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Michal Horváth, Matúš Senaj, Zuzana Siebertová,
Norbert Švarda, Jana Valachyová

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Evaluating the Aggregate Effects of Tax and Benefit Reforms¹

*Michal Horvath², Matus Senaj³, Zuzana Siebertova⁴,
Norbert Svarda⁵, Jana Valachyova⁶*

ABSTRACT

The paper introduces a new way of linking microsimulation models with dynamic general equilibrium frameworks to obtain an evaluation of the impact of detailed tax and benefit measures on the aggregate economy. The approach involving polynomial approximation to aggregated output from behavioural microsimulation permits the solution for the long-run steady state and the transition path in one numerical simulation of the dynamic aggregate economy. The practical usefulness of the approach is demonstrated by evaluating actual and hypothetical tax reforms in the context of Slovakia.

Keywords: microsimulation, dynamic general equilibrium, unemployment, labour supply elasticity, tax reform

JEL classification: E24, H24, H31, J22

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² Corresponding author. University of York E-Mail: michal.horvath@york.ac.uk

³ Council for Budget Responsibility E-Mail: senaj@rrz.sk

⁴ Council for Budget Responsibility E-Mail: siebertova@rrz.sk

⁵ Council for Budget Responsibility. E-Mail: svarda@rrz.sk

⁶ Council for Budget Responsibility. E-Mail: valachyova@rrz.sk



1 Introduction

We introduce a new way of embedding microsimulation analysis into a dynamic general equilibrium framework. Our aim is to facilitate important policy evaluation work in which the individual-level consequences of detailed policy decisions interact with a dynamic macro-economy. The current literature that considers general equilibrium feedback into microsimulation analysis is only beginning to address the associated challenges. In the approach presented in this paper, income heterogeneity interacts with the macro-economy via aggregated individual labour supply decisions which influence, and are influenced by, the dynamic evolution of the real wage rate. Our method offers a general, efficient and sufficiently accurate way of integrating microsimulation work and dynamic general equilibrium analysis, compatible with standard solution methods used in macroeconomics. We demonstrate the practical usefulness of our approach on actual and hypothetical tax reforms evaluated in the context of the Slovak economy in a way that is relevant for budgeting at the aggregate level.

The dynamic general equilibrium framework in this paper is small open economy general equilibrium model with a labour market augmented for the presence of matching frictions.⁷ In this framework, we replace the standard equilibrium real wage determination through theoretical bargaining with a mapping of wage responses into labour supply changes obtained from a behavioural microsimulation exercise. In other words, an empirical schedule linking the economy-wide real wage rate to aggregate labour supply obtained from a behavioural microsimulation exercise is used to close the macroeconomic model. This echoes the analysis of Farmer (2013, 2014) with the notable difference that the task of equilibrium selection in a model with multiple solutions is assigned to a relationship obtained from empirical analysis outside the theoretical model rather than a belief function.

The approach taken in this paper as well as the solution algorithm we employ also bears resemblance to the methods used to solve incomplete market models.⁸ There are two

⁷ Our choice of the macroeconomic framework is motivated by analytical tractability and internal consistency with the behavioural microsimulation part. The approach outlined in the paper would, however, work with a wide range of dynamic general equilibrium frameworks featuring various real and nominal rigidities, and is not specific to the setup presented here.

⁸ See Marcet et al. (2007), for a tractable example, or Holter et al. (2015) for a comprehensive setup also involving extensive and intensive margin labour market effects similar to ours.



differences. First, the individual-level decision function is an empirically estimated labour supply relationship. This is the point where aggregate outcomes such as the wage rate matter for individual decisions.⁹ Rather than calibrating an elasticity parameter in a micro-founded theoretical model, we use estimates of labour supply elasticities from models consistent with welfare optimization.¹⁰ Second, the underlying heterogeneity is fed into the model directly from an empirical sample used in the microsimulation part rather than simulations of interaction of individual decision functions and idiosyncratic uncertainty. The aggregate labour supply input generated by individual decisions following policy changes and at different wage rates is then obtained by aggregation from the behavioural microsimulation model. It is at this point that heterogeneity matters for aggregate dynamics in the model. As in the case of incomplete market models, the solution algorithm then searches for equilibrium prices that equate aggregate factor supply and demand.

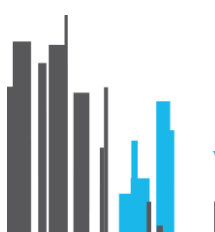
A clear practical advantage of combining theoretical and empirical blocks in the model relative to the purely theoretical (incomplete-market) setups is that we have a framework that can readily evaluate the consequences of a wide range of tax and benefit reforms at a fine level of detail relevant for policy evaluation. At the same time, such an internally consistent model allows us to capture the dynamic response of the economy to reforms, and therefore evaluate general equilibrium transitional effects in addition to general equilibrium long-run effects. This is a significant step forward relative to the existing microsimulation literature.

More specifically, the possibility to operate in a dynamic context without being restrictive at the microsimulation level is a notable strength of our approach relative to the related work that aims to integrate microsimulation with computable general equilibrium (CGE) models. In broad terms, our solution method represents a ‘layered approach’ (see Colombo, 2010 or Peichl, 2016), and is probably closest to the top-down/bottom-up approach of Savard (2003).¹¹ Indeed, we

⁹ We assume households are pooling income, and that there is risk-sharing across households, so that the consumption decision takes place at the level of the representative household. Further work should relax this assumption.

¹⁰ Such a structural approach to estimation mitigates the vulnerability of our approach to the Lucas critique. Our work on the estimation of labour supply responses builds on the extensive body of literature neatly summarized in Chetty et al. (2013) and McClelland and Mok (2012). The approach we take, set out in full detail in Senaj et al. (2016), is a discretized version of the standard Hausman (1981) approach and closest to the one in Benczur et al. (2014).

¹¹ For another comprehensive discussion on linking micro and macro models, see Cockburn et al. (2014).



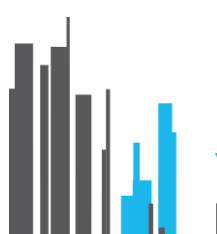
demonstrate the equivalence of the two approaches when it comes to the long-run steady state. However, we do not rely on such an iterative approach to obtain equilibrium factor prices.¹² Instead, we discretise an interval of real wage rates, and use the microsimulation model with a post-reform policy parameterisation to obtain aggregate outcomes corresponding to the various points on the interval. We then apply polynomial approximation to obtain continuous non-linear functions linking the real wage rate to aggregate outcomes that close our macroeconomic model. In the last step, we can solve the macroeconomic model for the long-run equilibrium as well as the transition in one go using standard techniques. Our approach achieves integration between microsimulation and the macroeconomic model without imposing parameter restrictions on the microsimulation through consistency conditions as in the top-down approach of Bourguignon et al. (2005). Our method is also applicable in environments in which data limitations rule out assuming the specific type of choice by individual agents that allows obtaining consistent aggregation in both the microsimulation and CGE modules in the approach of Magnani and Mercenier (2009), which has recently been used in Barrios et al. (2017).

We demonstrate our method and its usefulness by evaluating the aggregate macroeconomic and fiscal effects of actual and hypothetical tax reforms in Slovakia. The late 1990s and early 2000s saw a wave of radical tax reforms introducing flat tax regimes in several Central and Eastern European countries. The one that took place in 2004 in Slovakia bore close resemblance to the simple system proposed in Hall and Rabushka (1983). The personal income tax element of the reform involved a simple linear schedule that some consider to be close to optimal following Mirrlees (1971).¹³ Whilst in some countries, the system stood the test of time, policy makers in Slovakia opted for a gradual repeal of the simple progressive system over time citing the need to improve overall budget balance in an equitable way.

We show that the enacted departures from the flat income tax schedule are associated with neither significant fiscal or employment gains or losses.

¹² Benczur et al. (2012) have used such an iterative approach to solve for the long-run general equilibrium in their framework.

¹³ See Mankiw et al. (2009) for more recent considerations along the same lines. There is also a body of literature featuring incomplete markets supporting simple linear tax structures, e.g. Ventura (1999), Conesa and Krueger (2006), Diaz-Gimenez and Pijoan-Mas (2006), and Conesa et al. (2009). Henceforth, we shall refer to the personal income tax element of the tax reform as the “flat tax” regime.



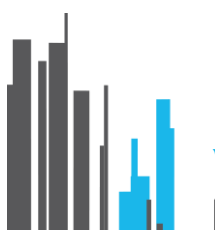
In hypothetical exercises, we find that a return to an even more redistributive system of graduated marginal tax rates would generate only small employment/unemployment changes if accompanied by cuts in allowances.¹⁴ The long-run impact on tax revenue may well be negative due to the disincentive effect posed by higher marginal tax rates on the high earners and the general equilibrium drop in real wages. This echoes some of the findings in Fuest et al. (2008). We also show that a radical reversal of the flat tax reform in which short-run fiscal neutrality is ensured through very high marginal tax rates on top earners is associated with significant output and tax revenue losses in the long run, although there are small associated gains in employment. Similar effects are also generated in the incomplete markets setup of Holter et al. (2015).

Our work is thus also related to the literature examining the consequences of flat tax reforms in Central and Eastern Europe. Our results confirm the importance of considering the tax reform in the wider context of tax-benefit changes, as emphasized in Keen et al. (2006). Ivanova et al. (2005) do not find strong effects on work incentives of the flat tax reform in Russia, casting doubt on the importance of the incentive effect of large cuts in top marginal rates. Whilst reporting some intensive margin effects for males in general and females at both ends of the work hour distribution, Duncan and Sabirianova Peter (2010) do not attribute significant aggregate employment and tax revenue gains to the introduction of the flat tax reform in Russia. Finally, we do not consider the endogenous growth implications of tax reforms, although this may be a potentially important channel in the long run as shown in Azacis and Gillman (2010), albeit one that needs to be subjected to a proper empirical test.¹⁵

The rest of the paper is organized as follows. Section 2 sets out the details of the different elements of the model, specifies the calibration of the key parameters of the macroeconomic framework, and explains the solution algorithm. Section 3 describes the tax reform scenarios examined in the paper. Section 4 presents the key results and, finally, section 5 concludes.

¹⁴ A large body of literature has questioned the optimality of flat tax regimes. See, for example, Tuomala (1984), Tuomala (1990), Diamond and Saez (2011), and Heathcote and Tsujiyama (2015). Zelenak and Moreland (1999) also provide a good non-technical overview of the arguments for a graduated tax structure.

¹⁵ Cassou and Lansing (2004) have also found such growth enhancing effects of the Hall-Rabushka proposal in a theoretical framework. Holter et al. (2015) point out that the consequences of tax reforms for human capital accumulation also depend on how it is modelled.



2 The model

The model used in our study is a representative-agent dynamic general equilibrium framework with a fully integrated behavioural microsimulation part.¹⁶

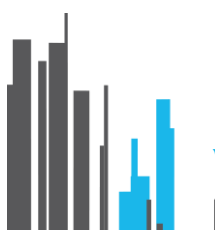
The framework is a standard open economy model of the labour market with a matching friction with one notable modification. Instead of explicitly modelling a bargaining process over the surplus generated by matches, equilibrium wage determination is captured by an approximated relationship between the wage rate and employment coming from a behavioural microsimulation exercise. For a given tax reform, potential financial gains and losses for every individual in the sample are calculated, and individual labour supply reactions are assessed. Individual labour supply responses are then aggregated to obtain an aggregate employment response, together with effective (productivity-adjusted) labour and total household disutility, that will allow us to close the model. For a given tax reform scenario, such aggregate responses are calculated assuming simultaneous aggregate real wage shocks of different magnitudes. Polynomial approximation is then used to obtain a continuous schedule in the (real wage, employment) plane, among others, that is embedded into the dynamic macroeconomic framework. Under the assumptions of the model, this setup permits the computation of the post-reform long-run steady state as well as the sequence of rational expectations equilibria occurring in transition to that steady state in a single numerical exercise.

2.1 The theoretical block

Households.- Our small open economy is inhabited by an infinite number of identical households. The representative household is made up of a continuum of members (indexed i) occupying the unit interval. The household's preferences are given by

$$E_0 \sum \beta^t \left\{ \frac{\left[C_t - \int \frac{N_t(i)^{1+\epsilon_i}}{1+\epsilon_i} di \right]^{1-\gamma}}{1-\gamma} - \frac{1}{1-\gamma} \right\}$$

¹⁶ For the different aspects of microsimulation modelling, see O'Donoghue (2014).



in which C is household consumption of a homogeneous good, $N(i)$ stands for the fraction of time each household member spends in employment (with $N(i) \in [0,1]$), the parameter $\epsilon_i > 0$ denotes individual-level (inverse) labour-supply elasticity and, finally, $\gamma > 0$ is a risk aversion parameter.¹⁷

The household budget constraint is given by

$$(1 + \tau_c)C_t + \frac{a_t}{1+r} = a_{t-1} + \int [w_t(i)N_t(i) + \pi_t(i) - T_t(i)]di \quad (1)$$

where a stands for assets accumulated by the household, r is the world real interest rate, $w(i)$ stands for the real wage rate earned by the member of the household and can be thought of as a product of an economy-wide real wage rate w and an idiosyncratic productivity component $\omega(i)$ with a mean of 1.¹⁸ The variable $\pi(i)$ stands for dividend income. The variable $T(i)$ represent the net transfer payments paid by the members of the household and τ_c is the consumption tax rate.

It is assumed here that income is pooled within the household, and that all households in the economy start with identical asset holdings.

Technology.- We assume that production of goods is given by a standard CES production function which combines effective aggregate labour and capital:

$$Y_t = [\alpha K_t^\sigma + (1 - \alpha)L_t^\sigma]^{\frac{1}{\sigma}} \quad (2)$$

The parameters α and elasticity of substitution defined as $\frac{1}{(1-\sigma)}$ are positive with $\alpha \in (0,1)$. Effective labour is derived from individual household member labour supply. Total labour supply (employment) in the economy is given by $N_t = \int N_t(i)di$. Total effective labour in the economy is given by $L_t = \int \omega_t(i)N_t(i)di$. And so on aggregate, we have

$$L_t = \omega_t N_t. \quad (3)$$

Aggregate employment evolves according to

$$N_t = (1 - \lambda)N_{t-1} + m_t, \quad (4)$$

¹⁷ Note that $N(i)$ can also be interpreted as the probability of being employed (which is consistent with our output from the microsimulation exercise). As a result, the average N across household members can be interpreted as the aggregate employment rate.

¹⁸ This idiosyncratic component is a combination of ex ante observable and unobservable, deterministic and stochastic components.



in which λ stands for the exogenous separation rate and m denotes the number of new matches (hires) in each period. Following Blanchard and Galí (2010), we assume that newly hired labour becomes productive immediately.

The model is that of a small open economy and capital is supplied elastically at the world interest rate r .

Labour market.- The hiring process is governed by the standard Cobb-Douglas matching function

$$m_t = \mu u_t^\xi v_t^{1-\xi} \quad (5)$$

where

$$u_t = 1 - N_t \quad (6)$$

is the unemployment (rate) in our economy. The variable v denotes vacancies, while parameter μ measures the efficiency of matching process and ξ is the match elasticity of the unemployed.

The probability of filling a vacancy and the probability of being matched with a job are then given by

$$q_t = \frac{m_t}{v_t} \quad (7)$$

and $p_t = \frac{m_t}{u_t}$, respectively.

Firms.- There is a large number of competitive profit-maximizing firms. They employ capital and labour to produce a homogeneous good. The representative firm solves the problem given by

$$\max_{K_t, L_t, v_t} E_t \sum \beta^t \{ (1 - \tau_F) [Y_t - (1 + \tau_{w,t}) w_t L_t - c v_t] - r K_t \}.$$

This setup assumes firms make their decision after the individual productivity levels have been revealed. In this equation, τ_w denotes the average payroll tax rate paid by employers.

In addition to these economic profits, we consider the accounting profits of firms which in each period are simply given by $Y_t - (1 + \tau_{w,t}) w_t L_t - c v_t$.¹⁹ These profits are taxed at a rate τ_F . The

¹⁹ See Anagnostopoulos et al. (2014) for a discussion of the difference between economic and accounting profits. The consideration of accounting profits allows us to capture the impact of policy changes on the reported profitability of the private sector.



last term in the profit function stands for the hiring costs, assuming there is a constant cost c per vacancy associated with posting vacancies.

Government.- The government issues one-period debt at the world interest rate to bridge the gap between revenue and spending. The government budget constraint is given by

$$\frac{b_t}{1+r} = b_{t-1} - \int T_t(i)di - \tau_{w,t}w_tL_t - \tau_cC_t - \tau_F[Y_t - (1 + \tau_w)w_tL_t - cv_t] + G_t \quad (8)$$

where G is general government consumption, assumed to be exogenous and in terms of international units of consumption.

Policy shocks.- The model allows us to investigate a number of various policy experiments. The ones we concentrate on in this paper enter the model through the net transfer payments to the household $T(i)$ and indirectly through the effective $\tau_{w,t}$.

Equilibrium in a decentralized economy.- The problem of the household yields the following consumption Euler equation

$$\beta E_t \frac{\left[C_{t+1} - \int \frac{N_{t+1}(i)^{1+\epsilon_i}}{1+\epsilon_i} di \right]^{-\gamma}}{\left[C_t - \int \frac{N_t(i)^{1+\epsilon_i}}{1+\epsilon_i} di \right]^{-\gamma}} = \frac{1}{1+r}. \quad (9)$$

Firms maximize profits subject to the equation describing the dynamic of employment with $m_t = q(\theta_t)v_t$, taking labour market tightness as given. The optimality conditions are

$$\frac{c}{\omega_t q_t} = (1 - \alpha)L_t^{\sigma-1}[\alpha K_t^\sigma + (1 - \alpha)L_t^\sigma]^{\left(\frac{1}{\sigma}-1\right)} - (1 + \tau_w)w_t + (1 - \lambda)\beta E_t \frac{c}{\omega_t q_{t+1}}, \quad (10)$$

$$\alpha K_t^{\sigma-1}[\alpha K_t^\sigma + (1 - \alpha)L_t^\sigma]^{\left(\frac{1}{\sigma}-1\right)} = \frac{r}{(1-\tau_F)}. \quad (11)$$

The aggregate period resource constraint of the economy is given by

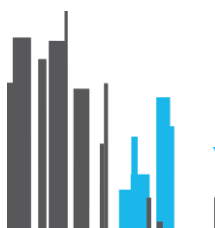
$$Y_t - cv_t = C_t + I + G_t + tb_t \quad (12)$$

in which the variable tb stands for trade balance. The external asset balance of the economy evolves according to

$$a_t - b_t = tb_t + (1 + r)(a_{t-1} - b_{t-1}). \quad (13)$$

Investments I evolve following the capital accumulation equation

$$K_{t+1} = (1 - \delta)K_t + I_t \quad (14)$$



where δ is the depreciation rate.

Equilibrium in our economy is a set of allocations $\{C_t, D_t, a_t, N_t, Y_t, K_t, L_t, \omega_t, m_t, u_t, v_t, q_t, \tau_{w,t}, b_t, tb_t, I_t\}_{t=0}^{\infty}$ and the price of labour $\{w_t\}_{t=0}^{\infty}$ such that satisfy equations (2) – (14), and the transversality conditions on household and government net assets. We have defined aggregate disutility from work $D_t = \int \frac{N_t(i)^{1+\epsilon_i}}{1+\epsilon_i} di$.

There are fewer equations than unknowns at this stage, and hence there are multiple solutions to the model. To pin down a unique solution, we use relationships between the wage rate and a vector of variables (including employment), conditional on a given policy shock, obtained from the behavioural microsimulation exercise. The exact procedure to obtain the wage-employment relationship is described in the next subsection.

The results of the empirical exercise – for a given tax-benefit reform scenario – are sets of pairs $\{(\hat{w}, N), (\hat{w}, L), (\hat{w}, \tau_w), (\hat{w}, D)\}$ with $\hat{w} = \ln \frac{w_t}{w}$ where w is the steady-state wage rate defined below. Here, \hat{w} takes on a discrete set of values on an interval covering a reasonable distance from the steady state. The relationship between the respective variables and the real wage can be approximated using polynomials $x_t = \sum_{i=0}^n \alpha_{x,i} \hat{w}_t^i$ for $x = \{N, L, \tau_w, D\}$.²⁰ These polynomials then determine the rational expectations equilibrium in our model.²¹

The steady state.– The non-stochastic steady state equilibrium is a vector $\theta = \{C, a, N, Y, K, L, \omega, m, u, v, \theta, \tau_w, b, tb, I, w\}$ that solves the equations

$$Y = [\alpha K^\sigma + (1 - \alpha)L^\sigma]^{\frac{1}{\sigma}}$$

$$L = \omega N$$

$$N = \frac{m}{\lambda}$$

$$m = \mu u^\xi v^{1-\xi}$$

$$u = 1 - N$$

²⁰ One could use other approximation techniques, including non-parametric interpolation methods, and possibly achieve a higher degree of accuracy. In incomplete market models, such approximations are applied to the individual decision function but that is impractical in the present context.

²¹ Note that the household budget constraint (1) is satisfied by Walras's law. We do not provide a proof of the uniqueness of this equilibrium but we tested the existence of other rational expectations equilibria by starting the numerical search for the final steady state from different initial values.



$$\theta = \frac{u}{v}$$

$$\frac{r}{1+r}b = \int T(i)di + \tau_w wL + rK + \tau_c C + \tau_F [Y - (1 + \tau_w)wL - cv] - G$$

$$\frac{c}{\omega q(\theta)} [1 - (1 - \lambda)\beta] = (1 - \alpha)L^{\sigma-1}[\alpha K^\sigma + (1 - \alpha)L^\sigma]^{\left(\frac{1}{\sigma}-1\right)} - (1 + \tau_w)w$$

$$\alpha K^{\sigma-1}[\alpha K^\sigma + (1 - \alpha)L^\sigma]^{\left(\frac{1}{\sigma}-1\right)} = \frac{r}{(1 - \tau_F)}$$

$$Y - cv = C + I + G + tb$$

$$r(a - b) = tb$$

$$\delta K = I$$

$$x = \alpha_{x,0} \text{ for } x = \{N, L, \tau_w\}.$$

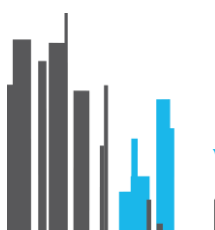
The value of C (and G) in the initial steady state are determined by calibrating the different component shares of aggregate income to empirical values.

2.2 The wage-employment schedule

The microsimulation block of the model underlies the empirical side of the analysis. The aim of this part is to simulate the labour supply response of individuals to changes in taxes and transfers resulting from actual or hypothetical reforms and simultaneous wage shocks of different magnitudes (according to the discretised values, including zero). Labour supply of an individual consists of two main components – the decision at the extensive (whether to supply labour) and the intensive margins (hours worked conditional on being employed).

The behavioural response to an income shock at the extensive margin is evaluated as the adjustment of individuals' probability of being economically active, using the econometric approach presented in Senaj et al. (2016). The individuals' decision about supplying labour is based on the rationale of utility maximization.²² Individual participation probabilities are determined by comparing income in two labour market states: being economically active (and work full-time) and being inactive (and receiving full amount of transfers). In other words, it is

²² For a useful overview of alternative approaches of modelling labour supply within microsimulation frameworks, see for example Aaberge and Colombino (2014).



necessary to accurately evaluate the disposable income of an individual. To do so, the concept of the gains to work (effective net wage) of an individual j is defined as the difference between the net wage (w_j) and the amount of welfare benefits lost when individual is working.²³ To construct the vector of gains to work (GTW_j), a microsimulation tool is needed. We use the SIMTASK calculator to compute net wages from gross wages and simulate the amount of social benefits an individual is entitled to when working and when not working, taking into account the individual's characteristics as well as the characteristics of the corresponding household.²⁴ The probability of being economically active of an individual j in the sample is estimated by a probit equation:

$$p(\text{activity}_j) = \Phi(\gamma \log GTW_j + Z_j' \alpha + \psi \log NY_j). \quad (15)$$

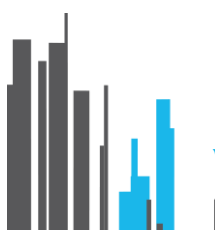
NY_j stands for non-labour income and sums three components, namely the social transfers that one receives when not working, the non-labour income of all household members including and the net labour income of other household members. The construction of this variable also involves using our microsimulation tool. Finally, Z_j denotes a set of observable individual characteristics. The computed elasticities are broadly in line with the results usually reported in the literature. The results document that participation probabilities are in general dependent on the level of net income and social transfers and that low-skilled and females are the groups that are particularly responsive to changes in taxes and transfers.²⁵ On average, a one percent rise in net-wage leads to 0.14 percentage point increase in the participation probability for females and 0.1 for males. The effect of non-labour income on participation probability is comparable for both genders: a one percent rise yields around 0.04 percentage points decrease in supplying labour for both genders.²⁶

²³ Since income from employment is naturally unobservable for those who are unemployed or inactive, we use Heckman's sample selection methodology to predict gross wages.

²⁴ For the simulation of the Slovak tax-benefit system we use SIMTASK, a static tax-benefit calculator described in detail in Siebertova et al. (2016). This tool can be used to simulate direct taxes (namely labour and capital income taxes), health, social insurance contributions paid by employees/employers and selected transfers (for example child allowances or means tested material need benefit). SIMTASK runs on the survey dataset SILC (Statistics on Income and Living Conditions) that comprises detailed information on individuals and households living in Slovakia.

²⁵ See Senaj et al. (2016) for the results and a detailed discussion.

²⁶ The estimated elasticities used in this study are slightly different from those reported in Senaj et al. (2016). Here, we are using a pooled sample corresponding to years 2010-13 and an updated version of the microsimulation model SIMTASK. Detailed results are available upon request.



The results from the estimation of the probit model directly feed into the assessment of the participation effect of the analysed reforms. Using the microsimulation model SIMTASK of tax and transfer system, the gains to work and non-labour income are evaluated for every individual j both in baseline (pre-reform) and scenario (post-reform). In the next step, using the estimated coefficients from the probit model, individual participation probabilities $\hat{p}_j = \Phi(\hat{\gamma} \log W_j + Z_j' \hat{\alpha} + \hat{\psi} \log NY_j)$ are evaluated both in baseline and scenario cases.

The second decision about supplying labour deals with the number of hours worked, conditional on being employed. For this intensive margin response, the pre- and post-reform changes in the effective average (*AETR*) and marginal (*METR*) tax rates need to be calculated. It can be shown, that as a result of the optimization of labour supply decision of an individual, the following relationship between income growth \hat{w} and tax rates holds (see Kiss and Mossberger, 2015):

$$\Delta \ln(\hat{w}) = \varepsilon_m \Delta \ln(1 - METR) + \varepsilon_a \Delta \ln(1 - AETR).$$

The parameter ε_m represents the effective marginal net-of-tax rate elasticity (substitution effect) and ε_a represents the effective average net-of-tax rate elasticity (income effect). Intensive margin elasticities ε_m and ε_a are calibrated since suitable Slovak data are not available. The parameter ε_m is set to 0.2 for the top 20 percent of the income distribution and ε_a is set to zero, following Kiss and Mosberger's (2015) estimation for Hungary. By definition, hours worked in baseline are set to 1. After some manipulations, the labour supply response at the intensive margin of an individual j , conditional on being employed, is then the relative change in the effective hours worked and can be expressed as a function of the marginal and the average effective tax rates and income growth:

$$\hat{h} = \frac{h_{sc}}{h_{ba}} = 1 + \xi(AETR, METR, \hat{w}).$$

In the micro part, employment is modelled so that the labour supply model of individual participation decision is combined with a rationing risk model (Bargain et al., 2005). In the standard labour supply models, it is assumed that individuals can find an employment with certainty. If this assumption is relaxed, there exist individuals who want to work but do not find an employment, thus they are involuntary unemployed. The risk of rationing - an individual probability of being involuntary unemployed - can be estimated as a probit specification



$$\Pr(IUNEMP_j = 1) = \Phi^R(X_j' \beta). \quad (16)$$

IUNEMP is a binary variable that equals one if an individual is involuntary unemployed and zero otherwise, *X* contains individual and local labour market characteristics (demand side variables) that influence the probability of rationing.²⁷ If we assume that there exist individuals who are involuntarily unemployed, the decision process of an individual can be described as a double-hurdle. First, decision whether to participate in the labour market or to stay inactive should be taken. Second hurdle concerns the probability of being involuntarily unemployed if the person is active. Therefore, individual can be found in one of the following 3 states: being inactive, being active and involuntarily unemployed and finally, active and working full-time. Under the assumption that the two processes are independent, the probit equations can be estimated separately. The probability of being employed considered in the second hurdle is estimated such that probabilities of the standard model are multiplied by the probabilities implied by the rationing risk model:

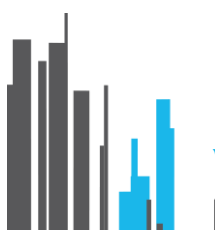
$$p(\widehat{emp})_j = \Phi(\hat{\gamma} \log GTW_j + Z_j' \hat{\alpha} - \hat{\psi} \log NY_j) \left(1 - \Phi^R(X_i' \hat{\beta})\right). \quad (17)$$

Finally, individual employment probabilities in the sample are summed up to get an estimate of the aggregate employment rate. Effective aggregate labour, total disutility from work and the effective companies' payroll tax rate are also constructed by a similar aggregation from the microsimulation model. We repeat this for different wage shocks interacted with the policy reforms that are examined.

2.3 Model parameterization and solution

Calibration. - The parameters of the macro model are set to match Slovak data wherever possible. The production function parameters α and σ are set at 0.43 and -1.1, respectively, from the CES production function estimates presented in Bencik (2008). The job separation rate λ is set at 0.004 in line with the figures presented in European Commission (2013). The matching elasticity

²⁷ In our representation, individual characteristics include education, age in the quadratic form, labour market experience in the quadratic form, dummies for no work history and unfavourable health status. Controls for local labour market characteristics include dummy for the density of settlement and regional unemployment rate. Detailed specification and estimation results are available upon request.



of the unemployed ξ is calibrated to 0.8 in line with the search and matching literature for Slovakia (see Zeleznik, 2012 or Nemeč, 2013), whilst the scaling factor of matching function μ is chosen at 0.05 in order to match Slovak data on vacancies and unemployment. The cost of posting a vacancy c is normalized to 1. We set the quarterly discount factor β at a value corresponding to the inverse of the gross real interest rate which is set at 4 percent in annual terms.²⁸ The preference parameter γ is set to 1 in the baseline parameterization.

Computing final steady state and transitional dynamics.- In order to compute the dynamic solution to the model, we proceed as follows.

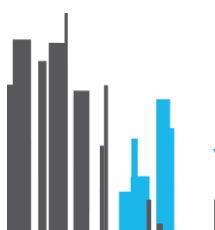
First, we solve for the initial steady state, given the calibration above.

To obtain the final steady state and transition to that steady state, we embed an algorithm that solves a system of nonlinear equations (implemented through the `fsolve` function in Matlab) into a shooting algorithm.²⁹ The algorithm can be described as follows:

1. Guess the length of transition T .
2. Compute the final steady state of the model, given the parameter values, most notably the post-reform α_x 's.
3. Guess the path of employment from the initial steady state to the final steady state $N^0 = \{N_t^0\}_{t=0}^T$
4. Given the final steady state obtained in step 2, and the guess for the transition path in step 3, solve the equilibrium conditions backwards to period 2.
5. Solve the model forwards from period 1, given the transition path for q obtained in step 4.
6. Check if the path obtained for N in step 5, denoted N^1 is the same as N^0 . If not, update guess in step 3 as follows: $N^0 = \vartheta N^0 + (1 - \vartheta)N^1$ with $\vartheta \in (0,1)$.

²⁸ The results are quantitatively sensitive to the choice of the world interest rate. Arguably, 4 percent is high for reforms enacted in 2012. The model is, however, not meant to be a real-time forecasting tool in its current form, and it also abstracts from deeper cyclical considerations.

²⁹ It is possible to use linear approximation to obtain a dynamic solution for the model. But given the scale of the changes in the tax system we examine, and the nonlinearities involved in both the theoretical setup and the microsimulation exercise, we decided to stick to a nonlinear solution.



7. Repeat steps 3 to 5 until $N^0 \approx N^1$.
8. Adjust T, if necessary.

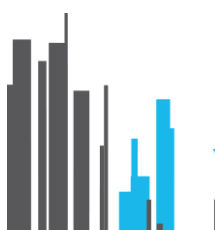
We also show that the final steady state obtained this way is a close approximation of the one obtained from an iterative algorithm of Savard (2003) also used in Benczur et al. (2012). In such an iterative algorithm, the estimated aggregate labour supply response enters the macro model as a shock, and the corresponding wage level is computed. This new wage level is in turn returned to the microsimulation exercise to obtain a new evaluation of the aggregate labour supply response. Such iteration continues until convergence.³⁰

3 Tax reform scenarios

The tax and social transfer system in Slovakia went through a significant change over the past ten years. In 2004, both the tax system and social benefits were substantially redesigned. The main idea of the reform was set on the assumption that Slovak tax system is too complicated and burdensome and that all rates should be replaced by a single tax rate. Therefore, effective from 2004, the system of graduated personal income tax (PIT) rates was simplified to a 19% flat rate system. Krajcir and Odor (2005) show that increases in non-taxable allowances played a key role in preserving the system as moderately progressive and ensuring that the 2004 Slovak flat tax reform made certain groups of lower middle class earners no worse off *ceteris paribus*. Payroll taxes, i.e. social and health insurance paid by economically active population, stayed in general unreformed, although contributions were reduced by about 2 percent. In the end, the system as a whole remained complicated, with different bases and ceilings needed to be applied to different types of social and health insurance contributions. A large part of the system of social transfers was overhauled involving significant cuts in levels of benefits, with the aim to increase work incentives.

Only few minor changes in the system followed this bigger overhaul, some of which can be seen as a process of a gradual – mostly symbolic - departure from the system of a single marginal tax rate. These measures are the focus of this paper. They include:

³⁰ Like other iterative numerical algorithms, individual iterations in such a procedure cannot be treated as adjustment in units of time.



1. Tapering of the basic tax allowance (2007): a gradual reduction in basic tax allowance of PIT has been introduced to tax payers with annual gross earnings exceeding about 18,000 euros. This amount is approximately twice the Slovak average yearly gross wage and the arrangement affected roughly the top 10 percent of the tax payers.
2. Abandonment of the flat tax rate: an additional income tax band starting at annual earnings worth 34,400 euros with a 25 percent personal income tax rate was introduced. Based on the actual earnings distribution of economically active population, the higher tax rate applies roughly to the top 1.5 percent of Slovak tax payers.

In addition to these measures enacted in practice, we also examine two hypothetical scenarios involving a return to the system of graduated tax rates similar to the one that existed in Slovakia before the introduction of the flat-rate system. In both experiments, we uprate the tax bands valid in 2003 using the average wage index. In our first hypothetical scenario, we make sure the reform is approximately fiscally neutral in a static simulation by undoing the increase in the basic non-taxable allowance and the child tax credit whose introduction formed an integral part of the flat-tax reform. In the second scenario, we keep these implicit transfers at their elevated level, and adjust the top rates of income tax to ensure revenue neutrality.

The initial steady state assumed in this study is the situation in Slovakia in 2012. The reference dataset is the SK-SILC survey corresponding to the income reference period 2012 and the reference microsimulation model is SIMTASK calibrated to replicate the state of legislation valid in 2012.

In sum, the assessment of the following four departures from the 2012 baseline is provided:

- Scenario 1: abolition of the progressive reduction in tax allowance

In this scenario, a progressive reduction in basic tax allowance of PIT, originally introduced in 2007, is abolished.

- Scenario 2: two tax brackets in 2013

This scenario directly assesses the effect of change valid from 2013 when two tax brackets of the PIT were introduced. Incomes are taxed by the 19 percent tax rate and a 25 percent income tax is applied to earnings exceeding a threshold value.



- Scenario 3: Hypothetical larger-scale abolition of the flat tax

This hypothetical scenario simulates the effect of introduction of tax brackets that were valid before the flat-tax reform in 2004. Five tax brackets with rates 10, 20, 28, 35 and 38 percent were defined as in 2003, their thresholds were updated according to the growth of average nominal wage between 2003-2013. Moreover, the scenario assumes the cancellation of the child tax credit and a reduction in the basic tax allowance by 22 percent. The latter makes the reform revenue neutral in a static sense and a good approximation of the inverse of the flat tax reform enacted in 2004.

- Scenario 4: Hypothetical larger-scale abolition of the flat tax

This scenario is similar to the scenario 3 but the highest marginal rates are being adjusted to ensure revenue neutrality (again, in a static sense) instead of the cuts in allowances. More specifically, the tax rates become 10, 30, 52, 55 and 60 percent.

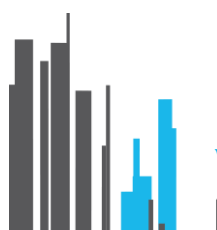
4 Results

First, we discuss the impact of the alternative tax reforms on the aggregate economy. This is shown in Figures 1 and 2.

Marginal departures from the flat tax in Scenarios 1 and 2 (shown in Figure 1) have only negligible consequences at the level of the aggregate economy. The hypothetical scenarios, in particular Scenario 4, however, produce quantitatively more significant impacts (see Figure 2), and indicate that policy makers may face interesting trade-offs in policy design.³¹

Due to the statutory settings of the Slovak tax and transfers system, the marginal departures from the 2004 flat tax leave the income of most earners largely unaffected, and so we are left with insignificant effects on the intensive as well as extensive margins. On the other hand, when we examine the more radical hypothetical reform under Scenario 4 involving significant increases in the progressivity of the tax system, we identify the intensive margin effect as an important driving force of the results. The reform also involves positive net income changes for the low- to middle-income earners, and so we see positive labour supply, and ultimately,

³¹ The trade-offs are even more pronounced once distributional consequences are considered, as in Peichl (2009). The main focus in this paper is on aggregate outcomes. Evaluating the distributional implications in a model-consistent way is an important challenge for the future (see concluding remarks).



employment effects. These employment gains, however, amount to the involvement of a pool of relatively low-skilled workers in the production process. Such gains in labour input do little to offset the negative effect of high marginal tax rates on the effective (productivity-adjusted) hours worked in the economy. Hence, employment gains are associated with a negative composition effect leading to a dilution of the overall productivity of the workforce, and a fall in aggregate output.³² The intensive and extensive margin effects thus operate in opposing directions just as in Holter et al. (2015).

In Slovakia, the original intention was to make the flat tax system revenue-neutral *ceteris paribus* relative to its predecessor. This involved raising some of the transfers implicit in the tax system to offset the increased taxation of low-income households under unified marginal taxation. Nevertheless, some below-average earners experienced moderate net income losses in the short run (Krajcir and Odor, 2005). Above average earners experienced a moderate cut in their marginal tax rate. Our Scenario 3 mimics the inverse of this reform. We see virtually all macroeconomic variables, including employment, real wages, and output, remaining largely unchanged following the reform.

Overall, our analysis implies that the distribution of gains and losses matters not only at the level of the individual but on aggregate too. It is essential to consider the extensive margin effects together with the effects on top earners to get a complex view of tax and benefit reforms.

³² The fact that certain income groups could lose out (gain) *ceteris paribus* from the introduction (abolishing) of a flat tax reform was recognized by Hall and Rabushka (1983). This has been confirmed with particular reference to the middle classes in the simulations of Altig et al. (2001) for the United States and Fuest et al. (2008) for Germany.

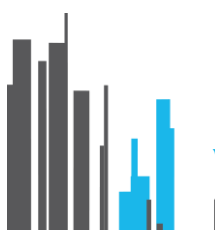


Figure 1 The response of the macroeconomic variables under Scenarios 1 and 2

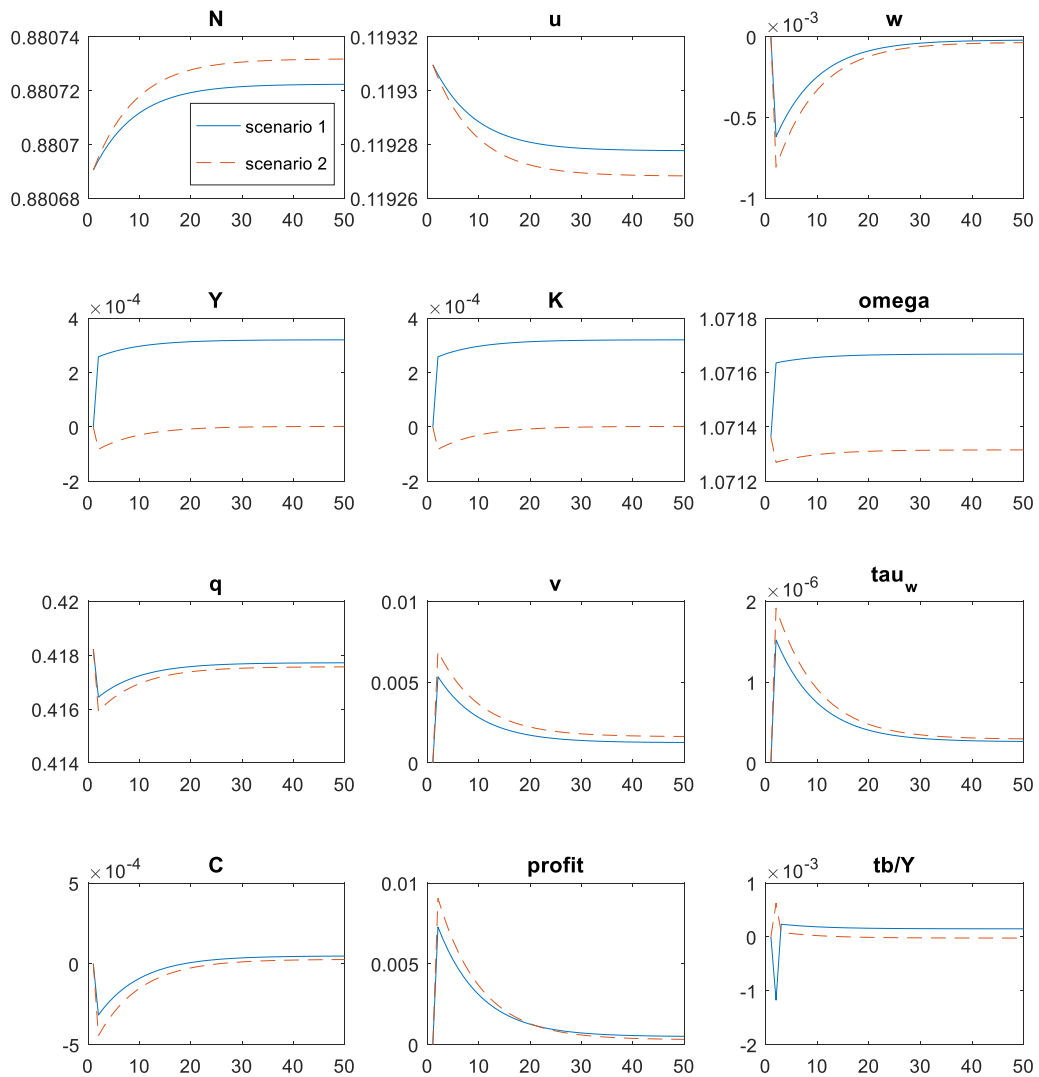
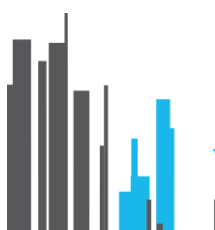
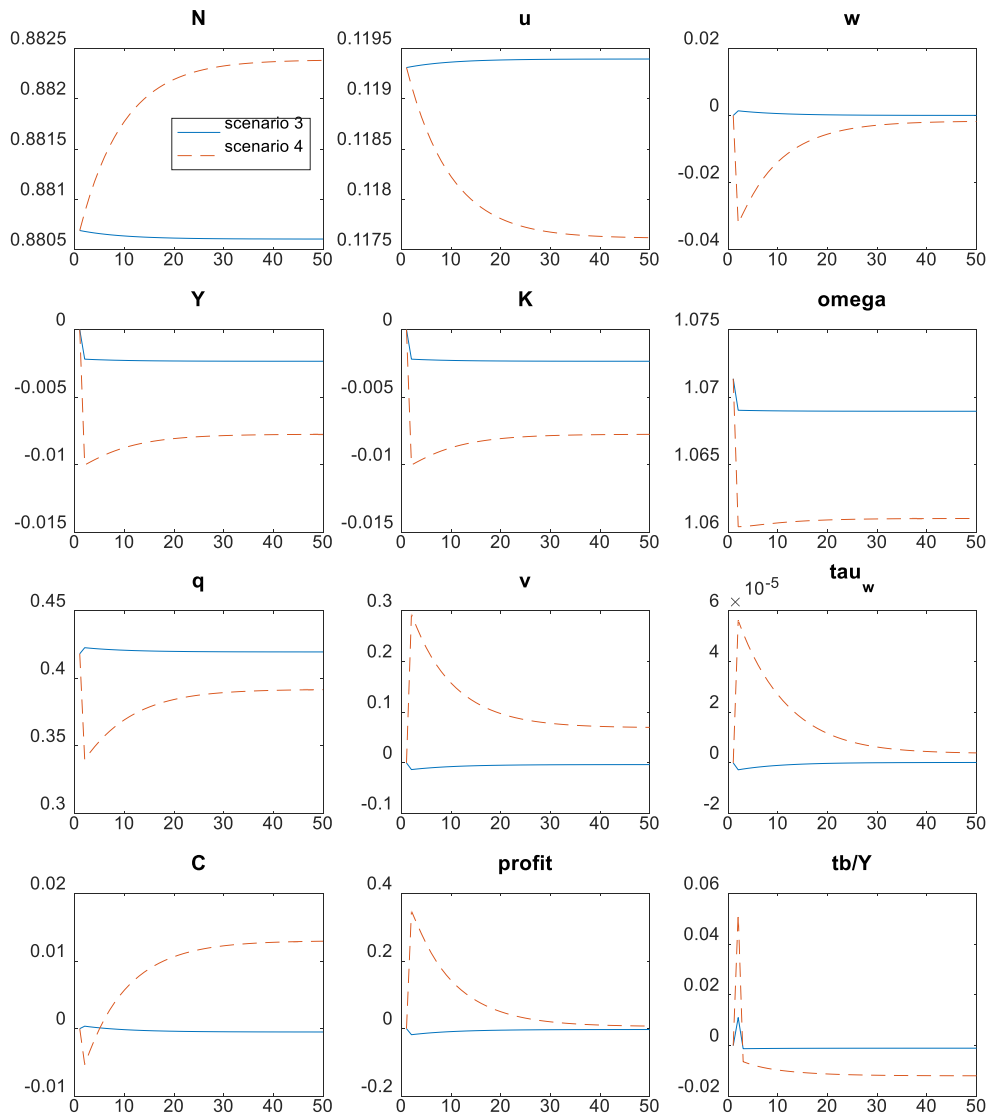


Figure 2 The response of the macro variables under hypothetical tax-reform scenarios



Next, in Table 1 we display static as well as the long run fiscal effects. The static effects (day-after effects) capture only direct consequences of the new tax systems. The long run effects, on the other hand, incorporate the general equilibrium effects.³³

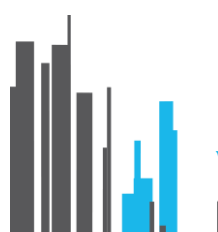
In general, the first two scenarios – in which we simulate marginal departures from 2004 flat tax system - lead only to negligible changes in fiscal revenues.

The tax systems simulated in the third and fourth scenarios are constructed to be approximately fiscally neutral in a static simulation. The long run effects are therefore more interesting. We see a significant drop in personal income tax and the related social insurance contributions. The effect is even more pronounced in the last scenario, where we levy very high tax rates on the incomes of top earners. Consequently, the top earners decrease labour supply at the intensive margin, and the new equilibrium value for gross real wages is also lower than its baseline value. As a result, revenue from personal income tax decreases by 10 per cent and income from social and health insurance contributions decreases by 4 per cent. Saving on social benefits spending arising from the favourable employment dynamic does little to offset the revenue shortfall.

Table 1 Percentage change in fiscal variables under different scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Short-run effects				
Personal income tax	-1.2	0.2	0.1	0.1
Social and Health insurance contr.	0.0	0.0	0.0	0.0
Social benefits	0.0	0.0	0.0	0.0
Long-run effects				
Personal income tax	-1.0	0.1	-1.8	-10.3
Social and Health insurance contr.	0.2	0.0	-1.0	-4.1
Social benefits	-0.2	-0.2	0.7	-0.4

³³ One could compute the transition effects along the whole transition path based on the path for the probability of employment and the real wage rate.



Last but not least, we demonstrate that the long-run results reported above are a very close approximation to those one would obtain in an iterative solution à la Savard (2003), should the (static) steady-state equations of the model in section 2 be seen as a CGE setup. Table 2 shows that the percentage changes in key variables relative to the initial steady state under different scenarios differ only on the fifth decimal place at most.

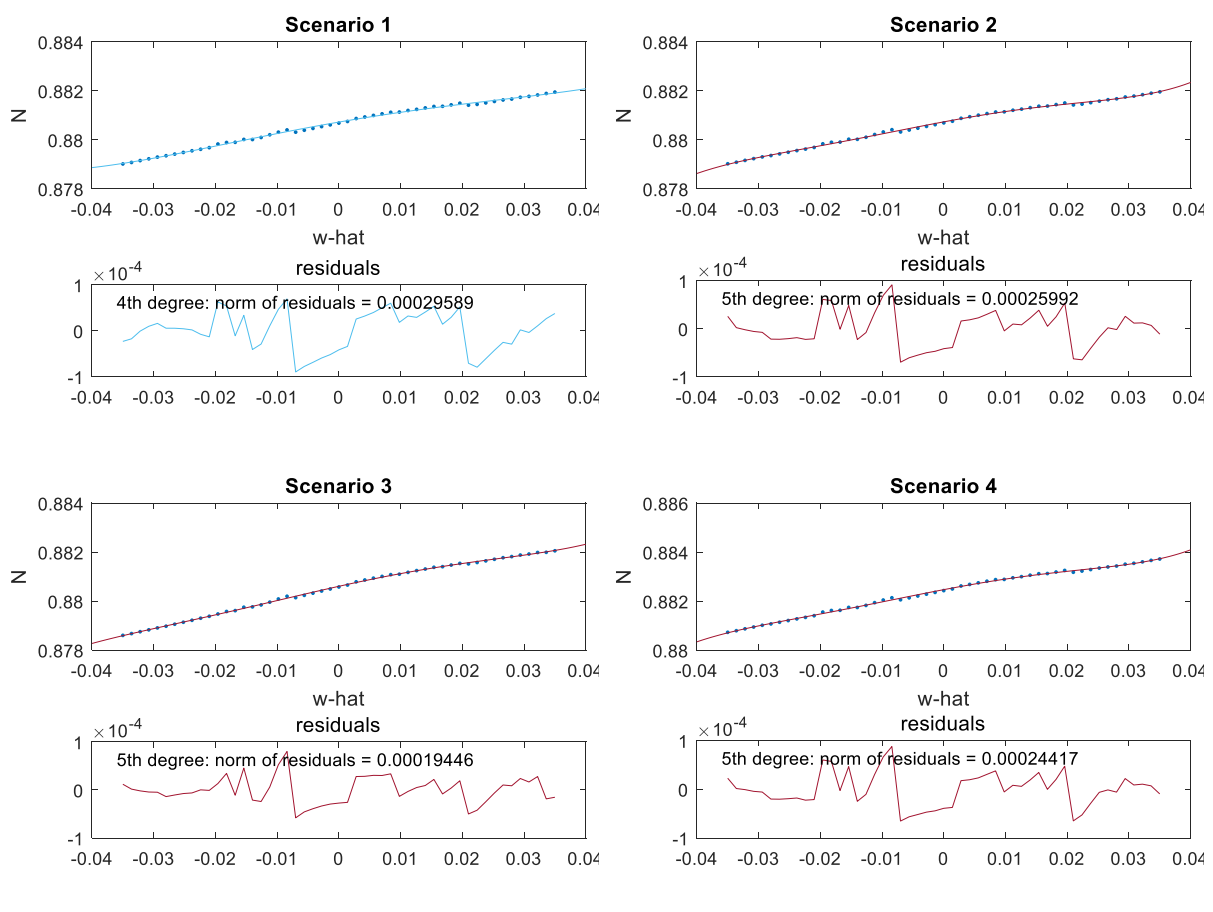
Table 2 Difference in the long-run changes indicated by the two methodologies

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
<i>N</i>	-3.96E-05	-3.98E-05	-2.58E-05	-4.30E-05
<i>L</i>	-2.03E-05	-3.98E-05	4.58E-06	3.95E-05
<i>w</i>	3.28E-05	-1.38E-05	2.18E-05	3.91E-05
<i>Y</i>	-2.15E-05	-1.46E-05	4.86E-06	4.18E-07
<i>v</i>	-1.30E-05	-1.31E-05	-8.45E-06	-1.53E-05



This is a result of our polynomials providing a good approximation to employment-wage (labour supply) schedule obtained for a discrete set of values from the microsimulation exercise. This fact is demonstrated in Figure 3 which plots the actual and fitted employment levels for various wage shocks relative to the baseline wage level under the different scenarios. As mentioned before, different approximation methods could raise this accuracy further but the obtained level of accuracy was deemed sufficient for practical purposes.

Figure 3 Employment-wage relationship: Accuracy of polynomial approximations



5 Concluding remarks

We have introduced a novel way of linking microsimulation models with dynamic general equilibrium frameworks. Our modelling approach allows us to consider the impact of a wide



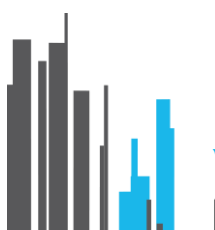
range of finely-tuned tax and benefit reforms range of effects on important aggregate and cross-sectional indicators, including their transitional dynamics, in a relatively simple simulation exercise.

We demonstrated the usefulness of this approach by evaluating the aggregate macroeconomic and fiscal effects of actual and hypothetical tax reforms in the context of Slovakia. We have shown that positive employment effects are likely to emerge if reforms are designed to increase the after-tax income of the low earners. On the other hand, reform-driven employment increases brought about through an inflow of low-skilled workers coupled with a reduction in work intensity by the highly skilled may be negative for growth. We have thus demonstrated yet again that policy makers face non-trivial trade-offs when designing tax systems.

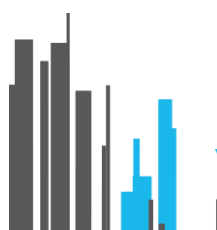
The focus of this paper has been on the aggregate macroeconomic and fiscal effects. There are two areas where important further work could be done to broaden the scope of the analysis. First, extending the analysis to have a thorough assessment of the distributive impact of reforms consistent with the general equilibrium model is a natural start. Second, whilst our model considers lots of heterogeneity in terms of income, the construction of the macro model still assumes complete insurance with regards to consumption. Relaxing this assumption is important to have a more complex understanding of the consequences of tax and benefit reforms, including specifically on indirect taxation, and to allow a meaningful welfare analysis.

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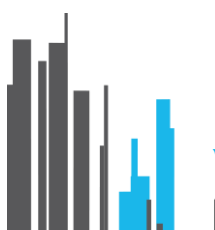
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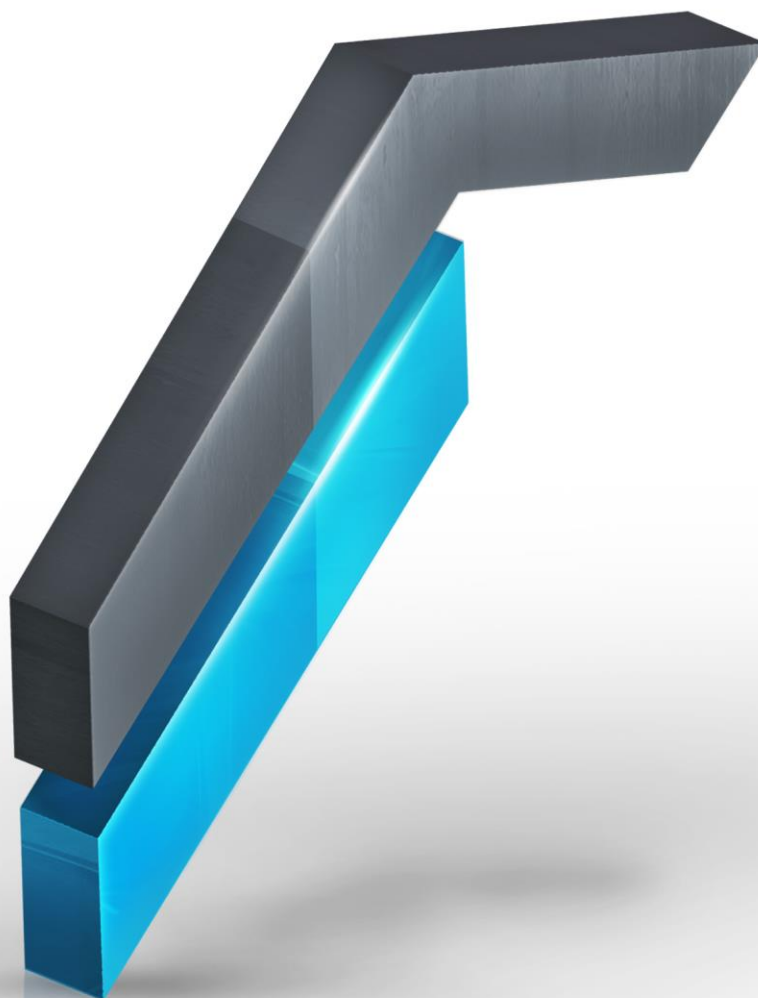


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