary and fiscal variables in the economy that can lead to non-negligible second-round effects on tax-revenues. By linking QUEST with EUROMOD, these effects are also included in the analysis. In order to do so, we estimate country specific labor supply elasticities using a discrete choice labor supply model (Bargain et al. 2014) based on the EUROMOD micro data and feed them into the QUEST model.

We illustrate our dynamic scoring approach with an analysis of two hypothetical reforms of the Belgian social insurance system: a reduction of the social insurance contributions paid by employees and employers, respectively.[11] We provide various robustness checks in order to assess the sensitivity of the macroeconomic effects of the tax reform to the assumptions of the QUEST model. In addition to the analysis of the macroeconomic and fiscal effects of these tax reforms, we provide insights into the distributional effects of the reform scenarios under consideration which is novel to the previous dynamic scoring literature.[12]

Our results indicate that accounting for labor supply responses and the macroeconomic feedback to tax policy changes is essential for a comprehensive assessment of the fiscal and distributional effects of tax reforms. We find only weak self-financing effects for tax reforms

[11] We also examine reform proposals made for Italy's and Poland's tax system (see Appendix A). All reform scenarios can be precisely simulated in EUROMOD, and are straightforward examples of reforms affecting personal income taxes or social insurance contributions.

[12] Note that in a different literature microsimulation models are combined with Computable General Equilibrium (CGE) models (see, e.g., Peichl 2009, 2016, Cockburn et al. 2014 or Bourguignon and Bussolo 2013). While many of these micro-macro linkages are static, there are some approaches that introduce dynamics through projections into the model. However, these models don't feature labor market dynamics from optimizing firms as in our analysis using QUEST.

lowering the employees' tax burden. After 3 (5) years, the self-financing effect amounts to 6% (13%), measured as the percentage change of labor tax revenues upon the tax shock. The reform generates responses of wages and employment of opposite sign, with an expansion of labor supply leading to higher employment, but lower wages. These counteracting effects explain why first-round tax revenue effects derived from the microsimulation model and second-round effects reflecting behavioral responses and the macroeconomic trajectories derived from the macroeconomic model QUEST differ only slightly. In contrast, we find much larger self-financing effects amounting to roughly 49% (50%) after 3 (5) years resulting from cuts in employers' social insurance contributions. In this case both wages and employment evolve positively because of the expansionary labor demand effect generated by the tax cut. In terms of distributional implications, we show that both reductions in social insurance contributions have regressive effects with increasing gains along the income distribution.

The rest of the paper is organized as follows. Section 2 presents our modelling choices and describes in detail the models used in the dynamic scoring exercise. Section 3 illustrates our approach for hypothetical tax reforms in Belgium. Section 4 concludes.

# 2. Modelling second-round effects of tax reforms

In this section, we first describe the different models used followed by an overview of the methodological steps of the dynamic scoring analysis.

## 2.1 The microsimulation model, EUROMOD

EUROMOD is a tax-benefit microsimulation model covering all 28 member states of the European Union. The model is a static tax and benefit calculator that makes use of representative microdata from the EU Statistics on Income and Living Conditions (EU-SILC) survey to simulate individual tax liabilities and social benefit entitlements according to the rules in place in each member state.[13] Starting from gross incomes contained in the micro data, EUROMOD simulates most of the (direct) tax liabilities and (non-contributory) benefit entitlements, and calculates household disposable incomes.[14] The model is unique in its area as it integrates taxes, social contributions and benefits in a consistent framework, thus accounting for interactions between the tax and benefits systems which - in the European case - can have a non-negligible impact in terms of tax revenues, disposable income distribution and also in terms of work incentives (see in particular Barrios et al., 2016). However, EUROMOD is "static" and only delivers the first-round effects of the simulations. It does not take into account the behavioral response of individuals to a given policy change. Long-term policy effects are also not addressed with this model.

EUROMOD uses the latest available EU-SILC data. However, since the frequency of the releases of the survey data does not coincide with each of the fiscal years included in the model, whenever the policy year does not match the one of the dataset, EUROMOD uses

[13] We use the latest available version "G3.0+" of EUROMOD together with the datasets based on the 2012 version of EU-SILC. 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. Uprating factors are used to inflate the non-simulated income components to 2013. The micro data include information on personal and household characteristics, several types of income (e.g., market income, pensions or social transfers), certain expenditures (e.g., housing costs or life insurance payments), and other variables related to living conditions. The validity of the simulated aggregates is ensured by comparison with the corresponding macroeconomic estimates provided by national tax authorities or by statistical institutes. Validation tables are offered in the EUROMOD country reports for the EU-28 Member States, which can be found at https://www.euromod.ac.uk/using-euromod/country-reports.

[14] Note that some contributory benefits (e.g., pensions as well as unemployment or disability benefits) are not simulated but taken directly from the EU-SILC data, given the lack of individual contribution histories that would be needed to simulate them.

index variables to inflate or deflate monetary values to the year of the simulated tax-benefit system. These index variables are called uprating factors and are usually taken from Eurostat (the European statistics agency) or national statistical offices.[15] In the context of this analysis, uprating factors will be used for including general equilibrium effects in EUROMOD.

## 2.2 The labor supply discrete choice model

In order to account for behavioral responses at the micro level, we estimate a labor supply model. We follow standard practice and in particular Bargain et al. (2014) to estimate a random utility discrete choice model.[16] The random utility framework (McFadden 1974) is based on the assumption that households maximize utility and thereby face the standard consumption-leisure trade-off. In this setting, agents face a discrete set of alternatives in terms of working hours. Individuals can choose to work zero hours, part-time (20 hours), full-time (40 hours) or over-time (60 hours) so that the choice covers both the extensive and intensive margin. The labor supply discrete choice model provides us with parameters that are fed into the macro model (among these the elasticities of labor supply).

Econometrically, our methodology entails the specification and estimation of consumption-leisure preferences, and the evaluation of utility at each discrete alternative.[17] Utility consists

[15] Examples of uprating factors are consumer price indices and evolution of earnings and statutory adjustment rules for certain benefits.

[16] Discrete choice models have their theoretical roots in the Random Utility Model of McFadden (1974). They have become increasingly popular in the labor supply literature (see Dagsvik 1994, Aaberge et al. 1995, van Soest 1995 or Hoynes 1996 for early contributions).

[17] In contrast to the classical labor 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

of a deterministic part which 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 (such as age, number and age of children, etc., allowing for heterogeneity in preferences) and characteristics of the hours category (leisure time, disposable income as well as fixed costs of taking up work). Besides preferences, household characteristics also influence how gross income translates into disposable income as effective tax rates vary with household characteristics (such as marital status, age, family composition, etc.).

For identification, we exploit the resulting variation created by nonlinearities and discontinuities inherent in the tax-benefit system and how they reflect on households and individuals consumption.[18] Although we include some of the household 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 disposable income (as proxy of consumption) that allows identifying the parameters of the econometric model.

The disposable income is calculated for each discrete hour category and each household by aggregating all sources of household income, adding benefits (family and social transfers), and subtracting direct taxes (on labor and capital income) and social insurance contributions using

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 et al. 2014).

[18] This is the usual source of variation for models estimated on cross-sectional data that cannot rely on variation over time.

EUROMOD.[19] Appendix B provides detailed information on the discrete choice model and its underlying assumptions.

## 2.3 The macroeconomic DSGE model QUEST III

The macroeconomic model used in this analysis is an extension of the European Commission's New-Keynesian model, QUEST (to be precise: version QUEST III, see Ratto et al. 2009), to include different skilled workers. The QUEST model is the standard model used by the European Commission to analyse the impact of fiscal scenarios and structural reforms in the EU Member States (see for instance Vogel 2012, in 't Veld 2013, Varga and in 't Veld 2014). As a fully forward-looking DSGE model, QUEST can capture the behavioral responses of major macroeconomic variables in an open economy context, going beyond the direct, static impact of specific tax reforms measured by EUROMOD. The labor market modelled in QUEST is strongly based on microeconomic theory and sufficiently general to adapt to the different labor market institutions of the EU countries.

More specifically, the model-version used for this exercise is a three-region open-economy model, calibrated for the country of interest (Belgium), the (rest of) euro area and the rest of the world. For each region, the model economy is populated by households and final goods

[19] In practical terms, the link between EUROMOD and the labor supply model is implemented according to the following methodological steps. First, we estimate the hourly wage rate using a Heckman selection model. Next, we calculate gross earnings for each hypothetical hours choice. For instance, for a single (couple) household, we obtain four (16) different gross labor incomes (describing all possible combinations of hours that can be chosen by the two partners). The key assumption here is that the predicted hourly wage rate does not depend on the number of hours supplied in the labor market. This is a standard assumption in discrete choice labor supply models, see, e.g., Aaberge et al. (2009), Bargain et al. (2014), Blundell et al. (2000), Creedy and Kalb (2005), van Soest (1994). Allowing wages to vary across choices would lead to complications when estimating the likelihood function which are beyond the scope of this paper (see the discussion in Löffler et al. 2014).

producing firms. There is a monetary and fiscal authority, both following rule-based stabilization policies. The domestic and foreign firms produce a continuum of differentiated goods under monopolistic competition. In order to measure the distributional consequences of policies we introduce three skill groups – high, medium and low – into the model earning different wages.[20] Appendix C explains in detail the main blocks of our macro model – households, firms, policies and trade.

In our dynamic scoring exercise, one of the links between EUROMOD and QUEST is the labor market. In the following, we describe the workings and main driving forces of this market in QUEST. Although the general equilibrium effects influence the numerical results – since output, consumption, capital utilisation and prices are fully endogenous in the model – the partial equilibrium analysis of Figures 1 and 2 can illustrate the basic wage setting mechanism in the QUEST model. These figures also highlight the role played by tax incidence after the different policy shocks are introduced in QUEST (section 3.2).

**Figure 1. Reduction of employer-paid taxes**

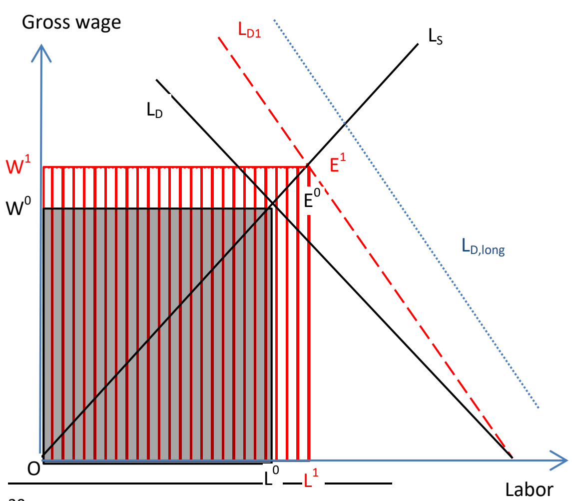
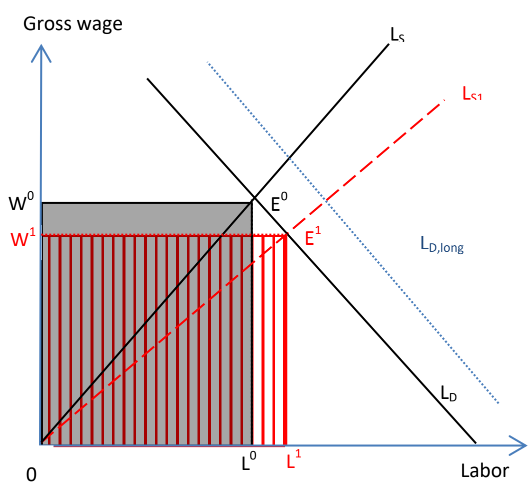



**Figure 2. Reduction of employee-paid taxes**




[20] 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.

Note: the rectangle of $OL^0E^0W^0$ is the pre-reform tax-base while $OL^1E^1W^1$ is the new tax-base after the corresponding tax-cut.

In the figures, $L_S$ denotes labor supply and $L_D$ is labor demand.[21] Let us consider two reforms to illustrate the wage setting mechanism in the labor market. The first reduces the tax burden of employers (Figure 1), the second the tax burden of employees (Figure 2). When employee-paid labor taxes decrease (Figure 2), workers are willing to offer more labor services at all levels of the gross wage, and $L_S$ rotates down to the right to $L_{S1}$. In this case, the tax-cut has two opposing effects on the tax-base: in the new equilibrium, gross wages are lower and firms are willing to hire more labor. The tax-base in Figure 2 transforms from the shaded $OL^0E^0W^0$ rectangle to the $OL^1E^1W^1$ rectangle with stripes. Due to these two opposing effects the tax-base may not even change significantly in the short-run and scoring exercises with or without endogenous wage and labor response might give similar results in the short-run.

When employer-paid labor taxes decrease (Figure 1), firms are willing to hire more labor services at all levels of the gross wage and $L_D$ rotates up to $L_{D1}$. In the new equilibrium gross wages are higher and firms are willing to hire more labor at the new wage rate. As both wages and employment rise, the tax-cut unambiguously increases the tax-base (from the shaded $OL^0E^0W^0$ rectangle to the $OL^1E^1W^1$ rectangle with stripes). Notice that this effect would be completely missed in a simple static scoring framework where wages and employment are kept exogenous.

In the long-run, the capital stock will gradually increase to its new steady-state level, which will lead to higher labor demand (e.g. $L_{D\text{-}long}$ in Figure 1 and 2), higher wages and a larger tax-

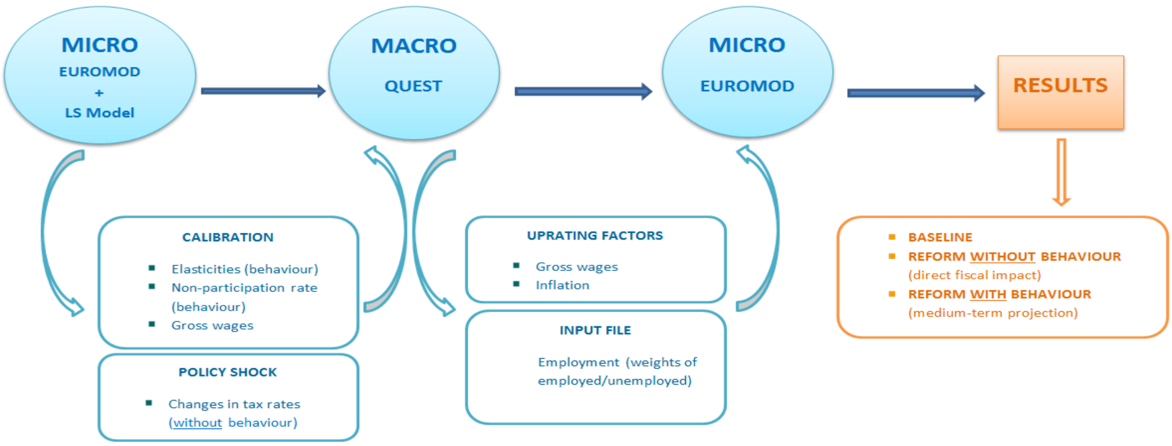
[21] Equations C.7 and C.15 in Appendix C, respectively. For simplicity, we assume that all other variables are constant, except real gross wages and labor, and there are no adjustment costs.

base. Consequently, along the transition path the difference between the static and dynamic scoring revenue estimates will increase.[22]

## 2.4. Methodological framework

For our analysis, we combine the three models described in the previous sections as shown in Figure 3. The first step of our analysis consists in running EUROMOD for the actual tax-benefit system and the reform scenario for the year of interest, using the household micro-data for Belgium. This step provides us with the change in the effective tax burden on labor income for employees and employers, i.e. an aggregate indicator of the change in the tax burden resulting from the tax reform implemented in the microsimulation set-up. This tax burden is calculated as the ratio of taxes and social insurance contributions on labor income to the total compensation of employees and payroll taxes (see European Commission 2013).

**Figure 3. Methodological steps**




[22] It is important to stress that the Invariance of Incidence Proposition (IIP) does hold in the model over the medium to long-run: a shift of taxation from employers to employees, which leaves overall labor tax revenues constant, or only changes the composition of the tax-wedge but not its size, does not affect employment and GDP (Goerke 2000).

Next, we estimate the discrete choice labor supply model. From this we obtain estimates for parameters such as the non-participation rate – i.e. the expected number of individuals offering zero labor hours – and the labor supply elasticities – i.e. the percentage change in labor supply, given a one percentage change in gross wages – for Belgium.

After having estimated the labor supply model, the change in the tax burden resulting from the tax reform is introduced in QUEST as policy shocks and labor market parameters such as the level of gross wages (obtained from the household microdata), the non-participation rates and labor supply elasticities (obtained form the discrete choice labor supply model) – each obtained for three skill levels – feed into the calibration of QUEST.[23] By calibrating the main labor market parameters in QUEST with the micro-econometric estimates obtained from the labor supply model, we ensure consistency between the labor markets in QUEST and the discrete choise model.[24]

[23] QUEST is calibrated so that the model matches the observed empirical data from Eurostat in terms of labor productivity, investment, consumption to GDP ratios, the wage share, the employment rate, a given a set of structural indicators describing market frictions in goods and labor markets, tax wedges and skill endowments. Most of the variables and parameters are taken from available statistical or empirical sources from the literature. 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. In this paper, we focus only on the calibration of selected parameters which are directly related to the labor market. The remaining parameters are pinned down by the mathematical relationships of the model equilibrium conditions, i.e. all agents are maximizing their utility given their budget constraints, and the feasibility conditions of the economy are met.

[24] Appendix D provides information on the aggregation issues that arise from linking the two models. It compares the worker's optimization problem and derives the labor supply elasticities in both models. It is shown that the labor supply elasticity estimated from the discrete choice model can be consistently used to calibrate the parameter guiding this elasticity in QUEST.

The second step of our analysis consists in running QUEST in order to obtain the three years macroeconomic trajectories for the endogenous variables of the model. We are mainly interested in the trajectories for the price level, employment and gross wages, since these variables are fed back into the EUROMOD model.

In the third step, we analyze the fiscal and distributional effects of the tax reforms by feeding the macroeconomic trajectories obtained in the second step into EUROMOD. This is done by uprating prices and wages for the three-year period after the reform.[25] In addition, we simulate the employment trajectory by adjusting the sample weights in our household micro data.

## 3. Illustration: hypothetical social insurance contributions cuts in Belgium

In this section, we focus on two hypothetical tax reforms in Belgium. The first reform reduces the social insurance contributions paid by employees, the second those paid by employers. More precisely, we simulate:

i. a reduction of the social insurance contributions rate paid by employees from 13.07% to 9.07% (by cutting the rate for public pensions by 3 percentage points and the one for public health insurance by 1 percentage point);

[25] Recall that EUROMOD inflates or deflates monetary variables using uprating factors whenever the year of the simulated tax-benefit system does not coincide with the reference year of the survey data.

ii. a reduction of the standard social insurance contributions[26] rate paid by employers from 25.36% to 17.75% (by cutting the rate for public pensions by 5 percentage points and the one for public health insurance by 2.6 percentage points).

In both scenarios, the total statutory tax rate of the social insurance contributions paid by employees and employers is cut by 30%. We simulate reductions of the same contributions – pensions and health contributions – so that both reforms "mirror" each other and their fiscal and distributional impact can be directly compared.

## 3.1. First step: Labor market characterization and policy shocks

We first calculate the change in the effective labor tax burden for both reforms using EUROMOD, which we introduce as policy shocks in QUEST. Furthermore, with the help of the discrete choice model, we estimate the labor supply elasticities and the expected voluntary unemployment rate which will be used to calibrate QUEST.

***Policy shocks***

We follow European Commission (2013) and define the average effective tax rate on labor as the ratio between total taxes paid on labor income over total compensation.[27] For the

[26] These standard social insurance contributions include contributions for pensions, healthcare, disabilities, unemployment, family allowances, accidents at work (standard and special), work-related illness (standard and asbestos fund), educational leave, integration and guidance programs for youth, daycare provision and (re)employment of vulnerable groups. As of 2016, the referred contributions have been substituted by the "global social insurance contribution".

[27] More formally, the average effective tax rate on labor is defined as the ratio $\frac{\sum_i w_i * PIT_i + SIC_{EE} + SIC_{ER}}{Gross\ Wages + SIC_{ER}}$, where $PIT_i$ is the personal income tax liability of individual *i*, and $SIC_{EE}$ and $SIC_{ER}$ are the social insurance contributions paid by employees and employers, respectively. $w_i$ is the ratio of wages relative to the total taxable income of taxpayer *i*, and is defined as $w_i = \frac{Gross\ wages_i}{Total\ Taxable\ Income_i}$. Note that this ratio does not change after the reform, because it is calculated only from the

calculation of the policy shock, we simulate both reforms of the Belgian tax-benefit system using EUROMOD and compute the difference between the pre- and post-reform effective tax rates on labor income. This is done both for employees and employers, for three skill groups respectively. In this way, we are able to introduce the changes in the tax rates simulated in EUROMOD as policy shocks in QUEST[28]. Note that these changes are so-called "morning-after" effects and do not include any behavioral responses, neither from workers nor from firms.

**Table 1. Tax rates and policy shocks for the Belgium reforms**

| | REFORMS | | | | | |
|---|---|---|---|---|---|---|
| | **30% Reduction of the SICee tax rate** | | | **30% Reduction of the SICer tax rate** | | |
| | **High** | **Medium** | **Low** | **High** | **Medium** | **Low** |
| **Tax rates on labor income paid by employees (QUEST)** | | | | | | |
| **Baseline** | 33.5% | 28.8% | 27.1% | 33.5% | 28.8% | 27.1% |

microsimulation set-up, without including any type of behavior effects. We can further derive the average effective tax rates for employees and employers as $\frac{\sum_i w_i * PIT_i + SIC_{EE}}{Gross\ Wages + SIC_{ER}}$ and $\frac{SIC_{ER}}{Gross\ Wages + SIC_{ER}}$, respectively.

[28] Notice that in QUEST the corresponding tax policy variables are the statutory tax rates on labor, levied on workers and firms. These rates are defined in terms of gross wages. Let $t_{w,s}$ and $t_{er,s}$ be the tax rates levied on employees and employers for skill group *s*, respectively. In QUEST, the tax burden is defined as $t_{w,s} * Gross\ Wages$ and $t_{er,s} * Gross\ Wages$ (see also Appendix D for a description of the tax incidence mechanism in QUEST). Then, statutory tax rates in QUEST and average effective tax rates in EUROMOD are related as follows. Let $t_{w,s,EUROMOD}$ and $t_{er,s,EUROMOD}$ be the average effective tax rates of employees and employers for skill group *s* derived from EUROMOD, then:

$$t_{w,s} * Gross\ Wages = \left(\sum_i w_i * PIT_i + SIC_{EE}\right) = t_{w,s,EUROMOD} * (Gross\ Wages)$$

and,

$$t_{er,s} * Gross\ Wages = SIC_{ER} = t_{er,s,EUROMOD} * (Gross\ Wages + SIC_{ER})$$

It follows that, $t_{er,s} = \frac{t_{er,s,EUROMOD}}{1 - t_{er,s,EUROMOD}}$ and $t_{w,s} = \frac{t_{w,s,EUROMOD}}{1 - t_{er,s,EUROMOD}}$. These are the rates presented in Table 1.

| | | | | | | |
|---|---|---|---|---|---|---|
| **Reform** | 31.1% | 26.3% | 24.5% | 33.5% | 28.8% | 27.1% |
| **Shocks (percentage points)** | **-2.35** | **-2.52** | **-2.63** | **0.00** | **0.00** | **0.00** |
| **Tax rates on labor income paid by employers (QUEST)** | | | | | | |
| **Baseline** | 20.3% | 25.9% | 26.9% | 20.3% | 25.9% | 26.9% |
| **Reform** | 20.3% | 25.9% | 26.9% | 16.6% | 20.7% | 21.4% |
| **Shocks (percentage points)** | **0.00** | **0.00** | **0.00** | **-3.72** | **-5.21** | **-5.54** |

Table 1 shows that both reforms reduce the tax rates and that the size of the policy shock is larger in case of the reduction of employers' contributions, ranging from -3.7 percentage points for high-skilled to -5.5 percentage points for low-skilled workers.

***Labor supply elasticities and non-participaticipation rates***

Labor supply elasticities are estimated using the discrete choice labor supply model described in section 2.2. They are used to calibrate the Frisch elasticity in QUEST.[29] The expected number of voluntary unemployed is also obtained from the discrete choice model based on the estimated probability of supplying zero hours in the labor market.[30] The elasticities as well as the non-participation rate calculated for three skill categories are shown in Table 2. In line with the literature, we find that labor-supply elasticities as well as non-participation rates are highest for the low-skilled (see e.g. Bargain et al. 2014).

**Table 2. Calibration of labor supply elasticity parameter and nonparticipation rates, by skill level, in QUEST**

| Labor supply elasticities | Non participation rates |
|---|---|

[29] Explained in detail in Appendix C, equations C.23 to C.41.

[30] See equation (C.22) derived in Appendix C.

| High | Medium | Low | High | Medium | Low |
|---|---|---|---|---|---|
| 0.357 | 0.395 | 0.716 | 0.057 | 0.107 | 0.246 |

## 3.2. Second step: The macroeconomic impact

We have calibrated QUEST for the Belgian economy, the rest of the euro area and the rest of the world. As explained in the previous section, we have set the parameters representing the Frisch elasticity and the non-participation rate, based on the elasticities and predicted labor supply responses obtained from the discrete choice microeconometric model.

In the next step, the changes in the average effective tax rates on labor paid by employees and employers are introduced as permanent policy shocks in QUEST. Importantly, we temporarily set off the debt-stabilization rule[31] for the first fifteen years in order to analyze the direct budgetary effect of the reforms. By doing so we are generating a government budget deficit which is only closed through adjustments of labor tax rates after fifteen years. Note that different ways to tackle the government deficit generated by the reforms may have different second-round effects and that our results have to be interpreted in the light of this simplifying assumption.[32]

[31] Equation (C.21) in Appendix C.

[32] In the long-run, these tax-reforms are reversed by an equivalent budgetary change in employee paid labor taxes. Alternatively, the QUEST model offers a wide range of closure rules which could be based on the revenue or expenditure items of the government's budget constraint. Exploring the long-run implications of these various alternative fiscal closure rules goes beyond the scope of the paper.

***Impulse responses and tax incidence***

The introduction of the shocks for each of the reforms in QUEST originates impulse responses for the model's endogenous variables showing how the endogenous variables of the model react to the changes in the tax rates and at the same time how they evolve together with the other endogenous variables. Impulse responses are informative shedding light on the dynamics of the model: from the trajectories of the endogenous variables after a shock, we can observe how these variables evolve simultaneously over time towards the new equilibrium. The impulse response functions generated by the policy shocks for the main labor market variables – net real wages,[33] total compensation of employees,[34] gross real wages, and employment – are presented in Appendix E (graphs E.1 to E.8). Note again that the trajectories shown imply the presence of a government deficit in the economy. The model goes back to the equilibrium only after fifteen years, when the debt stabilization rule is again binding.

Graphs E.1 to E.4 show the impulse response functions for the reform of employees' contributions. In line with the simplified partial equilibrium analysis of Figure 2 (see section 2.3), we observe a decrease (an increase) in gross wages decrease (employment) (Graph E.3) because employees are willing to work more at higher net-real wage due to the cut in contributions (Graph E.1). The total compensation of employees (Graph E.2) falls for all skill groups but in a smoother way because the tax rate paid by employers remains constant in our simulations and the changes derive only from the smooth decrease (increase) in gross wages (employment).

[33] Net real wages are defined as gross wages minus taxes paid by employees, as in expression (C.42) in Appendix C.

[34] Recall that total compensation of employees is defined as the sum of gross wages plus taxes paid by employers on labor income, as in expression (D.43) in Appendix D.

Graphs E.5 to E.8 show the impulse response functions for the reform of employers' contributions. As shown in the partial equilibrium analysis of Figure 1, firms are willing to offer higher gross wages to their employees due to the reduced tax burden. Employment increases over the simulation period (Graph E.8) as well as gross (and net) wages (Graphs E.5 and E.7). The total compensation of employees (Graph E.6.) immediately drops for all skill groups after the tax cut is introduced, then smoothly recovers over the period of analysis due to the increase in gross wages along the transition path.

These results are also consistent with the partial equilibrium analysis of tax incidence.[35]

***Sensitivity analysis***

We have performed a sensitivity analysis in order to check to what extent our results depend on the type of shocks considered and on selected QUEST parameters and variables. More precisely, we compare the following three alternative scenarios with the reform of the employers' contributions:

Scenario 1: We replicate the policy shocks of the employers' contributions reform and simulate an equivalent reform of the employees' contributions leaving unchanged the baseline social insurance contributions rate paid by employers. This means that ex-ante, without any behavioral effect the reduction in labor tax revenues resulting from this reform equals the reduction resulting from the previous reform of employers' contributions;

Scenario 2: We consider a new baseline with half of the Frisch elasticities of the original estimates, for each skill group, and apply the policy shocks derived from the employers' contributions reform;

[35] Described analytically in Appendix D.

Scenario 3: We start from a new baseline with half of the nominal wage and price adjustment costs and apply the policy shocks derived from the employers' contributions reform.

Figures 4 to 6 below show the impulse responses for selected variables – labor tax revenues, total gross wages and total employment – obtained for each of the three scenarios described above and for the baseline reform of employers' contributions. Besides these four scenarios, Figure 4 also plots the static revenue estimate scenario, which reflects only the mechanical tax cut of the employers' social insurance contributions without any endogenous wage and employment response (denoted by "SICer reform no behavior").

**Figure 4. Labor tax revenues impulse responses (quarterly percentage deviations from baseline)**

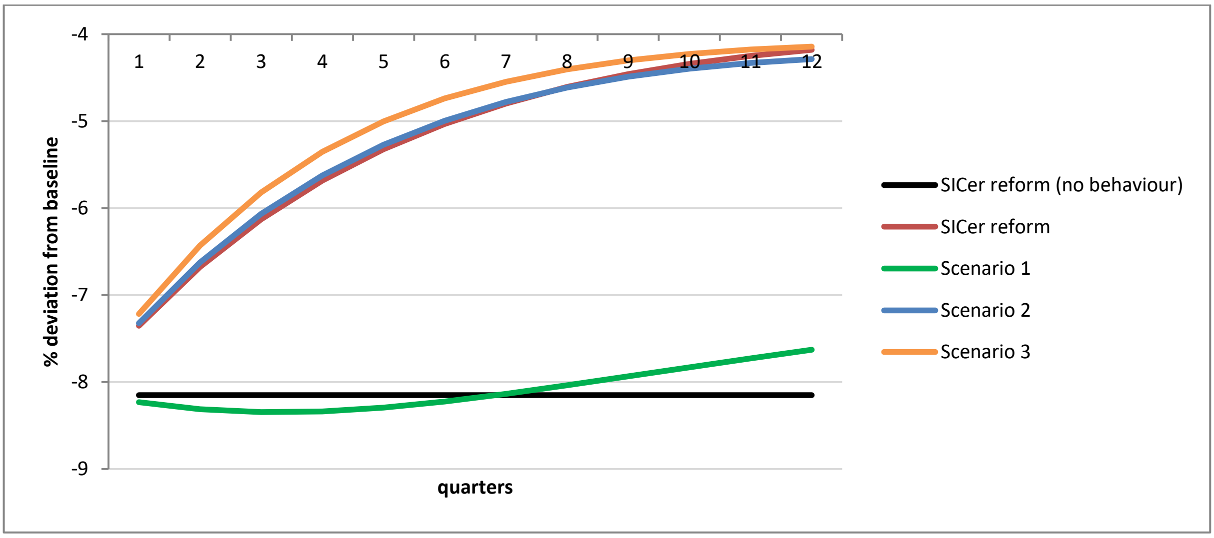



Figure 4 shows that as expected labor tax revenues decrease after the policy shock in all reform scenarios. However, we observe that when the the employers' social insurance contributions are cut, the decrease in tax revenues gets smaller over the period of analysis, revealing that this reform is to some extent self-financing.

**Figure 5. Total gross wages impulse responses (quarterly percentage point deviations from baseline)**

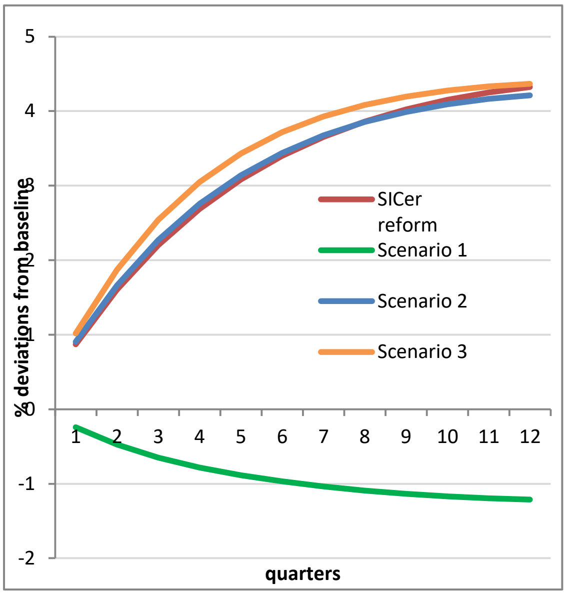
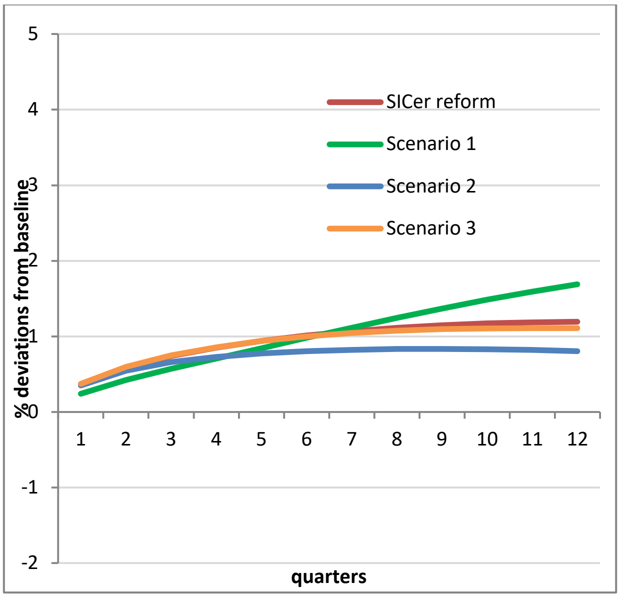



**Figure 6. Total employment impulse responses (quarterly percentage point deviations from baseline)**




This self-financing effect can be explained by the trajectories of wages and employment: from Figures 5 and 6 above, we observe that when the tax cut affects firms, both the wage and employment have increasing trajectories. This result is robust with respect to the labor supply elasticity and the wage and price adjustment costs: the impulse responses obtained for scenarios 2 (lower Frisch elasticity) and 3 (lower nominal wage and price adjustment costs) follow closely the ones for the employers' social insurance contribution reform. From Figure 4, we also observe that in scenario 1 – where exactly the same tax cuts assigned before to employers are now granted to employees – labor tax revenues decrease steadily over the period of analysis. This result can be explained by the wage and employment trajectories shown in Figures 5 and 6: when the tax cut affects employees only, the wage and employment effects cancel each other out. As a consequence, we obtain only very modest self-financing effects which are close to the "no-behavior" situation. This result is in line with the trajectories obtained for wages and employment for the reform of employee's social insurance contributions (see Table 3 below).

***Feedback effects***

Following the standard practice in dynamic scoring exercises, we can also quantify the behavioral feedback effects of the reforms. Table 3 shows the revenue feedback effect for each scenario which is defined as the percentage difference of the revenue effect produced by the macroeconomic model relative to the static revenue estimate (see JCT, 2005). This measure allows us to quantify the extent to which the reforms are self-financing through economic growth (in our context changes in wages and employment). We also decompose the revenue feedback effect into the endogenous feedback contribution from wages and employment, respectively.

**Table 3. Decomposing the revenue feedback effects of tax reform scenarios (percentage changes relative to static estimates)**[36]

| Years | 3 ys | 5 ys |
|---|---|---|
| **Employee tax-cut, BE** | 6.4 | 12.9 |
| ***- effect from employment*** | *18.3* | *23.0* |
| ***- effect from wages*** | *-11.9* | *-10.1* |
| **Employer tax-cut, BE** | 48.7 | 50.3 |
| ***- effect from employment*** | *13.2* | *12.5* |
| ***- effect from wages*** | *35.4* | *37.8* |

.

[36] Note: Positive percentage change indicates that the estimated revenue loss is less when the macroeconomic effects are taken into account while negative percentage change indicates higher revenue loss compared to the static estimate

The reform implemented on the workers' side generates lower feedback effects compared to the reduction of firms' tax burden. By the end of the three year period, the combined effect of wages and employment accounts for self-financing of about 6.4% of the reduction in total labor tax revenues in case of the reform of employees' social insurance contributions.[37] The self-financing effect amounts to almost 50% in case of the employers' social insurance contribution reform.

In line with the theoretical predictions (see section 2.3, Figures 1 and 2), Table 3 illustrates that our result is due to the different behavioral effects of wages under the two scenarios: decreasing the firms' tax burden (Figure 1) induces an upward pressure on wages, increases the tax-base and the corresponding self-financing rate is up to 37.8 % after five years. On the other hand, cutting the tax burden on employees (Figure 2) has the opposite effect on the tax-base due to the downward pressure on wages and the corresponding self-financing rate is down by around 10 percentage points. Notice that the feedback effect from employment is positive in both cases: higher employment increases the tax-base and the corresponding self-financing rates are up by around 23 percentage points (employee tax-cut) and 13 percentage points (employer tax-cut) after five years, respectively.

The magnitude of these feedback effects is close to the dynamic scoring results of Mankiw and Weinzierl (2006). These authors find that in a standard neoclassical model, up to half of a capital tax cut can be self-financing. However, they obtain substantially lower feedback effect

[37] Note that we find similar self-financing effects for the Italian and Polish reforms presented in Appendix A which have the same counteracting effects on wages and employment as the Belgian reform of employees' social insurance contributions.

from a labor tax cut, ranging from 0% to 17% depending on the labor supply elasticity.[38] Other dynamic scoring studies including JCT (2005) and Trabandt and Uhlig (2011) report similar patterns for labor and capital tax reform scenarios. Note, however, that our simulated reform of employer social insurance contributions is distinctly different from the capital income tax cuts considered by Mankiw and Weinzierl (2006) and others. Therefore, our results are not directly comparable for the following two reasons. First and most importantly, the large feedback effect in Mankiw and Weinzierl (2006) is driven by the response of capital accumulation to the tax capital income tax cut, while we consider cuts in social insurance contributions that have no primary impact on capital accumulation. Second, Mankiw and Weinzierl (2006) focus on steady state results, while our feedback effects are limited to a 5-year adjustment period.[39]

***Macroeconomic trajectories***

The final annualized macroeconomic impact of the tax reforms on the variables of interest is summarized in Table 4 below. The main difference between the two reforms consists in the sign of the trajectories for wages: while the cut in the social insurance contributions paid by workers generates downward trajectories for wages for all skill-groups, the reduction in the

[38] In general, they find that independent of how labor supply is calibrated, "if capital and labor tax rates start off at the same level, cuts in capital taxes have greater feedback effects in the steady state than cuts in labor taxes".

[39] The steady state results depend on the budgetary rule which ensures that the government debt is sustainable in the long-run. Mankiw and Weinzierl (2006) assume that lump-sum transfers (or taxes) adjust in response to the changes in tax rates which offers a budget-neutral way to analyse the feedback effect without influencing the behaviour of economic agents. Although the same assumption could be introduced in the QUEST model, the genuine concept of lump-sum transfers cannot easily reconciled with EUROMOD. Therefore, we opt for switching off the fiscal rule in the short to medium-run leading to a temporary increase in debt and do not impose additional taxes which could influence the agents behaviour in the model. In the long-run, we use employee paid taxes to restore debt-sustainability which reverses both tax-reforms.

employers' contributions generates upward ones. This implies counteracting behavioral effects in the context of the employees' reform, resulting in small but non-negligible differences between the "no behavior" and "behavior" scenarios considered in the last step of our analysis which is presented in the next section.

**Table 4. Macro impact of the tax reforms (annualized % deviation from baseline) on the variables of interest, based on QUEST simulations**

| | REFORMS | | | | | |
|---|---|---|---|---|---|---|
| | 30% Reduction on the SICee tax rate | | | 30% Reduction on the SICer tax rate | | |
| | T+1 | T+2 | T+3 | T+1 | T+2 | T+3 |
| **Price level** | -0.043 | -0.101 | -0.128 | -0.096 | -0.161 | -0.154 |
| **Employment** | | | | | | |
| **Low skilled** | 0.171 | 0.444 | 0.739 | 0.825 | 1.338 | 1.445 |
| **Medium skilled** | 0.233 | 0.556 | 0.847 | 0.790 | 1.292 | 1.443 |
| **High skilled** | 0.278 | 0.614 | 0.874 | 0.449 | 0.720 | 0.868 |
| **Gross real wage** | | | | | | |
| **Low skilled** | -0.225 | -0.437 | -0.527 | 1.379 | 2.867 | 3.576 |
| **Medium skilled** | -0.334 | -0.566 | -0.619 | 1.336 | 2.749 | 3.370 |
| **High skilled** | -0.397 | -0.628 | -0.627 | 1.143 | 2.282 | 2.732 |
| **Total labor tax revenue** | -8.307 | -8.173 | -7.781 | -6.461 | -4.941 | -4.309 |

## 3.3. Third step: Microsimulation results

In the third step of our dynamic scoring exercise, we input the impulse responses for employment, gross real wages and consumer price index generated by QUEST back into the microsimulation model EUROMOD in order to assess the medium-term projections in tax revenues, social insurance contributions, and the distribution of disposable incomes. In addition, we simulate a second scenario in which the second round effects, i.e. the macroeconomic feedback and behavioral response to the tax change, are disregarded.

We analyse both scenarios over the period $t_1$ to $t_3$ and compare the medium-term projections against the baseline. More precisely, we apply the tax system of the baseline policy year $t_0$ to the subsequent three years, and assess the fiscal and distributional effects of the tax reforms embedding the second-round effects by amending the uprating factors and the weights in the household micro-data according to the macroeconomic feedback provided by the QUEST model (Table 4) for prices and wages.[40] The trajectory of employment is imputed into the microdata directly through adjustment of the sample weights.

The exact procedure is as follows. First, we incorporate the macro impact of the tax reforms by creating micro-datasets for each year of analysis ($t_1$, $t_2$, $t_3$). For each skill group, the weights of the employed are increased according to the corresponding impulse response, while the weights of the unemployed are scaled down keeping the total population constant. In this way, the employment effect estimated in QUEST is implemented as an extensive margin effect in the household micro-data. Second, the impulse response for the consumer price index is integrated in EUROMOD as a correction of the correspondent uprating factor. Finally, for gross wages we apply the same approach as for the consumer price index, with the only exception of having uprating factors for each skill category.

We subsequently run the microsimulation model to quantify the overall budgetary and distributional effects of the two reforms under the two scenarios. These results are presented

[40] The input data files used here are based on EU-SILC 2012 survey data, which do not correspond with the baseline year 2013 for the simulation of the tax reforms in EUROMOD. Therefore, the uprating factors allow for time consistency between the monetary variables of the survey and the tax system under analysis.

in detail in Figures 7-12. Figures 7 and 8 present the impact on the two affected subcomponents of employee and employer social insurance contributions – pension and health insurance contributions – while Figures 9 to 12 show the impact on broader categories of tax revenues (i.e. government revenue from personal income taxes and social insurance contributions) as well as the impact on household disposable income by income decile.

**Figure 7. Employee contributions impact in EUROMOD incorporating macro feedback on prices, wages and employment**

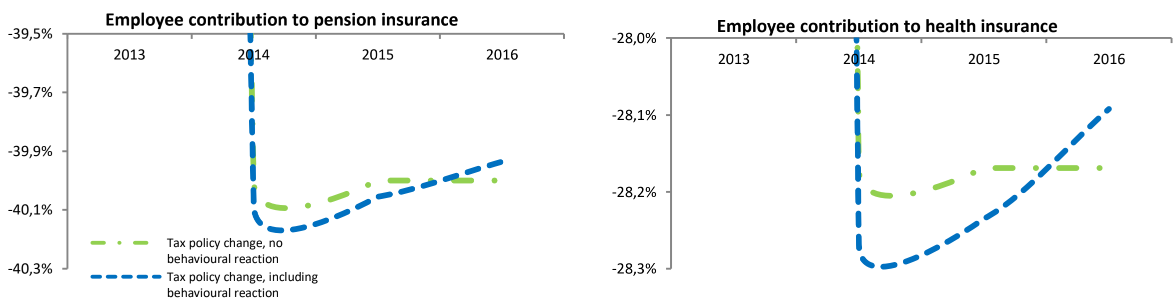



Figure 7 shows that employee social insurance contributions decrease both in the presence and in the absence of second-round effects. In $t_1$ and $t_2$, the drop is larger in the scenario accounting for second-round effects since the new equilibrium in the labor market implies lower gross wages, and consequently lower social insurance contributions. However, we find that the positive employment effect counterbalances the negative wage effect leading to a lower tax revenue loss in $t_3$. Pension insurance contributions decrease by around 40%, while health contributions decrease by 28%.

**Figure 8. Employer contributions impact in EUROMOD incorporating macro feedback on prices, wages and employment**

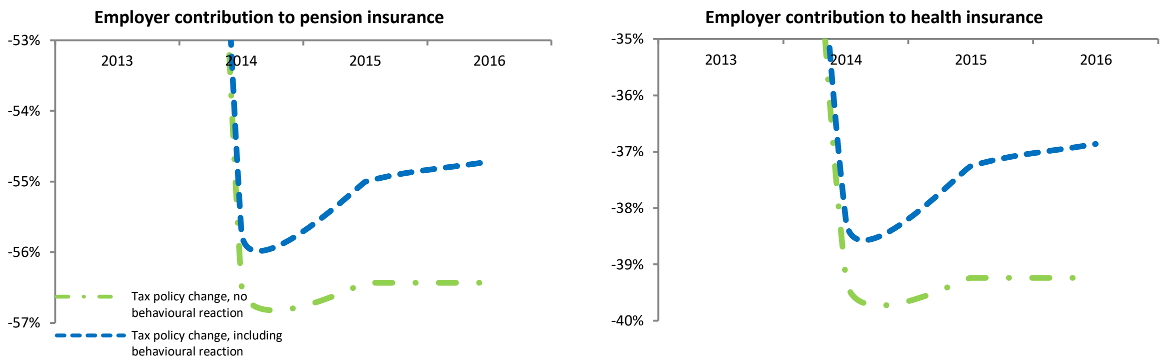



Figure 8 shows that employer social insurance contributions decline at different rates, depending on the affected tax category. In the scenario ignoring behavioral responses, the loss in health (pension) insurance contributions amounts to roughly 40% (57%) in year $t_1$. In the scenario accounting for second-round effects, the revenue losses in $t_1$ are marginally smaller (almost 1 percentage point). The gap gradually widens over the period of analysis and reaches 2 percentage points in year $t_3$. This is due to the labor demand expansion that pushes up wages and employment.

Figures 9 and 10 show the impact of the two tax reforms on broader tax categories (total net tax revenues[41], personal income taxes and total social insurance contributions).

[41] By total net tax revenues we refer to the government revenues derived from simulated taxes and social insurance contributions net of means-tested and non means-tested benefits (excluding pensions).

**Figure 9. Impact of the employee SIC reform on aggregate tax revenues**

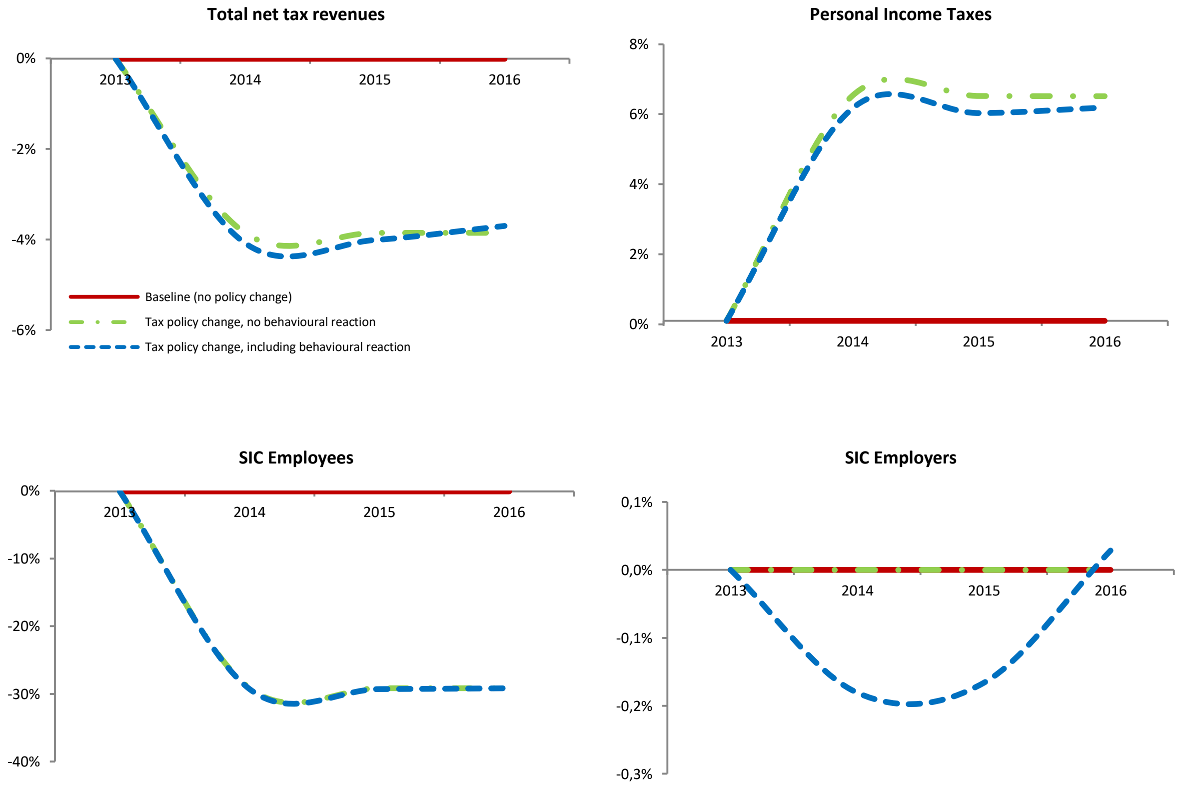



Figure 9 shows that the reduction in social insurance contributions paid by employees leads to a fall in total net government revenues of almost 3.8% in $t_3$ in both scenarios. This drop is the result of two direct "morning-after" effects that evolve in opposite directions: on the one hand, decreasing employees' social insurance contributions, and, on the other, increasing revenues from personal income taxation (as the taxable income, which is net of social contributions, broadens).

The evolution of total net tax revenues differs only slightly when we consider second-round effects: in the first two years following the reform, total net tax revenues are lower compared to the no-behavior scenario, but are higher in year $t_3$. The effect of lower gross wages pushing down total tax revenues dominates in $t_1$ and $t_2$, while the positive employment effect outweights the negative wage effect in year $t_3$. The positive employment effect also reduces unemployment benefit expenditure which contributes to the stronger increase in total net government revenues in the scenario including behavioral reactions. As regards the social insurance contributions paid by employers, we observe that they shrink in the first year, but start to recover afterwards, slightly exceeding the baseline level by the end of the analyzed period. This can be explained by the simultaneous decrease in gross wages (and correspondent decrease in contributions paid) and the increase in employment with the latter effect being stronger at the end of the simulation period.

**Figure 10. Impact of the employer SIC reform on aggregate tax revenues**

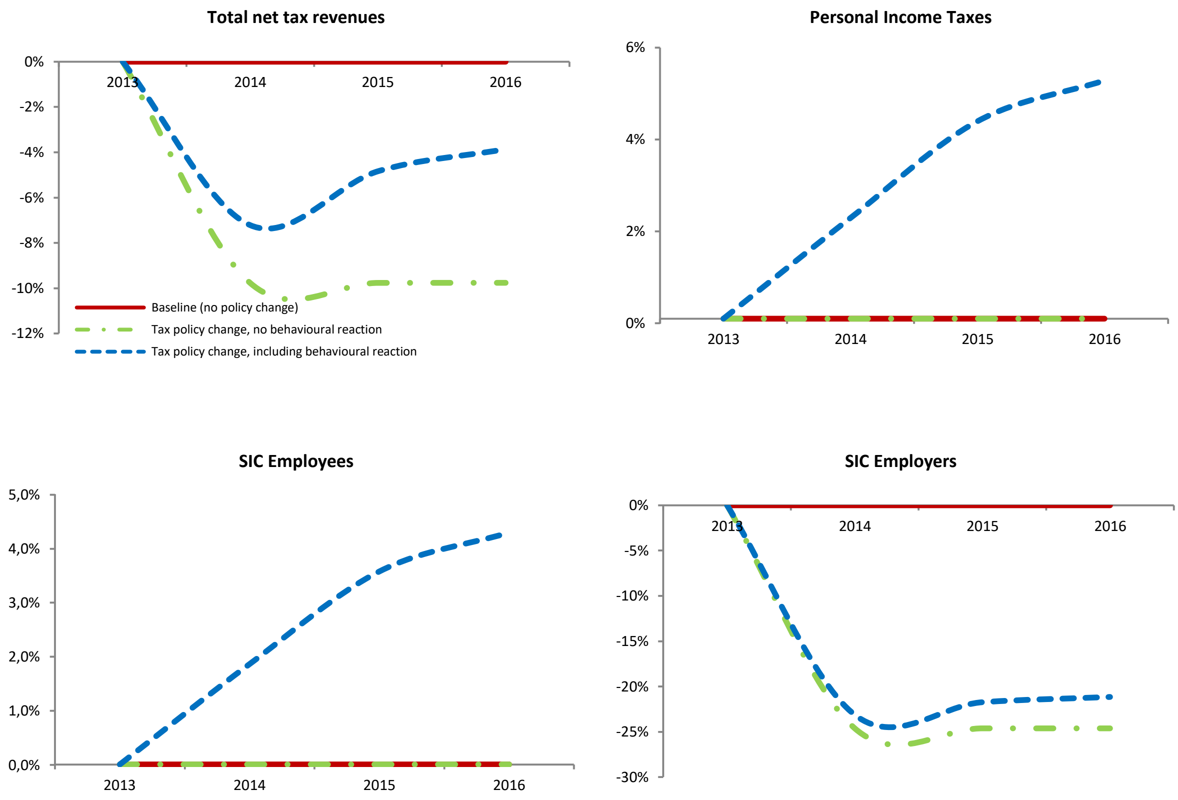



Figure 10 illustrates that there is a immediate revenue loss in $t_1$ amounting to 9.8% in the non-behavior scenario. When we account for the macro feedback on prices, wages and employment, we find that the revenue loss is smaller (7.2%) and shrinks to 3.9% by year $t_3$, i.e. a reduction of roughly 60% (from 7.2 to 2.9 billion euros). This is due to the positive effect on wages and employment, raising the revenues from personal income taxes (employees' social insurance contribution) by 5.2% (4.3%) in $t_3$. In constrast to the previous reform, the positive employment effect is now amplified by a positive wage effect (wages growth is up to 3.5% for the low-skilled in $t_3$). In addition, non-means tested benefits decline by 2.3% due to the decrease in unemployment.

Figures 11 and 12 present the effect of the reforms on equivalised disposable income by income deciles.

**Figure 11. Impact of the employee SIC reform on disposable income (by income decile)**

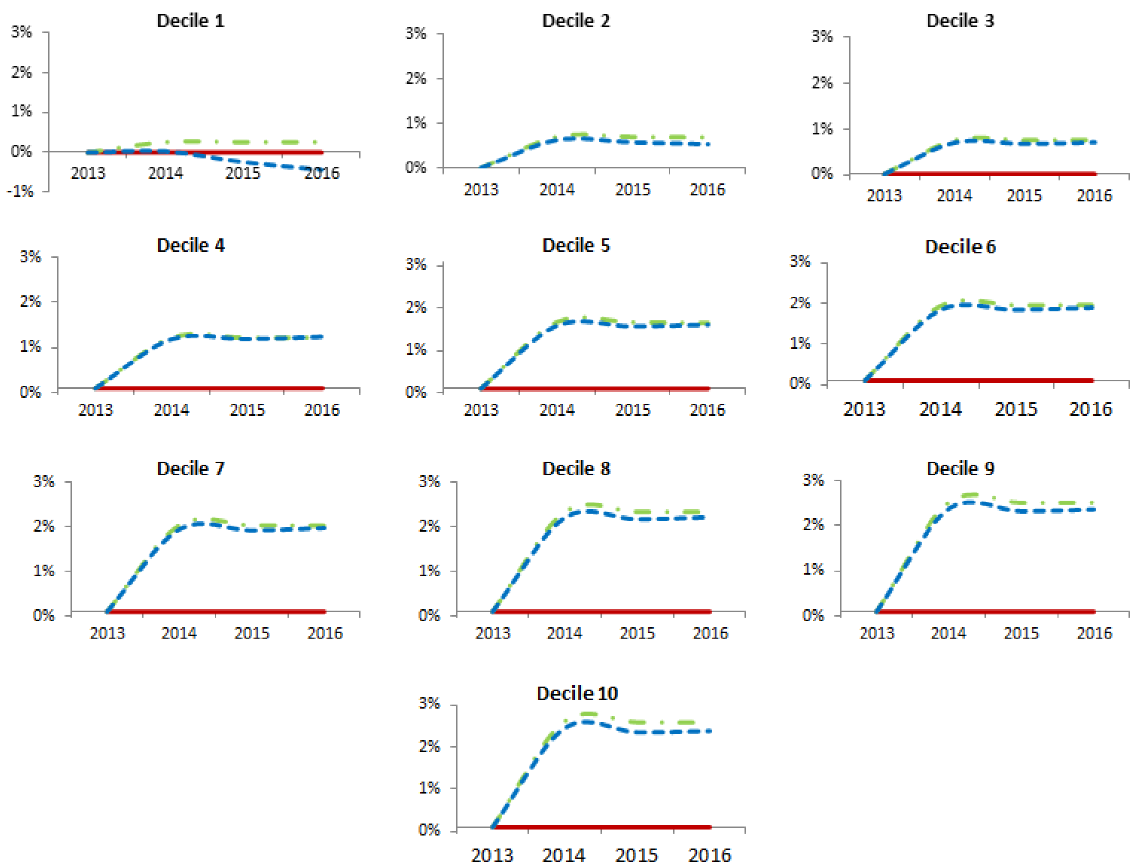



Figure 11 shows that only the first decile is worse off at the end of the simulation period (scenario including behavioral reactions), with the negative wage effect offsetting the positive "morning-after" effect. Overall, the reform has a regressive effect with lower deciles benefiting less than the top of the distribution. The increase in disposable income for the bottom (top) three deciles is smaller (larger) than 1% (2%) by year $t_3$.

**Figure 12. Impact of the employer SIC reform on disposable income (by income decile)**

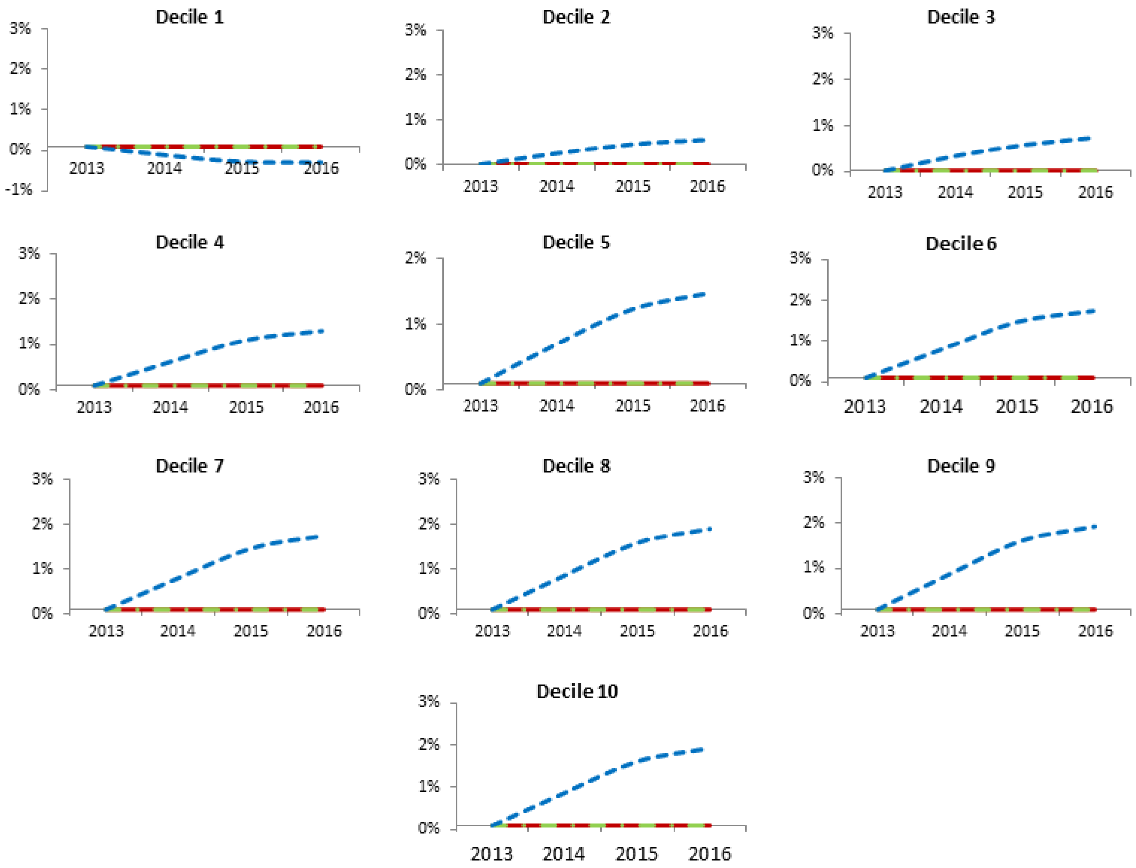



Figure 12 illustrates that the reform of employers' social insurance contributions raises household disposable income only in the scenario including behavioral responses, with the exception of the first decile. The reform has no no direct first-order distributive effects. The rise in disposable income is caused by an expansion in labor demand leading to higher wages and employment. This expansion has a regressive impact with largest gains for the top deciles. In spite of improving labor market conditions, the first decile faces a loss in disposable income which are due to lower benefit payments following the wage and employment increase.

## 4. Conclusion

We propose a dynamic scoring framework to analyse the impact of tax reforms in EU Member States, taking into account first and second order effects of the reforms. For this purpose, we have combined a microsimulation model, augmented with a microeconometric discrete choice labor supply model, with a New-Keynesian DSGE model. We establish a coherent link between the micro and macro models, in particular in terms of aggregation, by calibrating the macro-model with parameters derived from the micro data and by ensuring labor supply elasticities are consistent in both models. In order to illustrate our methodology, we have quantified the fiscal and distributional effects of tax cuts in Belgium implemented as reductions in social insurance contributions paid by employees and employers.

Our results indicate that accounting for behavioral responses and macreconomic feedback effects is essential for a comprehensive evaluation of tax reforms. We find a self-financing effect of a reduction in employers' social insurance contribution in Belgium of roughly 50%. The self-financing effect is smaller in case of a comparable reduction in employees' social insurance contributions amounting to 13%. The larger effect for the social insurance reform affecting employers rather than employees can be explained by the fact that the former increases both wages and employment, while the latter leads to higher employment, but lower wages in the short-run. In addition to the self-financing effects, we pay special attention to the distributional implications of the reforms. We show that both reforms have regressive effects.

Besides allowing for a very accurate and detailed implementation of "real-life" tax reforms, our approach combines the analyses of first-order fiscal and distributional effects of tax reforms using microsimulation methods and of second-order general equilibrium effects derived from a DSGE model. This opens up venues for future research and policy analysis in the European Union context. Our analysis could be extended to account for other types of behavioral adjustments to tax policy reforms, in particular consumption or saving responses. Ongoing extensions of the EUROMOD model broadening the coverage of EUROMOD to include consumption taxes (see Decoster et al. 2014) could be used for this purpose. For instance, tax shifting between labor and consumption taxes aims at reducing the distortionary effect of labor taxation, but is also likely to have an impact on consumption and equity. The framework developed here could be used to analyse these important policy questions as well. Future work could also analyse more sizeable tax reforms combined with structural reforms in order to investigate possible complementarities between these different policy instruments.

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# Appendix

**A. Extensions: Evaluating tax reforms in Italy and Poland**

**B. The discrete choice labor supply model**

**C. The QUEST model**

**D. Labor market modelling: labor supply function, labor supply elasticities and tax incidence**

**E. QUEST impulse responses**

**F. Budgetary and redistributive effects of the reforms**

## Appendix A. Extensions: Evaluating tax reforms in Italy and Poland

We use the methodology illustrated in the previous sections to evaluate two additional reforms: an already implemented refundable tax credit for workers in Italy and an announced, but not legislated, increase in the universal tax credit in Poland.

More specifically, the Italian reform consists in the introduction of a refundable in-work tax credit for low income earners. It was implemented in May 2014 and has been made permanent as of 2015[42], resulting in a tax credit of EUR 960 per year. The maximum amount (i.e. EUR 80 euro per month) is given to employees with a taxable income below EUR 24.000 per year. Above this threshold, the tax credit is linearly decreasing up to a maximum taxable income of EUR 26.000. In order to be eligible for the bonus, the employees must earn at least 8.000 euro per year (below the limit, employees do not pay income tax).

The proposed Polish reform consists in an increase in the income exempt from the personal income tax from PLN 3,090 to PLN 8,000. The reform was planned to be introduced by the recently appointed government on 1st January 2017 (though there has been no official draft legislation). The increase in the tax-free amount implies that the amount of the universal tax credit rises from PLN 556 up to PLN 1,440, due to the fact that the tax base free of taxation is derived by dividing the universal tax credit[43] to the tax rate of the first tax bracket (18%).

[42] With the Stability Law for 2015 (n.190 of 2014).

[43] The value of the universal tax credit in Poland is defined in The Natural Persons' Income Tax Act (PLN 556 per year).

A priori, both reforms increase incentives to participate in the labor market.[44] The labor supply elasticities and the non-participation rates computed in order to calibrate QUEST for each of the countries of interest are shown in Table A.1.

**Table A.1. Calibration of labor supply elasticity parameter and nonparticipation rates, by skill level, in QUEST**

| Countries | Labor supply elasticities | | | Parameter $\kappa$ | | | Non participation rates | | |
|---|---|---|---|---|---|---|---|---|---|
| | High | Medium | Low | High | Medium | Low | High | Medium | Low |
| **Italy** | 0.199 | 0.201 | 0.301 | 0.896 | 1.497 | 2.485 | 0.079 | 0.132 | 0.290 |
| **Poland** | 0.311 | 0.271 | 0.598 | 0.515 | 1.776 | 1.173 | 0.102 | 0.214 | 0.270 |

The correspondent policy shocks to be introduced in the QUEST model are presented in Table A.2 below. As expected, the two reforms reduce tax rates paid by employees on labor income. Low-skilled workers benefit relatively more from the tax cuts, especially in the case of Italy, where the reform has a stronger progressive nature.

[44] As for the Belgium reform, we use version G3.0 of the EUROMOD microsimultion model, together with the datasets based on the 2012 release of EU-SILC for Italy and Poland. Moreover, the described reforms are implemented in the 2013 tax-benefit systems of the two countries, as in the Belgian case.

**Table A.2. Effective tax rates, statutory tax rates and policy shocks for the Italian and Polish reforms**

| | REFORMS | | | | | |
|---|---|---|---|---|---|---|
| | Introduction in-work tax credit in Italy | | | Increase in universal tax credit in Poland | | |
| | **High** | **Medium** | **Low** | **High** | **Medium** | **Low** |
| **Tax rates on labor income paid by employees (QUEST)** | | | | | | |
| **Baseline** | 31.0 % | 26.3% | 23.4% | 20.1% | 18.7% | 19.0% |
| **Reform** | 29.5 % | 23.5% | 19.9% | 18.1% | 16.3% | 16.5% |
| **Shocks (percentage points)** | **-1.53** | **-2.82** | **-3.46** | **-2.00** | **-2.38** | **-2.50** |
| **Tax rates on labor income paid by employers (QUEST)** | | | | | | |
| **Baseline** | 33.3 % | 33.4% | 34.0% | 20.6% | 20.7% | 20.7% |
| **Reform** | 33.3 % | 33.4% | 34.0% | 20.6% | 20.7% | 20.7% |
| **Shocks (percentage points)** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** | **0.00** |

When introducing the shocks in QUEST, we obtain the three-year trajectories for the price level, employment and gross wages as shown in Table A.3. These are then fed back into the household micro data.

**Table A.3. Macro impact of the tax reforms (annualized % deviation from baseline) on the variables of interest, based on QUEST simulations, for Italy and Poland**

| | REFORMS | | | | | |
|---|---|---|---|---|---|---|
| | Introduction in-work tax credit in Italy | | | Increase in universal tax credit in Poland | | |
| | T+1 | T+2 | T+3 | T+1 | T+2 | T+3 |
| **Price level** | -0.027 | -0.127 | -0.177 | -0.087 | -0.233 | -0.350 |
| **Employment** | | | | | | |
| **Low skilled** | 0.257 | 0.424 | 0.539 | 0.201 | 0.444 | 0.626 |
| **Medium skilled** | 0.352 | 0.555 | 0.657 | 0.244 | 0.503 | 0.659 |
| **High skilled** | 0.271 | 0.336 | 0.387 | 0.285 | 0.538 | 0.664 |
| **Gross real wage** | | | | | | |
| **Low skilled** | -0.175 | -0.274 | -0.272 | -0.166 | -0.316 | -0.358 |
| **Medium skilled** | -0.289 | -0.386 | -0.351 | -0.251 | -0.389 | -0.384 |
| **High skilled** | -0.161 | -0.179 | -0.137 | -0.274 | -0.392 | -0.360 |

Similarly to the Belgium cut in employees' social insurance contributions, the tax cuts implemented in the personal income tax systems of Italy and Poland generate negative trajectories for wages, while employment increases over the period for all three skill levels. The wage and employment trajectories determine the evolution of labor tax revenues throughout the period and hence the magnitude of the feedback effect. We obtain a total revenue feedback effect accruing over a 5-year period that amounts to 9% in the Italian and to 8% in the Polish case, as shown in Table A.4 below. Our results are in line with estimates presented in other studies (see e.g. Gravelle 2014 who finds income tax feedback effects ranging between 3.3 to 10.5% for reasonable values of labor supply and capital stock elasticities). The decomposition of the revenue feedback effects illustrates the positive (negative) feedback effect of job creation (wages) on the tax-base (see Table A.4 below).

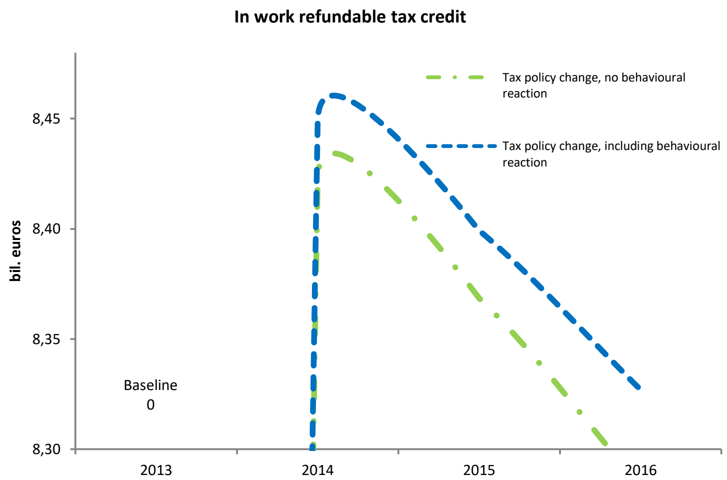
**Table A.4. Decomposing the revenue feedback effects of tax reform in Italy and Poland (% changes relative to static estimates)**

| Years | 3 ys | 5 ys |
|---|---|---|
| **Emloyee tax-cut, IT** | 6.9 | 9.1 |
| ***- effect from employment*** | *12.4* | *13.3* |
| ***- effect from wages*** | *-5.5* | *-4.2* |
| **Emloyee tax-cut, PL** | 5.6 | 7.8 |
| ***- effect from employment*** | *11.6* | *12.8* |
| ***- effect from wages*** | *-6.0* | *-5.0* |

Note: Positive percentage change indicates that the estimated revenue loss is less when the macroeconomic effects are taken into account while negative percentage change indicates higher revenue loss compared to the static estimate.

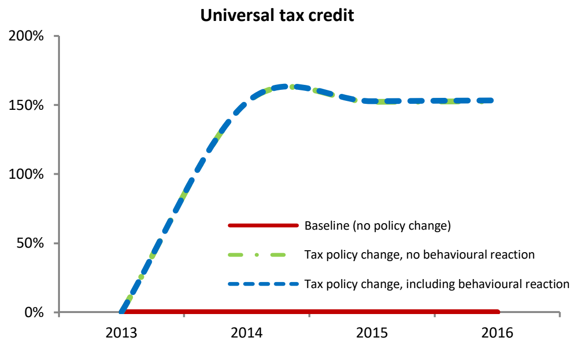
Figures A.1 and A.2 show budgetary effects for the particular components of the personal income tax system that are affected by the reforms.[45]

**Figure A.1. In work refundable tax credit impact in EUROMOD incorporating macro feedback on prices, wages and employment – Italy**




[45] Note that the numbers related with the Italian in-work tax credit are presented in absolute terms because in the baseline pre-reform scenario this tax credit did not exist as a component of the personal income tax system.

**Figure A.2. Universal tax credit impact in EUROMOD incorporating macro feedback on prices, wages and employment – Poland**

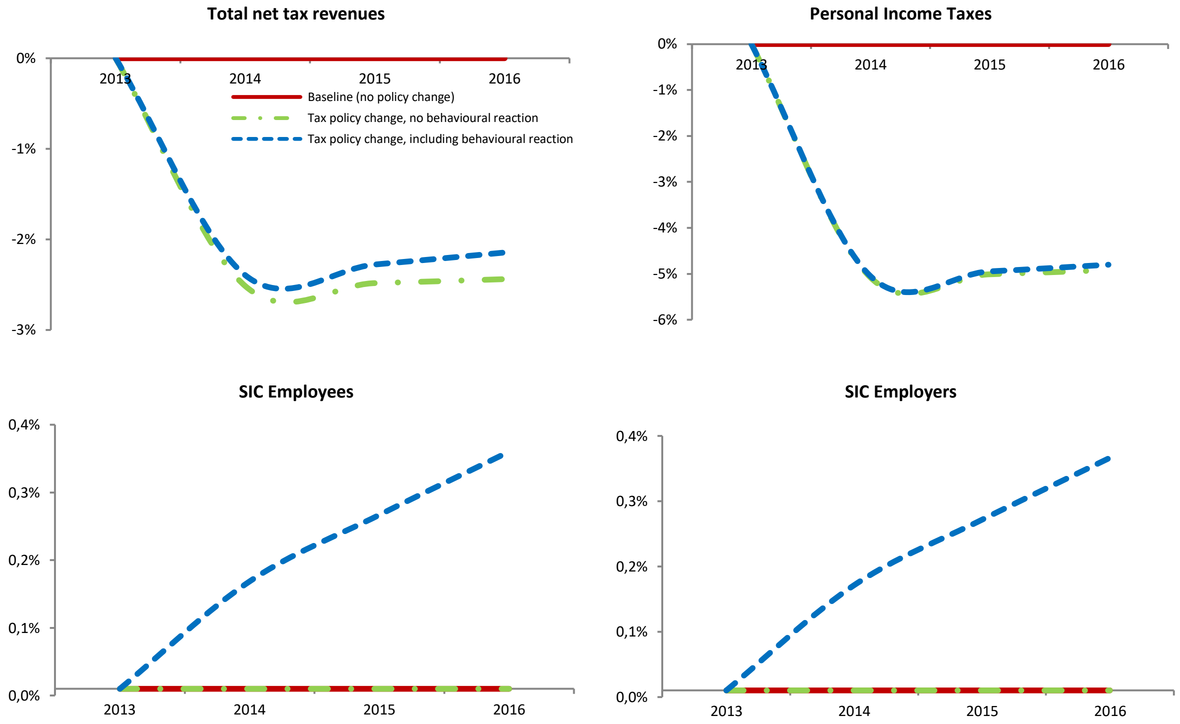



From Figure A.1, we observe that the change in expenditures for the Italian in-work refundable tax credit is higher in the scenario including second-round effects. This results from the increase in employment after the reform due to the positive reaction of labor supply.[46] More people take advantage of the tax credit and expenditures increase when behavioral adjustments are taken into account. Figure A.2 indicates that in the Polish case the positive labor supply effect does not change the direct costs of the universal tax credit.

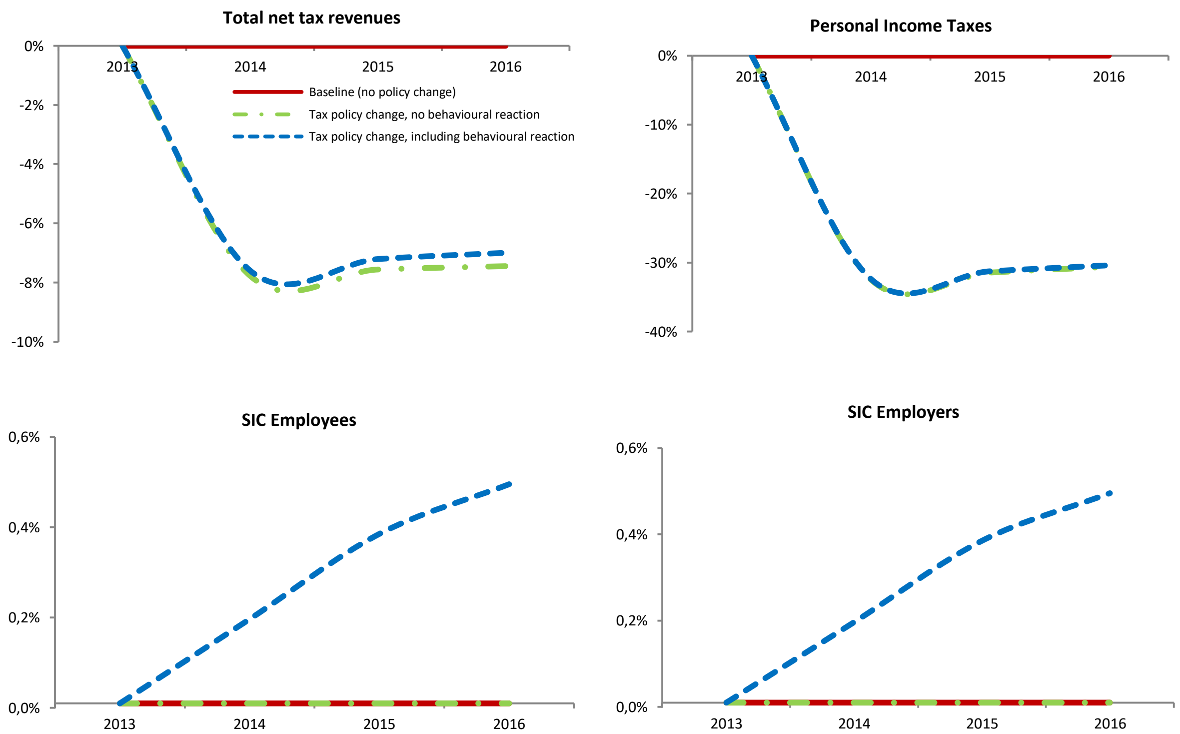
Figures A.3 and A.4 present the impact of the Italian and Polish reforms on the aggregated tax revenues. These figures suggest modest self-financing effects of the reforms, i.e. total tax revenues recover faster in the scenario including behavioral reactions, driven by higher revenues from personal income taxes and social insurance contributions.

[46] Notice that the positive macroeconomic trajectories for employment derived from QUEST are introduced in EUROMOD as changes in the weights of employed and unemployed in the micro-data used in the microsimulation model.

## Figure A.3. Impact of the refundable tax credit reform on aggregate tax revenues – Italy




## Figure A.4. Impact of the universal tax credit reform on aggregate tax revenues – Poland



Additional results for the Italian and Polish reforms are shown in Appendix F. Graph F.1 suggests that taxpayers in the $2^{nd}$-$6^{th}$ decile benefit most from the introduction of the in-work tax credit. In Poland, the effect is more progressive with taxpayers in the bottom half of the distribution benefiting most as shown in Graph F.2.

## Appendix B. The discrete choice labor supply model

We follow standard literature and especially Bargain et al. (2014) in setting up the labor supply model by choosing a flexible discrete choice household labor supply model.[47] In our baseline, we specify consumption-leisure preferences using a quadratic utility function with fixed costs.[48] The deterministic part of utility of a couple $i$ at each discrete choice $j = 1, \dots, J$ can be written as:

$$\begin{aligned} U_{ij} &= \alpha_{ci} C_{ij} + \alpha_{cc} C_{ij}^2 + \alpha_{h_f i} H_{ij}^f + \alpha_{h_m i} H_{ij}^m + \alpha_{h_{ff}} (H_{ij}^f)^2 + \alpha_{h_{mm}} (H_{ij}^m)^2 \\ &\quad + \alpha_{ch_f} C_{ij} H_{ij}^f + \alpha_{ch_m} C_{ij} H_{ij}^m + \alpha_{h_m h_f} H_{ij}^f H_{ij}^m - \eta_j^f \cdot 1(H_{ij}^f > 0) - \eta_j^m \cdot 1(H_{ij}^m > 0) \end{aligned}$$

(B.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:

$$\begin{aligned} \alpha_{ci} &= \alpha_c^0 + Z_i^c \alpha_c + u_i \\ \alpha_{h_f i} &= \alpha_{h_f}^0 + Z_i^f \alpha_{h_f} \\ \alpha_{h_m i} &= \alpha_{h_m}^0 + Z_i^m \alpha_{h_m}, \end{aligned} \qquad \text{(B.2)}$$

i.e. they vary linearly with observable taste-shifters $Z_i$ (including polynomial form of age, presence of children or dependent elderly persons and dummies for education). The term $\alpha_{ci}$ can incorporate unobserved heterogeneity, in the form of a normally-distributed error term

[47] 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 Moffitt (1998).

[48] Other common specifications include Box-Cox or translog utility. However, the choice of the functional form is not a significant driver of labor supply elasticities (Löffler, Peichl, and Siegloch 2014).

$u_i$, for the model to allow random taste variation and unrestricted substitution patterns between alternatives.[49] We include fixed costs of work into the model that help explain that there are very few observations with a small positive number of hours worked. These costs, denoted by $\eta_j^k$ for $k = f, m$, are non-zero for positive hours choices.[50] In general, the approach is flexible and allows imposing few constraints.[51] 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.[52] For each labor supply choice $j$, disposable income is calculated as a function

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

of female and male earnings, $w_i^f H_{ij}^f, w_i^m H_{ij}^m$, non-labor 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

[49] 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). Moreover, Haan (2006) shows that the IIA assumption typically does not matter for deriving labor supply elasticities in discrete choice models.

[50] Introducing fixed costs of work, estimated as model parameters as in Bargain et al. (2014), Callan et al. (2009) or Blundell et al. (2000), improves the fit of the model.

[51] See Bargain et al. (2014) and van Soest (1995).

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

elasticities we estimate are hence Marshallian elasticities.[53] 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 (B.1.3) using the tax-benefit calculator EUROMOD. Disposable income needs to be calculated at the discrete set of choices, that is, only certain points on the budget curve have to be evaluated. We obtain wage rates for individuals by dividing earnings by working hours in the choice category.[54] As our sample includes individuals that are not observed to be working, we estimate a Heckman selection model for wages and use predicted wages for all observations[55]. We assume that the hourly wage rate does not depend on the number of hours supplied in the labor market. As the model is stochastic in nature, the full specification of the labor supply model is obtained after including i.i.d. error terms $\epsilon_{ij}$ for each choice $j = 1, \ldots, J$. That is, total utility at each alternative is

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

with the observable part of utility $U_{ij}$ being defined as above in (B.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)

[53] Hicksian elasticities can be obtained by additionally estimating income elasticities and using the Slutsky decomposition.

[54] We use hours normalized through rounding to the nearest hours category instead of actual hours to reduce division bias, as in Bargain et al. (2014).

[55] Using predicted wages for all observations further reduces selection bias (see Bargain et al. 2014). It is common practice to first estimate wage rates and then use them in a labor supply estimation, (see Creedy and Kalb 2005; Creedy and Kalb 2006; Löffler et al. 2014).

probability for each household $i$ of choosing a given alternative $j$ has the explicit analytical solution below:[56]

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

***Labor supply effects from the augmented microsimulation model***

We report labor supply responses to the three reforms evaluated. In Table B.1. we present the labor supply responses to the employees' social insurance reform in Belgium in terms of aggregate weekly full time equivalent jobs[57], separately for the intensive and extensive margin.[58] The predictions for the baseline and the employees' social insurance contribution reform are based on the estimated labor supply model described above.[59] We find particular large effects on the extensive margin. This is in line with the literature and also confirmed by our findings of larger extensive than intensive margin elasticities.[60] Recall that we have considered two reforms in the Belgian case: a decrease in social insurance contributions on the employee and the employer side. The labor supply effects reported in Table B.1 for Belgium are only the effects from the decrease in the social insurance contributions paid by the employee, as the decrease on the employer contributions does not affect household

[56] See McFadden (1974) or Creedy and Kalb (2006).

[57] We calculate full time equivalents by dividing aggregate expected weekly working hours by 40.

[58] The intensive margin is the hours effect on those observed to be working, while the extensive effect is the change in hours for those observed to be not working (see Bargain et al. 2014). The total effect is the average of intensive and extensive margin effects, weighted by their respective share of the population.

[59] We only report results on aggregate hours. Additional detailed regression results of the discrete choice model are available on request.

[60] See Chetty (2012) and Chetty et al (2012).

disposable incomes in the microeconometric setup.[61] The reform leads to an increase in aggregate labor supply of 1.24%.

**Table B.1: Employment effects from the Belgian employees reform**

| **Changes in full time equivalents** | | | | |
|---|---|---|---|---|
| | | **Total** | **Intensive** | **Extensive** |
| **30% Reduction on the SICee tax rate** | baseline | 2,920,764 | 2,735,788 | 184,976 |
| | reform | 2,957,053 | 2,768,090 | 188,963 |
| | % change | 1.242 | 1.181 | 2.156 |

In the same way, Table B.2. below shows results from the discrete choice labor supply model on aggregate working hours for the Italian and Polish reforms. The in-work tax credit in Italy increases hours at the extensive margin, as it makes working more attractive relative to not working. However, for those already in work, the tax credit has an income effect on consumption and leisure, so that it reduces working hours. The latter effect is larger, so that the overall change in aggregate hours is negative. For Poland, we find a positive effect on intensive and extensive margin hours because of the nature of the reform. Again, the increase in participation is larger, as the extensive margin is in general more sensitive to changes in incentives. Overall, we find that total labor supply increases by 1% in Poland.

**Table B.2: Employment effects from the reforms in Italy and Poland**

[61] In principle, second-round effects can occur if the decrease in employer SIC is not fully born by employers, but passed on to the workers. In our modelling framework, second-round effects are considered in QUEST.

| Changes in full time equivalents | | | | |
|---|---|---|---|---|
| | | **total** | **intensive** | **extensive** |
| **Introduction in-work tax credit in Italy** | base | 10,607,323 | 9,879,253 | 728,070 |
| | reform | 10,570,537 | 9,841,150 | 729,387 |
| | % change | -0.347 | -0.386 | 0.181 |
| **Increase in universal tax credit in Poland** | base | 7,124,988 | 6,520,299 | 604,689 |
| | reform | 7,205,513 | 6,589,168 | 616,344 |
| | % change | 1.13 | 1.056 | 1.928 |

***Additional selected results***

Tables B.3 to B.5 present the estimated parameters of equation (B.1) for the three countries analysed, for different sample groups: couples, single women and single man.

## Table B.3: Couples

| | BE<br>choice | IT<br>choice | PL<br>choice |
|---|---|---|---|
| Cx | | | |
| age_m | -0.000209 | -0.0000234 | -0.00168$^{*}$ |
| | (-0.57) | (-0.09) | (-2.29) |
| age2_m | 0.000138 | -0.0000835 | 0.00195$^{*}$ |
| | (0.33) | (-0.28) | (2.28) |
| age_f | 0.000488 | 0.0000618 | 0.000483 |
| | (1.43) | (0.21) | (0.81) |
| age2_f | -0.000545 | -0.000224 | -0.000688 |
| | (-1.32) | (-0.68) | (-0.97) |
| pchild | 0.000597 | 0.000312 | -0.000167 |
| | (1.06) | (0.85) | (-0.17) |
| pold | 0.00459 | -0.000184 | -0.00185 |
| | (0.73) | (-0.08) | (-0.40) |
| ed_ter_m | 0.00125 | 0.000927$^{*}$ | 0.0128$^{***}$ |
| | (1.80) | (1.96) | (11.42) |
| ed_ter_f | 0.00130 | 0.00157$^{**}$ | 0.00567$^{***}$ |
| | (1.77) | (3.17) | (4.61) |
| ed_up_m | 0.00107 | 0.000545 | 0.0167$^{***}$ |
| | (1.94) | (1.88) | (16.35) |
| ed_up_f | 0.000664 | 0.00129$^{***}$ | 0.00773$^{***}$ |
| | (1.11) | (4.04) | (7.00) |
| _cons | 0.0150 | 0.00869 | 0.0363 |
| | (1.11) | (1.00) | (1.96) |
| CxC | | | |
| _cons | -0.00000289 | -3.30e-08 | -0.0000114 |
| | (-1.24) | (-0.05) | (-1.08) |
| CxL1 | | | |
| _cons | -0.0000253 | -0.00000659 | -0.0000463 |
| | (-0.54) | (-0.49) | (-0.72) |
| CxL2 | | | |
| _cons | -0.0000173 | 0.000000272 | 0.0000490 |
| | (-0.32) | (0.03) | (0.64) |
| L1x | | | |
| age_f | -0.000650 | 0.00642 | -0.00561$^{**}$ |
| | (-0.16) | (1.85) | (-2.60) |
| age2_f | 0.00333 | -0.0108$^{**}$ | 0.00667$^{*}$ |
| | (0.65) | (-2.64) | (2.53) |
| pchild02 | 0.0223$^{**}$ | 0.0103$^{*}$ | 0.00776 |
| | (3.16) | (2.04) | (1.71) |
| pchild36 | 0.0171$^{**}$ | -0.00150 | 0.00860$^{*}$ |
| | (2.74) | (-0.35) | (2.26) |
| pchild712 | 0.0143$^{*}$ | 0.00727 | 0.00439 |
| | (2.32) | (1.96) | (1.27) |
| pchild1317 | 0.00785 | 0.00129 | 0.00370 |
| | (1.19) | (0.32) | (1.04) |
| pold | 0.174$^{*}$ | 0.107$^{***}$ | 0.104$^{***}$ |
| | (2.43) | (4.09) | (7.04) |
| _cons | 0.427$^{***}$ | 0.412$^{***}$ | 0.507$^{***}$ |

| | | | |
|---|---|---|---|
| | (3.86) | (5.33) | (10.06) |
| L1xL1 | | | |
| _cons | -0.00349*** | -0.00406*** | -0.00308*** |
| | (-12.34) | (-25.41) | (-23.09) |
| L2x | | | |
| age_m | 0.00293 | -0.00323 | -0.00191 |
| | (0.62) | (-0.97) | (-0.70) |
| age2_m | -0.00219 | 0.00192 | 0.00235 |
| | (-0.39) | (0.51) | (0.73) |
| pchild02 | 0.00641 | -0.00470 | -0.00350 |
| | (0.78) | (-0.78) | (-0.72) |
| pchild36 | 0.0104 | 0.00305 | -0.00829* |
| | (1.44) | (0.60) | (-2.02) |
| pchild712 | 0.00610 | 0.000826 | -0.00307 |
| | (0.84) | (0.19) | (-0.86) |
| pchild1317 | -0.00839 | 0.00182 | -0.00517 |
| | (-1.08) | (0.39) | (-1.44) |
| pold | 0.149 | 0.0609** | 0.0382* |
| | (1.87) | (2.74) | (2.34) |
| _cons | 0.287* | 0.445*** | 0.297*** |
| | (2.26) | (6.10) | (4.75) |
| L2xL2 | | | |
| _cons | -0.00279*** | -0.00311*** | -0.00206*** |
| | (-8.18) | (-33.58) | (-13.20) |
| L1xL2 | | | |
| _cons | 0.000690 | 0.0000994 | -0.000181 |
| | (1.23) | (0.60) | (-0.71) |
| IND | | | |
| d_parttime_m | -2.460*** | -2.748*** | -1.786*** |
| | (-16.68) | (-28.31) | (-23.88) |
| d_parttime_f | -0.955*** | -1.697*** | -2.063*** |
| | (-10.68) | (-23.54) | (-29.55) |
| *N* | 21664 | 46288 | 45984 |

*t* statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

## Table 4: Single Women

| | BE choice | IT choice | PL choice |
|---|---|---|---|
| Cx | | | |
| age_f | -0.000798 | -0.000702 | -0.00346 |
| | (-0.84) | (-0.55) | (-1.40) |
| age2_f | 0.00107 | 0.000710 | 0.00409 |
| | (0.95) | (0.50) | (1.42) |
| nchild | -0.00201 | -0.00158 | -0.00273 |
| | (-1.79) | (-1.32) | (-1.18) |
| nold | -0.00448** | -0.00647*** | -0.0182*** |
| | (-3.18) | (-9.56) | (-5.59) |
| _cons | 0.0143 | 0.0330 | 0.0675 |
| | (0.70) | (1.18) | (1.28) |
| CxC | | | |
| _cons | 0.00000290 | -0.000000821 | 0.0000481* |
| | (1.17) | (-1.46) | (2.37) |
| CxL1 | | | |
| _cons | 0.0000758 | -0.0000133 | 0.000411*** |
| | (1.39) | (-1.40) | (3.31) |
| L1x | | | |
| age_f | -0.00989 | -0.00423 | -0.00815 |
| | (-1.29) | (-0.35) | (-1.28) |
| age2_f | 0.0134 | 0.00286 | 0.00907 |
| | (1.41) | (0.21) | (1.20) |
| nchild | -0.0157 | -0.0206 | -0.00924 |
| | (-1.52) | (-1.71) | (-1.39) |
| pold | -0.00893 | -0.00326 | -0.0151 |
| | (-0.61) | (-0.42) | (-1.50) |
| ed_ter_f | -0.0420*** | -0.0154* | -0.0558*** |
| | (-4.57) | (-1.96) | (-5.77) |
| ed_up_f | -0.0209*** | -0.0232*** | -0.0706*** |
| | (-3.41) | (-5.23) | (-9.83) |
| _cons | 0.487** | 0.641* | 0.466*** |
| | (3.03) | (2.45) | (3.54) |
| L1xL1 | | | |
| _cons | -0.00257*** | -0.00338*** | -0.00192*** |
| | (-7.32) | (-24.85) | (-8.51) |
| IND | | | |
| d_parttime_f | -1.213*** | -2.253*** | -2.157*** |
| | (-10.85) | (-26.09) | (-19.27) |
| *N* | 3036 | 8028 | 4776 |

*t* statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

## Table 5. Single Men

| | BE<br>choice | IT<br>choice | PL<br>choice |
|---|---|---|---|
| Cx | | | |
| age_m | -0.000332 | 0.0000636 | -0.00544* |
| | (-0.36) | (0.07) | (-2.24) |
| age2_m | 0.000493 | -0.000399 | 0.00715* |
| | (0.46) | (-0.38) | (2.52) |
| nchild | -0.000292 | 0.00273** | 0.00471** |
| | (-0.54) | (2.71) | (2.64) |
| nold | -0.00419*** | -0.00729*** | -0.0139*** |
| | (-3.49) | (-11.83) | (-6.58) |
| _cons | -0.00135 | 0.0196 | 0.113* |
| | (-0.07) | (0.96) | (2.07) |
| CxC | | | |
| _cons | 0.00000297 | -0.000000174 | 0.0000101 |
| | (0.91) | (-0.12) | (0.44) |
| CxL1 | | | |
| _cons | 0.000212** | -0.00000340 | 0.000294 |
| | (3.02) | (-0.14) | (1.85) |
| L1x | | | |
| age_m | -0.00272 | 0.00600 | -0.0113 |
| | (-0.36) | (0.85) | (-1.67) |
| age2_m | 0.00483 | -0.00869 | 0.0154 |
| | (0.53) | (-1.05) | (1.93) |
| pchild | -0.0395** | 0.0279* | 0.00299 |
| | (-3.13) | (2.04) | (0.30) |
| pold | -0.0520*** | -0.0199** | -0.0338*** |
| | (-3.42) | (-2.88) | (-4.05) |
| ed_ter_m | -0.0291** | -0.0131 | -0.0590*** |
| | (-2.77) | (-1.41) | (-5.30) |
| ed_up_m | -0.0268*** | -0.00260 | -0.0662*** |
| | (-4.09) | (-0.56) | (-6.22) |
| _cons | 0.0597 | 0.279 | 0.403** |
| | (0.38) | (1.90) | (2.78) |
| L1xL1 | | | |
| _cons | -0.000403 | -0.00255*** | -0.00102*** |
| | (-0.98) | (-17.53) | (-3.34) |
| IND | | | |
| d_parttime_m | -2.760*** | -2.645*** | -1.704*** |
| | (-12.85) | (-23.83) | (-13.29) |
| *N* | 2212 | 6616 | 3260 |

*t* statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

## Appendix C. The QUEST model

The household sector consists of a continuum of households $h \in [0,1]$. A share $(1-\varepsilon)$ of these households is not liquidity constrained and indexed by $i \in [0, 1-\varepsilon]$. They have access to financial markets where they can buy and sell domestic assets (government bonds), accumulate physical capital which they rent out to the final goods sector. The remaining share $\varepsilon$ of households is liquidity constrained and indexed by $k \in (1-\varepsilon,1]$. These households cannot trade in financial and physical assets and consume their disposable income each period. We identify the liquidity constrained households as low-skilled and the non-liquidity constrained households as medium- and high-skilled. For each skill group we assume that households (liquidity and non-liquidity constrained) supply differentiated labor services to unions which act as wage setters in monopolistically competitive labor 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 labor 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 ($i_t$, $i_{K,t}$). Hence, non-liquidity constrained households face the following Lagrangian

$$\max_{\left\{\begin{matrix} C_{i,t}, L_{i,s,t}, B_{i,t} \\ J_{i,t}, K_{i,t} \end{matrix}\right\}_{t=0}^{\infty}} V_{i,0} = E_0 \sum_{t=0}^{\infty} \beta^t \left( U(C_{i,t}) + \sum_z V(1 - L_{i,z,t}) \right)$$

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

$$- E_0 \sum_{t=0}^{\infty} \lambda_{i,t} \xi_{i,t} \beta^t \left(K_{i,t} - J_{i,t} - (1-\delta_K) K_{i,t-1}\right) \tag{C.1}$$

where $z$ is the index for the corresponding medium ($M$) and high-skilled ($H$) labor 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 ($1\text{-}L_{i,z,t}$). We assume log-utility for consumption and allow for habit persistence in consumption (with parameter $habc$) as follows:

$$U(C_{i,t}) = (1 - habc)\log\left(C_{i,t} - habc C_{t-1}\right) \tag{C.2}$$

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

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

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

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

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

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

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

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

$$\frac{\partial V_0}{\partial K_{i,t}} => E_t\left(\lambda_{i.t+1}\frac{\beta P_{I,t}}{P_{t+1}}\left((1-t_K)(i_{K,t}-rp_K)+t_K\delta_K\right)\right)-\lambda_{i,t}\xi_{i,t}+E_t\left(\lambda_{i,t+1}\xi_{i,t+1}\beta(1-\delta_K)\right)=0 \qquad \text{(C.5c)}$$

$$\frac{\partial V_0}{\partial J_{i,t}} => -\left(1+\gamma_K\left(\frac{J_{i,t}}{K_{i,t-1}}\right)+\gamma_I\Delta J_{i,t}\right)+E_t\left(\frac{1}{1+i_t}\frac{P_{I,t+1}}{P_{I,t}}\gamma_I\Delta J_{i,t+1}\right)+\xi_{i,t}\frac{P_t}{P_{I,t}}=0 \qquad \text{(C.5d)}$$

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:

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

Within each skill group a variety of labor 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 wage[62]. 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 labor taxes, consumption taxes and unemployment benefits, which act as a subsidy to leisure. Thus, the wage equation is given as

$$\frac{V_{1-L,h,s,t}}{U_{C,h,s,t}}\frac{1}{\eta_{s,t}}=\frac{W_{s,t}(1-t_{w,s,t}-b)}{P_{C,t}(1+t_{C,t})}\text{ for } s\in\{L,M,H\}\text{,}^{63} \tag{C.7}$$

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

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

Hence, aggregate consumption and employment are given by

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

[63] In order to find the wage equation, consider the problem of representative household *i*, of a subgroup *s* of the population given by (C.1). Then, the first order conditions with respect to labor ($L_{i,z,t}$) 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 labor:

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

We can recognize in the above condition equation (C.7), which determines the equilibrium wage. In fact, and as mentioned before, since within each sub-group *s* the labor 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.

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

and

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

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

$$Y_{j,t} = \left(L_{j,t} - FC_{j,L}\right)^{\alpha}\left(u_{j,t}K_{j,t}\right)^{1-\alpha} - FC_{j,Y} \quad \text{(C.11)}$$

with

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

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

$$PR_{j,t} = P_{j,t}Y_{j,t} - \sum_{s}\left(1 + t_{er,s,t}\right)W_{j,s,t}L_{j,s,t} - i_t^{K}P_{j,I,t}K_{j,t} - (\Gamma^{P}(P_{j,t}) + \Gamma^{L}(L_{j,L,t}, L_{j,M,t}, L_{j,H,t}) + \Gamma^{u}(u_{j,t}))$$
(C.13)

where $i^{K}$ denotes the rental rate of capital $t_{er,s,t}$ stands for the tax rate on labor 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):

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

where $\eta_{j,t}$ is the inverse price mark-up factor which is defined as a function of the elasticity of substitution ($\sigma^d$), changes in inflation ($\pi$) and the mark-up shock ($\varepsilon_{mkp}$)[64]. Skill-specific labor demand can be obtained from the first order condition with respect to labor:

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

where the marginal product of labor, 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:

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

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

[64] 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, $\eta_{j,t} = \eta = 1 - 1/\sigma^d - \gamma_P \left(\beta\left(sfpE_t\pi_{t+1} + \left(1 - sfp\right)\pi_{t-1}\right) - \pi_t\right) + \varepsilon_{mkp}$ , where $\gamma_P$ $\gamma_P$ is the corresponding adjustment cost parameter.

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

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

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

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

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

Government debt ( $B_t$ ) evolves according to

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

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

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

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

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

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

The central bank has a constant inflation target $(\pi_{TAR})$ and it adjusts interest rates whenever actual consumer price inflation $(\pi_{C,t})$ deviates from the target and it also responds to the output gap $(\breve{y}_t)$ via the corresponding $\gamma_{\inf}$ and $\gamma_{ygap}$ coefficients. There is also some inertia in nominal interest rate setting over the equilibrium real interest rate $r_{EQ}$ determined by $\gamma_{ilag}$. Output gap is defined as deviation of capital and labor utilisation from their long run trends. Note that in our multi-country setting, members of the euro area do not have independent monetary policy. In this way, we assume that the European Central Bank sets interest rate by taking into account the euro area wide aggregate inflation and output gap changes in its Taylor-rule.

Finally, concerning the trading sector 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:

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

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

## Appendix D. Labor market modelling: labor supply function, labor supply elasticities and tax incidence

### *Labor supply function*

The labor market plays the key role in linking the micro and macro models in our analysis. Here we follow the analysis of Magnani and Mercenier (2009),[65] which to some extent can be seen as a simplified version of linking the micro and macro models we use in our dynamic scoring analysis, in order to ensure consistency between our discrete choice labor supply model and the labor supply modelling in QUEST. Our aim is to compare the optimal labor supply produced in the micro and macroeconomic settings, in terms of how the decision is modelled. We also derive the labor supply elasticities for both the micro and macro models. Finally, we describe in detail how tax incidence works in the labor market modelled in QUEST.

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

$$V_{ij} = U_{ij}(C_{ij}, H_{ij}, .) + \epsilon_{ij} \qquad \text{(D.1)}$$

[65] These authors describe an exact aggregation of the results of a discrete choice model and a representative agent macroeconomic model, with constant elasticity of substitution/transformation utility function. They show that in order to ensure consistency between the micro and macro models , whereby both models can be characterized by similar equilibrium/optimality conditions, the calibration of the macro model labor parameters (labor elasticities and labor shares, fundamentally) must be tied to the statistical parameters of the probability distribution of the micro data. In Magnani and Mercenier (2009), like in our case, the labor 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 multinominal 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).

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

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

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

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

Function *H* satisfies all the necessary conditions to ensure that *F* is a cumulative distribution function. Following Magnani and Mercenier (2009), we assume that the following functional form for $H^f$ is:

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

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

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

(D.5)

and *F* assumes the following form:

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

(D.6)

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

$$Prob_{ij} = \mu \frac{\partial lnH(e^{U_{i0}}, e^{U_{i20}}, e^{U_{i40}}, e^{U_{i60}})}{\partial U_{ij}} \qquad \text{(D.7)}$$

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

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

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

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

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

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

(D.10)

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

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

Note that equation (D.11) is a simplified analytical expression of the labor 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 labor market, is equal to:

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

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

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

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

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

We turn now to the macroeconomic setting. In QUEST the labor market is populated by workers, and firms. The QUEST model therefore takes into account both the supply and demand of labor. Focusing only on the partial equilibrium, this translates into a system of equations that allows finding the equilibrium wage and working hours. In this way, and abstracting from other general equilibrium effects, the referred system is presented below:[66]

$$\begin{cases} \dfrac{V_{1-L,h,s,t}}{U_{C,h,s,t}} \dfrac{1}{\eta_{s,t}} = \dfrac{W_{s,t}(1-t_{w,s,t}-b)}{P_{C,t}(1+t_{C,t})} \\ P_{j,t} \dfrac{\partial Y_{j,t}}{\partial L_{j,s,t}} \eta_{j,t} = \left(1+t_{er,s,t}\right) W_{s,t} + \dfrac{\partial \Gamma^{L}(L_{j,L,t}, L_{j,M,t}, L_{j,H,t})}{\partial L_{j,s,t}^{j}} \end{cases} <=>$$

$$<=> \begin{cases} \dfrac{V_{1-L,h,s,t}}{U_{C,h,s,t}} \dfrac{1}{\eta_{s,t}} = \dfrac{W_{s,t}(1-t_{w,s,t}-b)}{P_{C,t}(1+t_{C,t})} \\ P_{j,t} \dfrac{\partial Y_{j,t}}{\partial L_{j,s,t}} \eta_{j,t} = \left(1+t_{er,s,t}\right) W_{s,t} + \dfrac{\partial \Gamma^{L}(L_{j,L,t}, L_{j,M,t}, L_{j,H,t})}{\partial L_{j,s,t}^{j}} \end{cases} \quad for\ s \epsilon \{H, M, L\}$$

(D.15)

where the first equation of the system[67] results from the combination between the first order conditions with respect to consumption and labor – i.e. is the inter-temporal and the intra-temporal optimality conditions, respectively – resulting from the household problem, and the second equation of the system results from maximizing firms profits with respect to labor.[68] From the system in (D.15), we obtain the partial equilibrium pair of hours worked and wage rate $\left(L_{s,t}^{*}, W_{s,t}^{*}\right), s \in \{H, M, L\}$ . Notice that the decisions modelled in the supply side of the labor 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 labor supply and labor demand functions, i.e. QUEST take into account the demand of labor. This demand effect, which is basically constrained by the labor demand

[66] 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.
[67] This corresponds to equation C.7 in Appendix C.
[68] This corresponds to equation C.15 in Appendix C.

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.[69] Considering the following functional form of the household utility function in QUEST, given by expressions (D.16) and (D.17) below [70], for skill group $s \in \{H, M, L\}$,

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

and,

$$U_{C,h,s,t} = \frac{1-habc}{C_{i,t}-habcC_{t-1}}, s \in \{H, M, L\} \tag{D.17}$$

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

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

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

(D.18)

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

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

[69] Notice that not considering labor 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.

[70] These correspond to expressions C.2 and C.3 in Appendix C.

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

$$L_{s,t} = N\big(1 - g(X_t;\ \mathrm{T}_t;\ \Omega)\big) \tag{D.20}$$

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

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

$$L_{j\neq 0} = N\left(1 - F\big(U_{ij};\ \Theta\big)\right) \tag{D.21}$$

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

$$UNEMPL = 1 - NPART_{L,t} - L_{L,t} \tag{D.22}$$

where *NPART* is the non-participation rate. In QUEST households only decide on the amount of hours supplied in the labor market, but they do not choose between unemployment and non-participation, explicitly. The non-participation rate is calibrated as the proportion of inactive people 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 labor 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 labor market, i.e. equation (D.12) in the discrete choice model.

***Labor market elasticities***

In our dynamic scoring exercise, labor market elasticities are crucial to understand the effects of a particular tax reforms on the households' disposable income, in particular, and on the economy as a whole. More specifically, the labor supply elasticity is a good measure of the work effort incentives, and, in this way, crucial to understand the effects of the tax reforms implemented on the workers behavior. Moreover, the analysis of the elasticities in both models is important to see whether we can calibrate QUEST with the elasticities obtained from our microeconometric model, so that a greater consistency can be achieved in linking the two models. In what follows we derive analytically the labor supply elasticities in the micro and macro settings, and see how these relate to each other. Recall that in what concerns QUEST, the parameter that we are interested in calibrating is the parameter $\kappa$.[71] This parameter relates the Frisch elasticity to the inter-temporal elasticity of substitution, as we will see in what follows.

[71] Please check the functional form given in expression (C.3) in Appendix C.

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

$$\varepsilon_{L,W}^{F} = \frac{\partial L_{s,t} / L_{s,t}}{\partial W_{s,t} / W_{s,t}} <=> \varepsilon_{L,W}^{F} = \frac{1}{\kappa}\left(\frac{N - L_{s,t}}{L_{s,t}}\right) \qquad \text{(D.23)}$$

The elasticity in (D.23) suggests a positive relationship between wages and labor supply, depending on the level of labor 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 labor supply evolves over time, given temporary changes in the wages path. This is known as the inter-temporal elasticity of substitution, $\varepsilon^{IES}$. In this way, this elasticity measures the relation between the changes in the ratio of labor supplied tomorrow and today, and the ratio of wages paid tomorrow and today. In order to derive this elasticity, we need to find the inter-temporal labor supply function, where we can relate the path of labor supply with the path of wages. For that consider the QUEST model described in Appendix D. Consider also the labor supply function in equation (D.19) of this appendix section. In order to derive the inter-temporal labor supply function, one needs to combine the intra-temporal optimality condition with the inter-temporal one (the Euler equation). Let us consider first the intra-temporal optimality condition given by equation (C.7) and write it one period ahead, as follows:

$$\frac{V_{1-L,h,s,t+1}}{U_{C,h,s,t+1}} \frac{1}{\eta_{s,t+1}} = \frac{W_{s,t+1}\left(1 - t_{W,s,t+1} - b\right)}{P_{c,t+1}\left(1 + t_{c,t+1}\right)} \qquad \text{(D.24)}$$

From this condition we can obtain the labor supply function of the $N$ households in group $s$, one period ahead:

$$L_{s,t+1} = N\left(1 - \left[\frac{\omega_s}{\eta_{s,t+1}} \frac{1}{W_{s,t+1}(1-t_{W,s,t+1}-b)} \frac{P_{c,t}(1+t_{c,t+1})}{U_{C,h,s,t+1}}\right]^{1/\kappa}\right) \quad \text{(D.25)}$$

We can now substitute in (D.25) the marginal utility of consumption $U_{C,h,s,t+1}$ by its expression one period ahead, given the functional form in expression (C.2):

$$L_{s,t+1} = N\left(1 - \left[\frac{\omega_s}{\eta_{s,t+1}} \frac{1}{W_{s,t+1}(1-t_{W,s,t+1}-b)} \frac{P_{c,t}(1+t_{c,t+1})}{1-habc}\left(C_{i,t+1} - habcC_t\right)\right]^{1/\kappa}\right) \quad \text{(D.26)}$$

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

$$\lambda_{i,t} = \frac{P_t}{P_{c,t}} \frac{U_{c,i,t}}{1+t_{c,t}} \quad \text{(D.27)}$$

And writing (D.27) one period ahead, we get:

$$\lambda_{i,t+1} = \frac{P_{t+1}}{P_{c,t+1}} \frac{U_{c,i,t+1}}{1+t_{c,t+1}} \quad \text{(D.28)}$$

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

$$\frac{U_{c,i,t}}{P_{c,t}(1+t_{c,t})} \frac{1}{\beta(1+i_t)} = E_t\left[\frac{U_{c,i,t+1}}{P_{c,t+1}(1+t_{c,t+1})}\right] \quad \text{(D.29)}$$

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:

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

(D.30)

The next step is to include the Euler equation derived in equation (D.30) in the labor supply function, equation (D.26) to obtain a relation between the labor supplied tomorrow and consumption today, as follows:

$$L_{s,t+1}=N\left(1-\left[\frac{\omega_s}{\eta_{s,t+1}}\frac{1}{W_{s,t+1}(1-t_{W,s,t+1}-b)}\frac{\beta(1+i_t)P_{c,t}\left(1+t_{c,t}\right)\left(C_{i,t}-habcC_{t-1}\right)}{1-habc}\right]^{1/\kappa}\right) \quad \text{(D.31)}$$

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

$$P_{c,t}\left(1+t_{c,t}\right)\left(C_{i,t}-habcC_{t-1}\right)=\frac{\eta_{s,t}(1-habc)}{\omega_s}W_{s,t}\left(1-t_{W,s,t}-b\right)\left(1-L_{i,s,t}\right)^{\kappa} \quad \text{(D.32)}$$

Substituting the previous result in the labor supply equation given by (D.31), we will obtain finally an expression which includes $L_{s,t+1}, L_{i,s,t}, W_{s,t+1}$and $W_{s,t}$, shown below.

$$L_{s,t+1}=N\left(1-\left[\frac{\eta_{s,t}}{\eta_{s,t+1}}\frac{W_{s,t}(1-t_{W,s,t}-b)}{W_{s,t+1}(1-t_{W,s,t+1}-b)}\beta(1+i_t)\left(1-L_{i,s,t}\right)^{\kappa}\right]^{1/\kappa}\right) \quad \text{(D.33)}$$

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

$$\frac{1-L_{i,s,t+1}}{1-L_{i,s,t}}=\left[\beta(1+i_t)\frac{\eta_{s,t}}{\eta_{s,t+1}}\frac{1-t_{W,s,t}-b}{1-t_{W,s,t+1}-b}\right]^{1/\kappa}\left(\frac{W_{s,t+1}}{W_{s,t}}\right)^{-1/\kappa} \quad \text{(D.34)}$$

Similarly to the Euler equation, equation (D.34) represents the inter-temporal optimality condition for leisure (labor). We can now denote $\frac{1-L_{i,s,t+1}}{1-L_{i,s,t}} = \left(\widehat{1-L_{\iota,s}}\right)$ and $\frac{W_{s,t+1}}{W_{s,t}} = \widehat{W_s}$ and rewrite equation (D.34) as follows:

$$\left(\widehat{1-L_{\iota,s}}\right) = \left[\beta(1+i_t)\frac{\eta_{s,t}}{\eta_{s,t+1}}\frac{1-t_{W,s,t}-b}{1-t_{W,s,t+1}-b}\right]^{1/\kappa}\left(\widehat{W}_s\right)^{-1/\kappa} \quad \text{(D.35)}$$

We can now compute the elasticity of inter-temporal substitution for leisure since the results are very easily extrapolated in terms of labor supply. We apply logarithms to equation (D.35) and then compute the derivative of the $ln\left(\widehat{1-L_{\iota,s}}\right)$ with respect to $ln\left(\widehat{W}\right)_s$. In this way, we obtain the following expression:

$$ln\left(\widehat{1-L_{\iota,s}}\right) = \frac{1}{\kappa}ln\left[\beta(1+i_t)\frac{\eta_{s,t}}{\eta_{s,t+1}}\frac{1-t_{W,s,t}-b}{1-t_{W,s,t+1}-b}\right] - \frac{1}{k}ln\left(\widehat{W_{s,t}}\right) \quad \text{(D.36)}$$

and

$$\frac{dln\left(\widehat{1-L_{\iota,s}}\right)}{dln\left(\widehat{W_{s,t}}\right)} = -\frac{1}{k} <=> \frac{d\left(\widehat{1-L_{\iota,s}}\right)\big/\left(\widehat{1-L_{\iota,s}}\right)}{d\left(\widehat{W_{s,t}}\right)\big/\left(\widehat{W_{s,t}}\right)} = -\frac{1}{k} <=> \varepsilon^{IES}_{1-L_{i,s}} = -\frac{1}{k} \quad \text{(D.37)}$$

As we can observe from expression (D.37), parameter $k$ guides the elasticity of inter-temporal substitution, and the smaller this parameter is, the higher (in absolute terms) is this elasticity, and the more willing is the household to change the path of leisure (or labor), given temporary changes in wages. Moreover, we can see clearly that the relation between the Frisch elasticity and the inter-temporal elasticity of substitution depends on the parameter $k$. In this way, we can establish the following relation between the two elasticities:

$$\varepsilon^F_{L,W} = -\varepsilon^{IES}_{1-L_{i,s}}\left(\frac{N-L_{s,t}}{L_{s,t}}\right) \quad \text{(D.38)}$$

In the nonlinear discrete choice econometric model, labor 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 (D.10) the expected hours supplied by household *i*. Denote by $\widetilde{U}_{ij}$ 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:

$$\widetilde{L_i} = \frac{\sum_{j\in\{0,20,40,60\}} j * e^{\widetilde{U}_{ij}}}{\sum_{s\in\{0,20,40,60\}} e^{\widetilde{U}_{is}}} = \sum_{j\in\{0,20,40,60\}} \widetilde{Prob}_{ij} * j. \qquad \text{(D.39)}$$

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

$$\varepsilon_{L_i,w} = \frac{\partial L_i / L_i}{\partial w_i / w_i} = \frac{(\tilde{L}_i - L_i) / L_i}{(\widetilde{w}_i - w_i) / w_i} \qquad \text{(D.40)}$$

The econometric framework from which the elasticity is calculated is static in nature. We rely on cross sectional data and do not observe households at multiple points in time. Moreover, the econometric model does not encompass saving decisions. The elasticities we estimate are uncompensated – Marshallian – elasticities. The Marshallian elasticity is related by the Slutsky equation to the compensated – Hicksian Hicksian) income elasticity. In studies focusing on the deadweight loss of taxation or steady state responses to tax changes, the Hicksian elasticity is the crucial parameter. However, these studies usually assume that tax revenue is redistributed as a lump sum payment to households, shutting off the income effect. As we do not make this assumption, tax changes have income effects, and the Marshallian elasticity is the appropriate parameter to use. In principle, we could obtain the Hicksian elasticity as the residual of the Marshallian elasticity (the one we estimate) and the income effect (which we could calculate by simulating a marginal increase in non-labor income) but since we focus on a situation with income effects, we refrain from doing so.[72]

Comparing the elasticities defined both in the micro and in macroeconomic settings, we conclude that, in fact, the elasticity defined in (D.40) is the micro-equivalent to the elasticity derived in (D.23), i.e. the Frisch elasticity, in the macro setting. This is a very important result, because we can greatly improve the consistency between the two models by calibrating the Frisch elasticity with the labor supply elasticities estimated from the discrete choice model. In this way, parameter $\kappa$ in QUEST can be obtained from the following expression:

$$\kappa = \frac{1}{\varepsilon^{F}_{L,W}} \frac{N - L_{s,t}}{L_{s,t}} \qquad \text{(D.41)}$$

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

[72] 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.

***Tax incidence in QUEST***

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

$$NW = (1 - t_w)W \qquad \text{(D.42)}$$

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

$$TC = (1 + t_{er})W \qquad \text{(D.43)}$$

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

$$\varepsilon_{LS} = \frac{dL_s/L_s}{dNW/NW} = \frac{dL_s/L_s}{d[(1-t_w)W]/[(1-t_w)W]} \cong \frac{\widehat{L_s}}{\widehat{W}-\widehat{t_w}}, \qquad \text{(D.44)}$$

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

$$\widehat{L_s} = \left(\widehat{W} - \widehat{t_w}\right)\varepsilon_{LS} \qquad \text{(D.45)}$$

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

$$\varepsilon_{LD} = \frac{dL_d/L_d}{dTC/TC} = \frac{dL_d/L_d}{d[(1+t_{er})W]/[(1+t_{er})W]} \cong \frac{\widehat{L_d}}{\widehat{W}+\widehat{t_{er}}} \qquad \text{(D.46)}$$

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

$$\widehat{L_d} = \left(\widehat{W} + \widehat{t_w}\right)\varepsilon_{LD} \qquad \text{(D.47)}$$

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

$$\widehat{L_s} = \widehat{L_d}\ . \qquad \text{(D.48)}$$

Substituting (D.45) and (D.47) into (D.48), we find that, in order to reach the new equilibrium, changes in gross wages will be given by the following expression:

$$\widehat{W} = \frac{\varepsilon_{LS}}{\varepsilon_{LS}-\varepsilon_{LD}}\widehat{t_W} + \frac{\varepsilon_{LD}}{\varepsilon_{LS}-\varepsilon_{LD}}\widehat{t_{er}}. \qquad \text{(D.49)}$$

Since in QUEST, $0 < \varepsilon_{LS} < \infty$ and $\varepsilon_{LD} < 0$, the final change in the equilibrium wage will depend on the relative magnitude of the elasticities and the signs and magnitude of the fiscal policy shocks, i.e., the relative changes in $t_W$ and $t_{er}$. In the same way, we can also find the changes in the net wages and total compensation of employees, given the changes in the tax rates for employees and employers. Consider the definition of net wages in (D.41). Applying logarithms and differentiating, we obtain:

$$\widehat{NW} = \widehat{W} - \widehat{t_w}\ . \qquad \text{(D.50)}$$

Substituting (D.49) in (D.50), we obtain that:

$$\widehat{NW} = \frac{\varepsilon_{LD}}{\varepsilon_{LS}-\varepsilon_{LD}}\left(\widehat{t_w} + \widehat{t_{er}}\right) \qquad \text{(D.51)}$$

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 labor 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 (D.43). Applying logarithms and differentiating, we obtain:

$$\widehat{TC} = \widehat{W} + \widehat{t_{er}} \,. \qquad \text{(D.52)}$$

Substituting (D.49) in (D.52), we obtain that:

$$\widehat{TC} = \frac{\varepsilon_{LS}}{\varepsilon_{LS}-\varepsilon_{LD}}(\widehat{t_w} + \widehat{t_{er}}) \qquad \text{(D.53)}$$

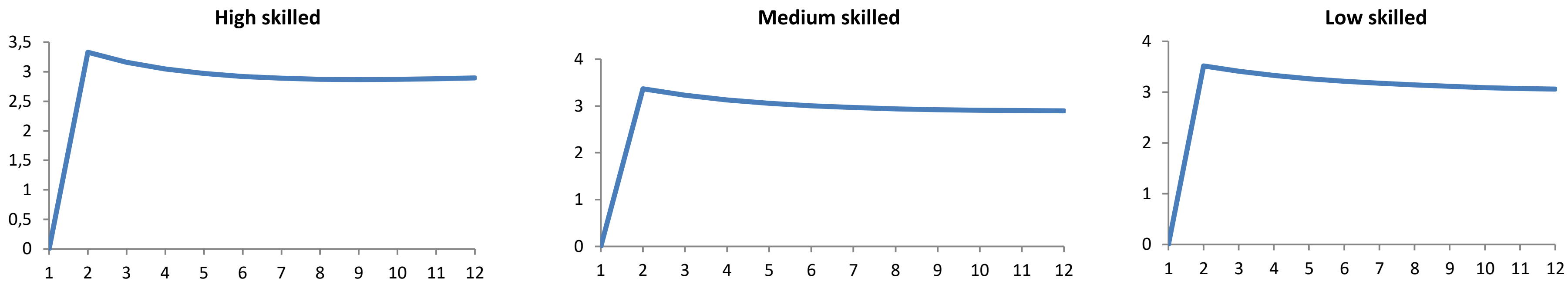
The ratio $\frac{\varepsilon_{LS}}{\varepsilon_{LS}-\varepsilon_{LD}}$ is positive. This means that there is a direct relationship between the change in total taxes on labor and the total compensation. As we can conclude, tax incidence in QUEST, i.e. the sharing of the tax burden between workers and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

In case of the Belgian reforms, when cutting employee paid contributions, the responses of net wages and of the total compensation of employees to an increase in labor tax are negative and positive, respectively, and are constrained by the elasticity of labor supply ($\varepsilon_{L,s} > 0$) and labor demand ($\varepsilon_{L,d} < 0$). Our shocks imply that $\widehat{t_w} < 0$ and $\widehat{t_{er}} = 0$, then from equation (D.49) gross wages should go down, i.e. $\widehat{W}$<0. In the same way, and now from equation (D.51), we should expect the net wages to rise in the new equilibrium. Note that $(\widehat{t_w} + \widehat{t_{er}}) < 0$, and, according to equation (D.51), there is an inverse relationship between the change in total taxes on labor income and net wages. This is also confirmed by the impulse response functions of the net wages (graph E.1). Finally, in what concerns the total compensation of employees paid by the firms, and according to equation (D.53), we should expect it to decrease. Equation (D.53) implies a positive relationship between the change in total taxes on labor income and the total compensation. In our case, $(\widehat{t_w} + \widehat{t_{er}}) < 0$. So, the total compensation of employees will decrease in the new equilibrium. Again this is shown in the impulse response functions of the total compensation of employees, in graph E.2.

A similar analysis can be done in case of cutting employer paid contributions. Again drawing from our tax incidence analysis and since our shocks imply that $\widehat{t_w} = 0$ and $\widehat{t_{er}} < 0$, from equation (D.49) gross wages should go up, i.e. $\widehat{W}$<0. In the same way, and now from equation (D.51), we should expect the net wages to rise in the new equilibrium, $(\widehat{t_w} + \widehat{t_{er}}) < 0$, and, according to equation (E.51), there is an inverse relationship between the change in total taxes on labor income and net wages. This is also confirmed by the impulse response functions of the net wages (graph E.5). Finally, in what concerns the total compensation of employees paid by the firms, and according to equation (D.53), we should expect it to decrease. Since $(\widehat{t_w} + \widehat{t_{er}}) < 0$, the total compensation of employees will decrease in the new equilibrium. Again this is shown in the impulse response functions of the total compensation of employees, in graph E.6.

## Appendix E. QUEST impulse responses

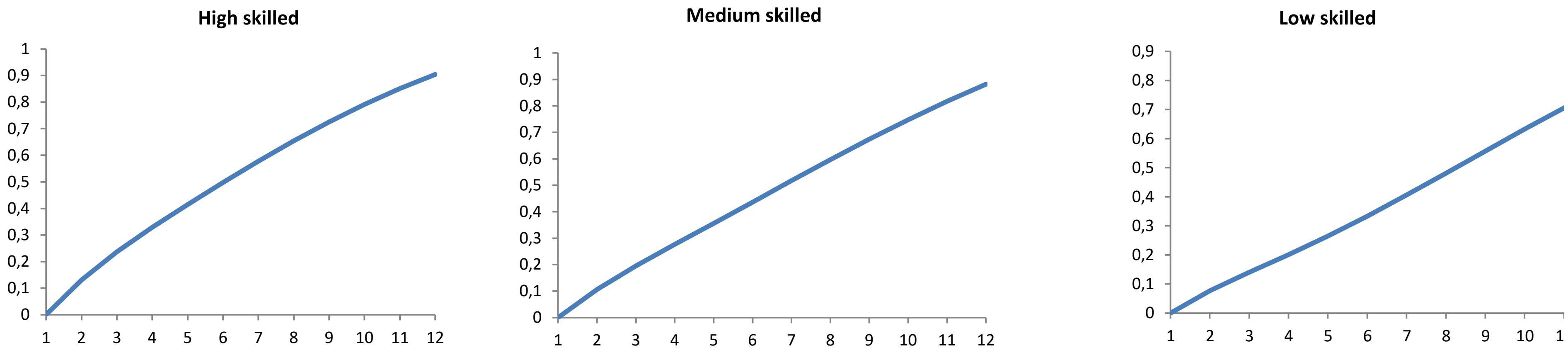
### E.1 Net real wage of employees, per skill level (% quarterly change from baseline) – Reform on employees contributions



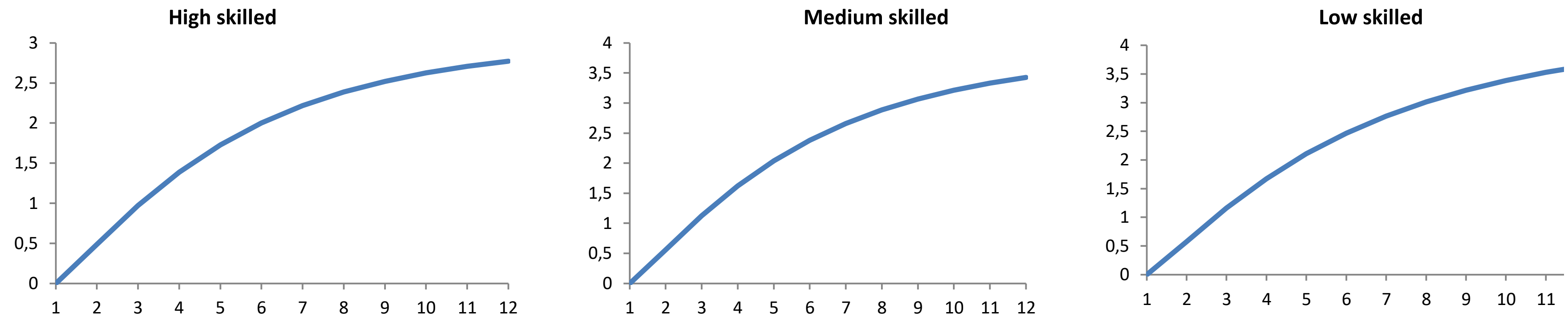

### E.2 Total compensation of employees, per skill level (% quarterly change from baseline) – Reform on employees contributions

## E.3 Gross real wage, per skill level (% quarterly change from baseline) – Reform on employees contributions

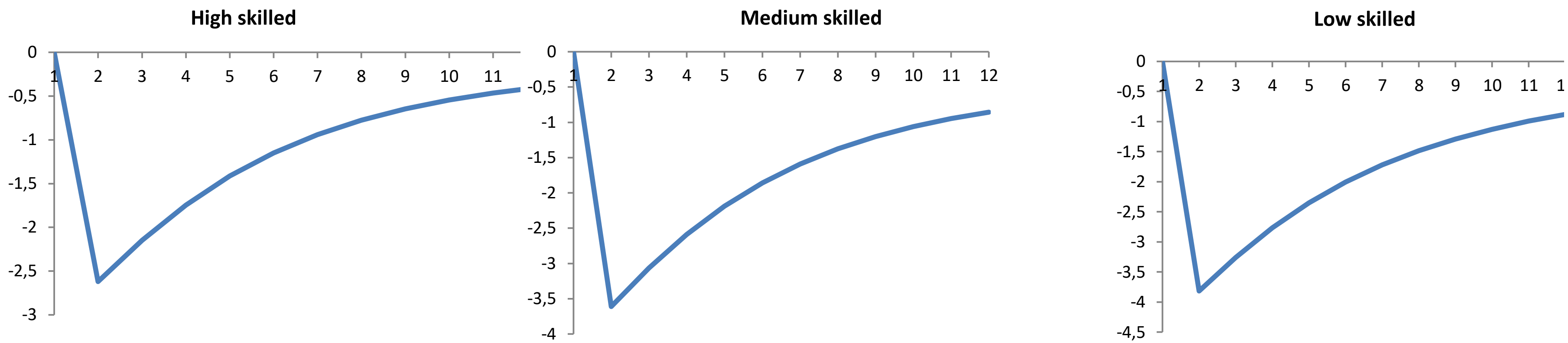

## E.4 Employment, per skill level (% quarterly change from baseline) – Reform on employees contributions



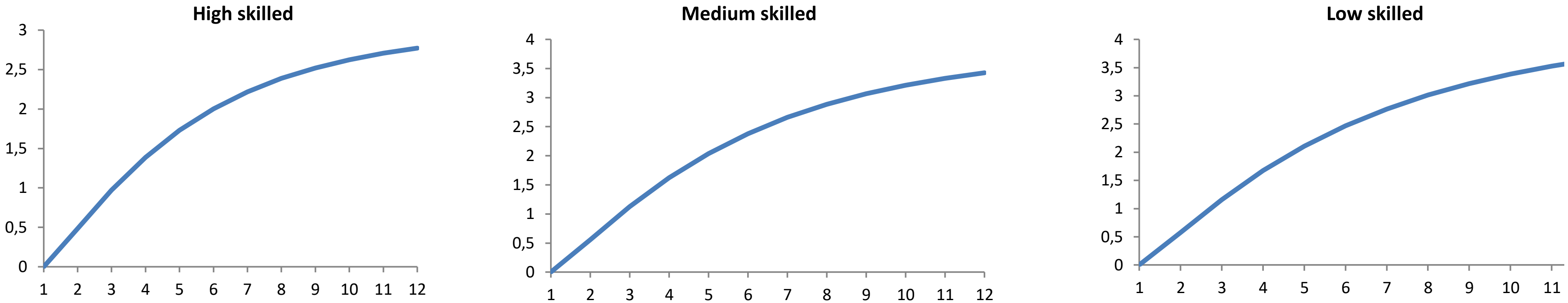
**E.5 Net real wage of employees, per skill level (% quarterly change from baseline) – Reform on employers contributions**




**E.6 Total compensation of employees, per skill level (% quarterly change from baseline) – Reform on employers contributions**



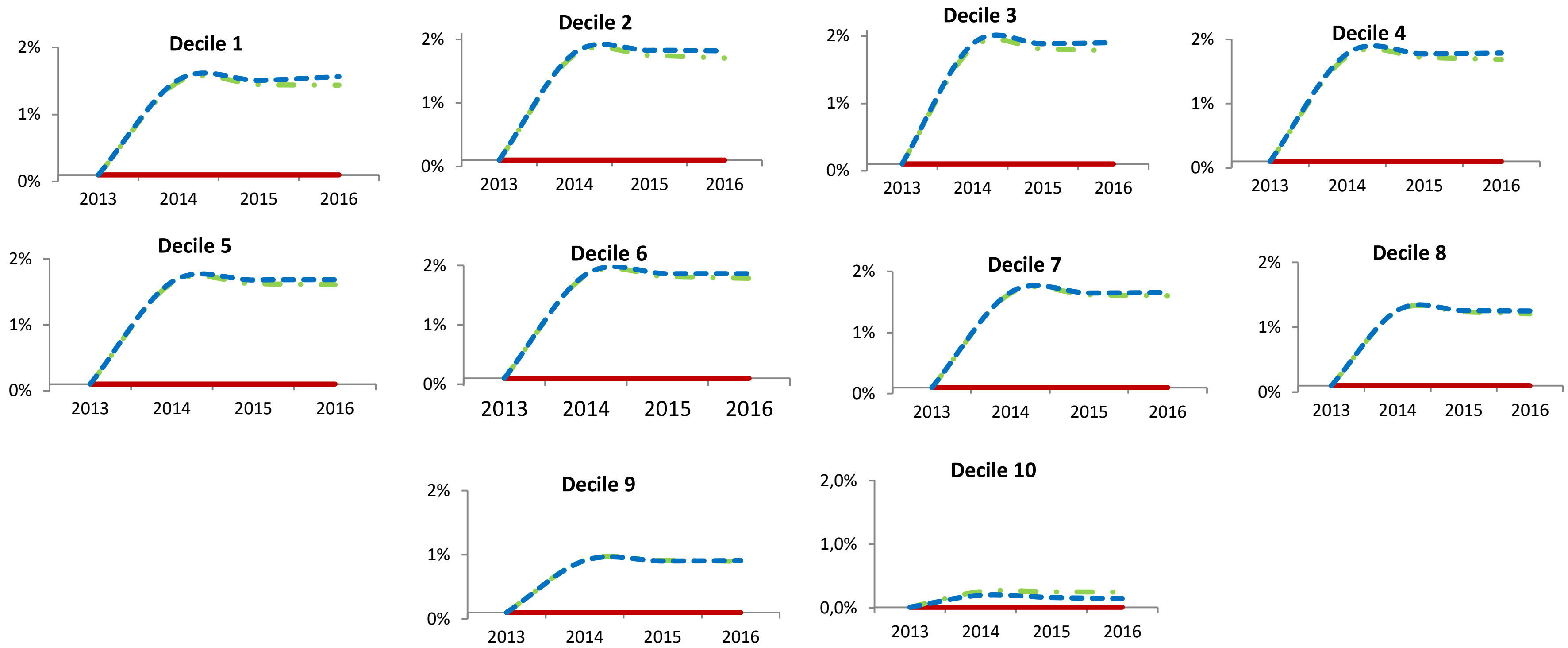
**E.7 Gross real wage, per skill level (% quarterly change from baseline) – Reform on employers contributions**



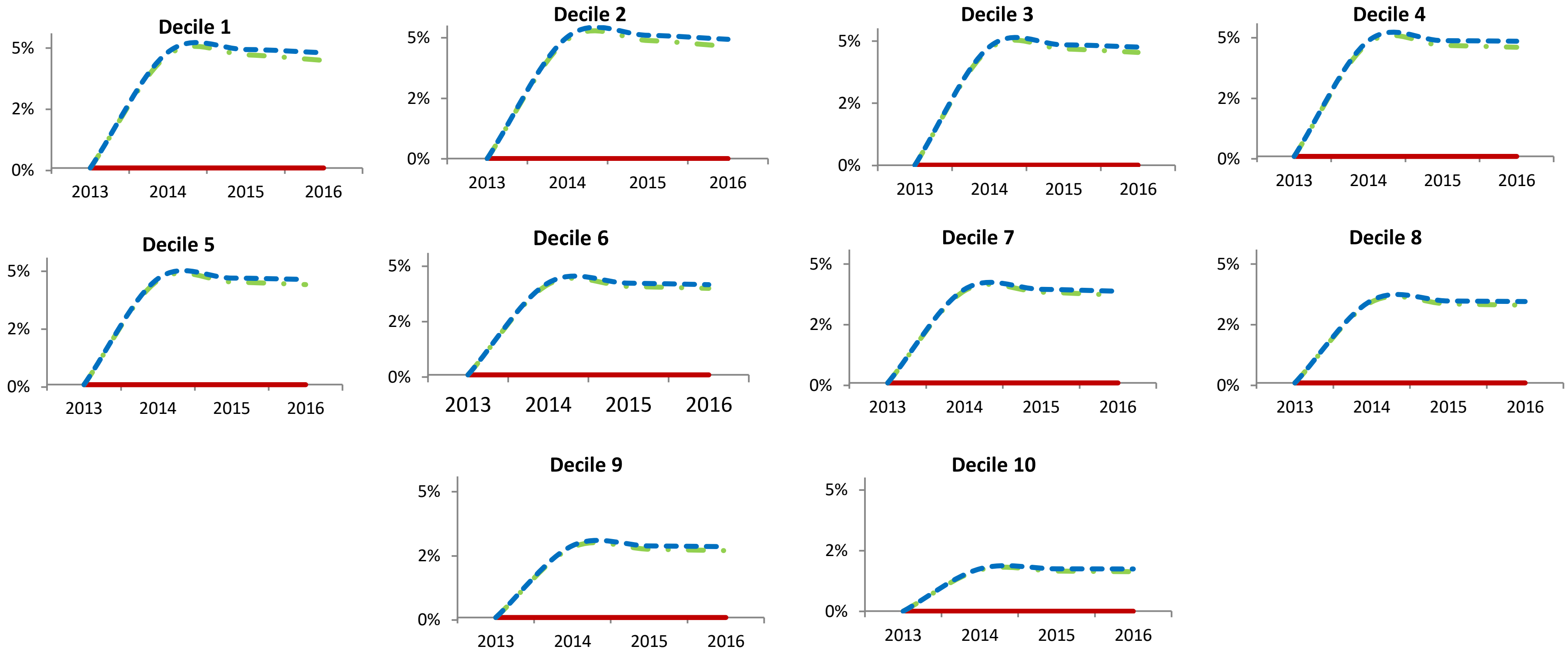

**E.8 Employment, per skill level (% quarterly change from baseline) – Reform on employers contributions**

## Appendix F. Budgetary and redistributive effects of the Italian and Polish reforms

### F.1. Impact of the refundable tax credit reform on disposable income (by income decile) – Italy



**F.2. Impact of the universal tax credit reform on disposable income (by income decile) – Poland**



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