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The end of the flat tax experiment in Slovakia: An evaluation using behavioural microsimulation in a dynamic macroeconomic framework

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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. 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. The method involves a reduced-form representation of the information flow between the macroeconomic and microeconomic blocks. The practical usefulness of the approach is demonstrated by evaluating actual and hypothetical tax reforms that involve abandoning the flat tax system in Slovakia. A hypothetical move to a highly progressive tax structure is shown to generate some employment gains but is associated with a drop in aggregate income and tax revenue.

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

JEL classification: E24, H24, H31, J22

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1. Introduction

We introduce a new way of linking microsimulation analysis with a dynamic general equilibrium framework. The method we propose makes it easier to evaluate quantitatively the aggregate effects of reform measures over time. The aim is to facilitate important policy evaluation work as a result of which policy makers will better understand the trade-offs involved in re-designing tax and benefit frameworks. The trade-offs can be of the usual equity versus efficiency nature but a dynamic framework enables to consider the intertemporal aspects of policy design too.

The fact that (the expectations of) the dynamic evolution of the economy matter in modern macroeconomic models but (behavioural) microsimulation exercises have been typically based on static frameworks have presented researchers with a difficult challenge when blending the two together. This has been particularly true for the class of models that rely on full integration of the micro and macro blocks. Such models require the same level of detail to be coherently elaborated in both blocks of the model.

Much of the existing literature that links microsimulation models with macroeconomic frameworks is therefore static in nature. Barrios et al. (2017) is a notable exception. They exploit a key insight from the work of Magnani and Mercenier (2009) according to which the problem of agents facing a specific choice among a discrete set of alternatives can be expressed and aggregated in a consistent manner in both a behavioural microsimulation model and a suitable macroeconomic framework. The microsimulation exercise is used to calibrate effective tax rates and a set of deep (i.e. policy-invariant) parameters affecting household decision making in a large-scale dynamic stochastic general equilibrium framework augmented to enhance its consistency with the behavioural microsimulation tool. The macroeconomic framework is then operated independently. The literature refers to this as the 'bottom-up' approach to linking microsimulation and macroeconomic models which belongs to the broader category of 'layered approaches' (see Colombo, 2010, Cockburn et al., 2014, or Peichl, 2016).

We also build on the earlier literature involving static computable general equilibrium models. Our approach has, however, roots in the 'top-down/bottom-up' tradition of Savard (2003). Models using such an approach would involve an iterative algorithm which feeds information about aggregate variables into the macroeconomic framework, and then in turn channels information from the macroeconomic model back into the microsimulation block until convergence. Benczur et al. (2018), for example, have used such an iterative approach to solve for the long-run general equilibrium in their framework.

We operationalise the two-way interaction between the macroeconomic and the microeconomic block in a dynamic context by estimating a reduced-form relationship between the variables that carry the information from one framework to another. The estimation is based on pairwise observations for those key variables generated in the microsimulation block. More specifically, we discretise an interval of real wage rates, and use the microsimulation model with a given policy parameterisation to obtain aggregate outcomes, such as the employment rate, corresponding to the various points on the interval. We then estimate the parameters of a polynomial to obtain continuous non-linear functions linking the real wage rate to the aggregate outcomes which close our macroeconomic model.

The dynamic general equilibrium framework in this paper is small open economy model with a labour market augmented for the presence of matching frictions.[2] In this framework, we replace the standard equilibrium real wage determination through theoretical bargaining with the mapping of wage responses into aggregate labour supply changes obtained from a behavioural microsimulation exercise as described above.[3] It is at this point that heterogeneity enters the picture and matters for aggregate dynamics in the model. Agents at different income (and productivity) levels will react to policy changes differently, which affects the aggregate effective labour supply that drives, together with physical capital, production in the economy.

One advantage of our approach is that we can solve the macroeconomic model for the long-run equilibrium as well as the transition in one go using standard techniques. We show the equivalence of our approach and the iterative approach à la Savard (2003) when it comes to the (static) long-run steady state. Understanding the features of the transition to that long-run steady state can, however, be important for policy design. Our methodology allows to establish whether that is the case. The implication of the results from one of the scenarios we examine is that transitional dynamics can have significant welfare and fiscal implications.

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[2] Our choice of the macroeconomic framework is motivated by analytical tractability that permits distilling the key mechanisms at work, as well as 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 to provide a better match with moments in the data. Extensions in that direction are discussed in section 5.

[3] This approach echoes the analysis of Farmer (2013, 2016) 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.

Our approach also 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). At the same time, consistency in preferences that underlie the analysis in both blocks of the model is a strength of the approach. The 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).

On the other hand, a drawback of our method is that the estimated reduced-form relationship conveying information between the macroeconomic and microsimulation blocks is not policy-invariant. One can think about its slope in the neighbourhood of the steady state as the aggregate-level labour supply elasticity in linear macroeconomic models. This, however, needs to be re-estimated for each alternative policy mix under consideration. The purely bottom-up approach, instead, aims to capture the micro-level elasticities.

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).[4] Whilst the system stood the test of times in some countries, 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.

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[4] 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. On the other hand, many have 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.

Furthermore, in a hypothetical exercise, we find that a return to an even more redistributive system of graduated marginal tax rates would generate only small employment/unemployment and aggregate income changes if accompanied by cuts in allowances to ensure short-term revenue neutrality. This scenario approximates the opposite of the reform introduced in 2004. The impact on tax revenue may well be negative over time due to the job losses. 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, although there are small associated gains in employment. Similar effects are also generated in the incomplete markets setup of Holter et al. (2015).[5]

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. (2008). 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.[6]

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

[5] The approach taken in this paper as well as the solution algorithm we employ also bears resemblance to the methods used to solve such incomplete market models going back to Marcet et al. (2007). There are two differences. First, the individual-level decision function is an empirically estimated labour supply relationship. 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. 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 is that the framework can readily evaluate the consequences of a wide range of tax and benefit reforms at a fine level of detail.

[6] 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.

framework, and explains the solution algorithm. Section 3 describes the tax reform scenarios examined in the paper. Section 4 presents the key results from the baseline model while section 5 discusses the sensitivity of the results to parametric changes as well as possible extensions of the model. Section 6 concludes.

2. The model

The model used in our study is a representative-agent dynamic general equilibrium framework linked with a behavioural microsimulation part (O'Donoghue, 2014).

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. 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

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

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.[7] The parameter β is the subjective discount factor of the household. One period in our model will correspond to one quarter.

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 quarterly 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 gross real wage rate w and an idiosyncratic productivity component $\omega(i)$ with a mean of 1. This idiosyncratic component can be thought of as a combination of ex ante observable and unobservable, deterministic and stochastic components that affect productivity. Labour is assumed to be perfectly substitutable. Hence, only the aggregate quantity of effective labour obtained as a productivity-weighted sum of individual labour supplies that enter the production process matter. Wage differentials only reflect differences in productivity.

The variable $\pi(i)$ stands for dividend income. The variable $T(i)$ represent the net tax and transfer payments paid by the members of the household (which includes the income tax paid by 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.

One convenient analytical consequence of the assumption of income pooling at the household level and of perfect elasticity of capital supply (the small open economy assumption) is that they permit solving the intertemporal consumption choice at the aggregate level independently of the production side of the economy. Hence, we only have one Euler equation (9) below rather than individual-level intertemporal choice.[8]

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[7] 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.

[8] Note that income pooling within household implies permanent lump-sum transfers across household members if idiosyncratic productivity differences are permanent. Considering formally the consequences of tax and benefit measures for consumption heterogeneity (and consumption tax receipts), and in turn of the heterogeneity in wealth effects on labour supply is an important future research agenda.

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

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

Equation (3) is a key relationship in our framework. It is through this relationship that the heterogeneous consequences of tax and benefit reforms enter the macroeconomy. Different tax and benefit measures will have a differentiated effect on individual labour supply $N_t(i)$, and it is crucial for the evolution of the aggregate economy which productivity types are affected and in what way, as the individual-level impacts then get weighted by productivity to determine effective labour supply in the economy.

Aggregate employment evolves according to

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

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

$$q_t = \frac{m_t}{v_t} \tag{7}$$

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

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

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 $Y_t - (1+\tau_{w,t})w_t L_t - cv_t$.[9] These profits are taxed at a rate τ_F. The 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

$$\frac{b_t}{1+r} = b_{t-1} - \int T_t(i)di - \tau_{w,t} w_t L_t - \tau_c C_t - \tau_F[\, Y_t - (1+\tau_w)w_t L_t - cv_t] + G_t \tag{8}$$

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

[9] 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.

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

Note that $\beta(1+r) = 1$ implies a perfectly smooth profile for household utility in equilibrium. 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

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

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

The aggregate period resource constraint of the economy is given by

$$Y_t - cv_t = C_t + I + G_t + tb_t \tag{12}$$

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

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

Investments I evolve following the capital accumulation equation

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

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). 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 $x_t = \sum_{i=0}^{n} \alpha_{x,i} \widehat{w}_t^i$ for $x = \{N, L, \tau_w, \mathrm{D}\}$. [10] These estimated polynomials, or reduced-form relationships between the variables, then determine the rational expectations equilibrium in our model. [11]

The exogenous shock that sets the economy into motion is an unexpected reform of the tax-benefit system. Fiscal policy parameters are otherwise held constant. In this sense, our model is not closed, as it misses a mechanism – a fiscal policy response function – that would guarantee a non-explosive trajectory for household and government net assets in the economy. The simulations from the model should, therefore, be treated as technical projections only solved under the assumption of perfect foresight.[12]

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

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

$$L = \omega N$$

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

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

$$u = 1 - N$$

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

[10] The estimation of parameters $\alpha_{x,i}$happens independently of the macroeconomic model. They are best thought of as aggregate-level elasticities obtained from the microsimulation exercise that are invariant to the developments in the macroeconomy. For example, the parameter $\alpha_{N,1}$ could be thought of as the analogue of the constant Frisch elasticity of labour supply parameter (with respect to gross wages) commonly used in macroeconomic models. 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.

[11] Note that the household budget constraint (1) is satisfied by Walras's law.

[12] It is implicit in the equilibrium conditions that the household and government net assets satisfy the transversality condition. In general, in the absence of such a rule, we have to appeal to the possibility of the government implementing a suitable lump-sum tax in the future to ensure the asset position remains finite. In practice, the asset position remains finite in the projections we consider.

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

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

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

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

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

$$\delta K = I$$

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

In the last equation, the coefficient $\alpha_{x,0}^{t}$ is indexed by t to distinguish between (policy in) the initial steady state ($t=0$) and the final steady state ($t=T$). The value of C (and G) in the initial steady state is 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) that are modelled separately.

When using the categorization of labour supply models within microsimulation framework provided by Aaberge and Colombino (2014), the approach taken can be classified as "marginalist". The applied set up leads to a re-definition of the reservation wage (the threshold to accept a wage offer) at the cost that the participation decision needs to be constrained to a full-time job. However, in the context of Slovakia, we claim that this assumption is not significantly restrictive. According to EUROSTAT data, Slovakia is the country with one of the lowest rates of part-time employment. The share of part-time workers reached only 3.9 percent in 2012 (5.7 in 2017) as opposed to the average 19 percent reported in the EU-28. In addition, in the underlying SILC dataset corresponding to income reference period 2012, only 2 percent of employees report their actual economic status as being employed part-time. Moreover, only few employees in the sample report hours worked other than corresponding to a full-time employment. These facts led us to estimate extensive and intensive margins separately rather than employing the discrete choice approach, where a set of options is considered simultaneously.

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 model follows to some extent the approach of Benczur et al. (2014). The individuals' decision about supplying labour is based on the rationale of utility maximization consistent with the preferences used in the macroeconomic framework. 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 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.[13] We need a microsimulation tool to construct the vector of gains to work (GTW_j). 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.[14] The probability of being economically active of an individual j in the sample is estimated by a probit equation:

$$\mathrm{p}\left(\mathrm{activity}_j\right) = \Phi\left(\gamma \log GTW_j + Z_j'\alpha + \psi \log NY_j\right). \qquad (15)$$

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

[13] 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.

[14] SIMTASK is 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.

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 in general depend 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 (see Senaj et al., 2016). 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.[15]

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 $\widehat{p_j} = \Phi(\hat{\gamma} \log W_j + Z_j' \hat{\alpha} + \hat{\psi} \log NY_j)$ 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. Using a variant of Gruber and Saez (2002) approach, Bakos et al. (2008) derived a link between income growth $\widehat{w}$ and tax rates::

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

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

[15] 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.

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:

$$\widehat{h(i)} = \frac{h(i)_{sc}}{h(i)_{ba}} = 1 + \xi(\text{AETR}, \text{METR}, \widehat{w}\ ).$$

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., 2010). 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

$$\Pr(\text{IUNEMP}_j = 1) = \Phi^R(X_j'\beta). \tag{16}$$

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.[16] 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:

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

[16] 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.

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

Parameterization.- 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 of the unemployed ξ is calibrated to 0.8 in line with the search and matching literature for Slovakia (see Zeleznik, 2012 or Nemec, 2013), whilst the scaling factor of matching function μ is chosen at 0.05 in order to match Slovak data on vacancies. 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.[17] The preference parameter γ is set to 1 in the baseline parameterization.

Computing the final steady state and transitional dynamics.- In order to compute the dynamic solution to the model assuming perfect foresight, 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 Fair and Taylor (1983)-type algorithm.[18] The algorithm consists of the following steps:

1. Guess the length of transition T.

[17] The results are quantitatively sensitive to the choice of the world interest rate (see section 5). Arguably, 4 percent is high for reforms enacted in 2012. The model as presented here is, however, not meant to be a real-time forecasting tool in its current form, and it also abstracts from deeper cyclical considerations.

[18] It is possible to use linear approximation to obtain a dynamic solution for the model (see the Appendix). But given the scale of the changes in the tax system we examine in one of our scenarios, and the potential nonlinearities involved in both the theoretical setup and the microsimulation exercise generally, we decided to stick to a nonlinear solution.

2. Compute the initial steady state using $x = \alpha_{x,0}^{0}$ for $x = \{N, L, \tau_w\}$ in the system of steady-state equilibrium relationships.

3. Compute the final steady state of the model, given the parameter values, most notably the post-reform α_x's. More specifically, use $x = \alpha_{x,0}^{T}$ for $x = \{N, L, \tau_w\}$ in the system of steady-state equations.

4. Guess the path of employment from the initial steady state to the final steady state $N^0 = \{N_t^0\}_{t=0}^{T}$

5. Given the final steady state obtained in step 3, and the guess for the transition path in step 4, solve the equilibrium conditions backwards to period 2.

6. Solve the model forwards from period 1, given the transition path for q obtained in step 5.

7. 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 4 as follows: $N^0 = \vartheta N^0 + (1 - \vartheta) N^1$ with $\vartheta \in (0,1)$.

8. Repeat steps 4 to 6 until $N^0 \approx N^1$.

9. Adjust T, if necessary.

It is easy to check by inspecting the residuals from the numerical solution to the equilibrium equations that this algorithm delivers a solution. In the Appendix, we show that the solution is locally stable and unique in the neighbourhood of the steady state defined above for the parameter values considered in the numerical exercise.

In section 4, 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. (2018). 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.

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:

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 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 provides 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.[19]

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, 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.[20] The intensive and extensive margin effects thus operate in opposing directions just as in Holter et al. (2015). The right-hand panel in Figure 3 plots the labour supply response by income deciles which supports the above narrative.

In Slovakia, the original intention back in the early 2000s 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. The reversal of the flat-tax reform would leave those on the lowest incomes with lower gains from employment, and hence their

[19] 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 our concluding remarks).

[20] 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.

labour supply falls, whilst people in the middle of the income distribution approximately up to the average wage would supply more labour. The left-hand panel in Figure 3 makes it clear that the aggregate result is a composite of such relatively small labour supply effects with different signs across income deciles that tend to counteract each other.

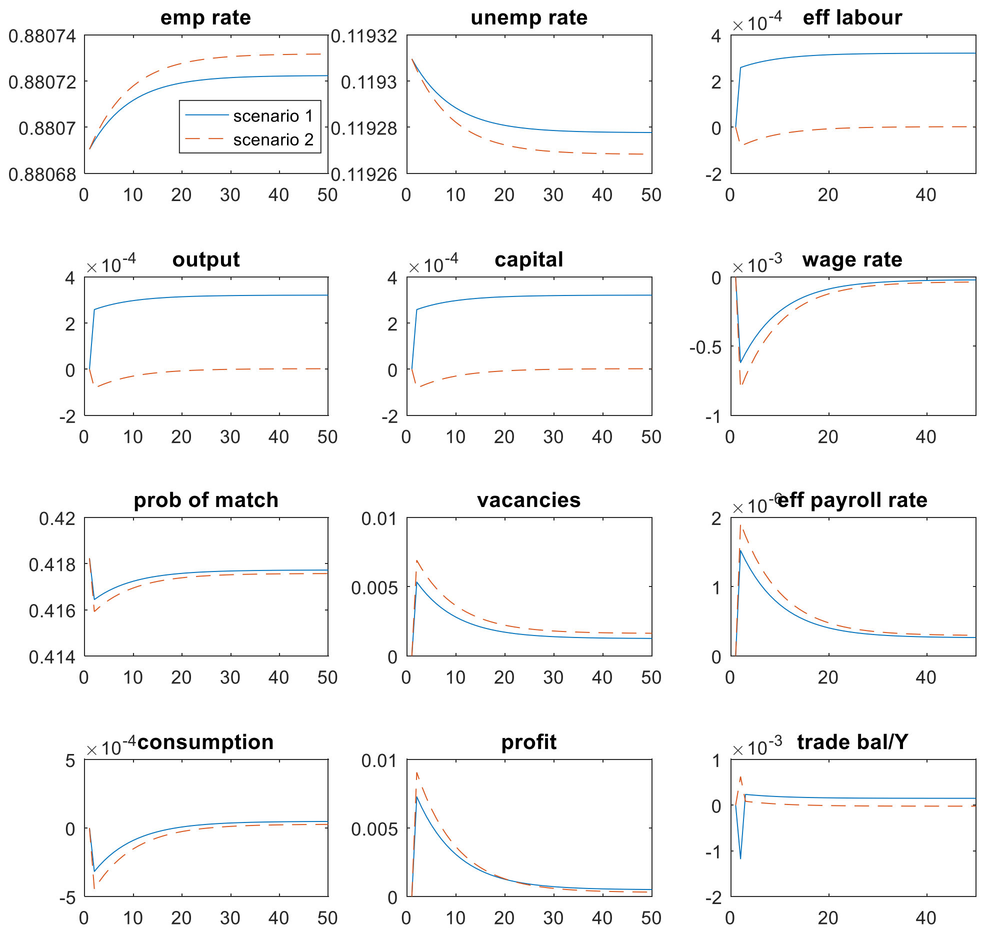
Overall, our analysis implies that the distribution of gains and losses due to the tax reforms may matter not only at the level of the individual but on aggregate too. Our method provides of way of establishing whether that is indeed the case. We saw that in the case of larger-scale reforms, it is essential to consider the extensive margin effects together with the effects on top earners to get a complex view of tax and benefit reforms.

As regards the speed of adjustment under the baseline calibration, about half of the adjustment from one steady state to another in (un)employment occurs within 7 quarters, although it may take in excess of ten years for these variables to adjust fully. By contrast, almost 70 percent of the adjustment in effective labour and capital happen on impact. This is due to the fact that the adjustment in labour supply on the intensive margin is assumed to be instantaneous. In section 5, we test the sensitivity of this speed of adjustment to different parameterizations and extensions of the model. The real wage rate and household consumption undershoot their long-run levels in transition in three out of the four scenarios we consider which is important for welfare considerations.

For the sake of completeness, in Table 1 we display static as well as the long run fiscal effects for some items of the budget obtained by plugging back the macroeconomic outcomes into our microsimulation tool. 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.

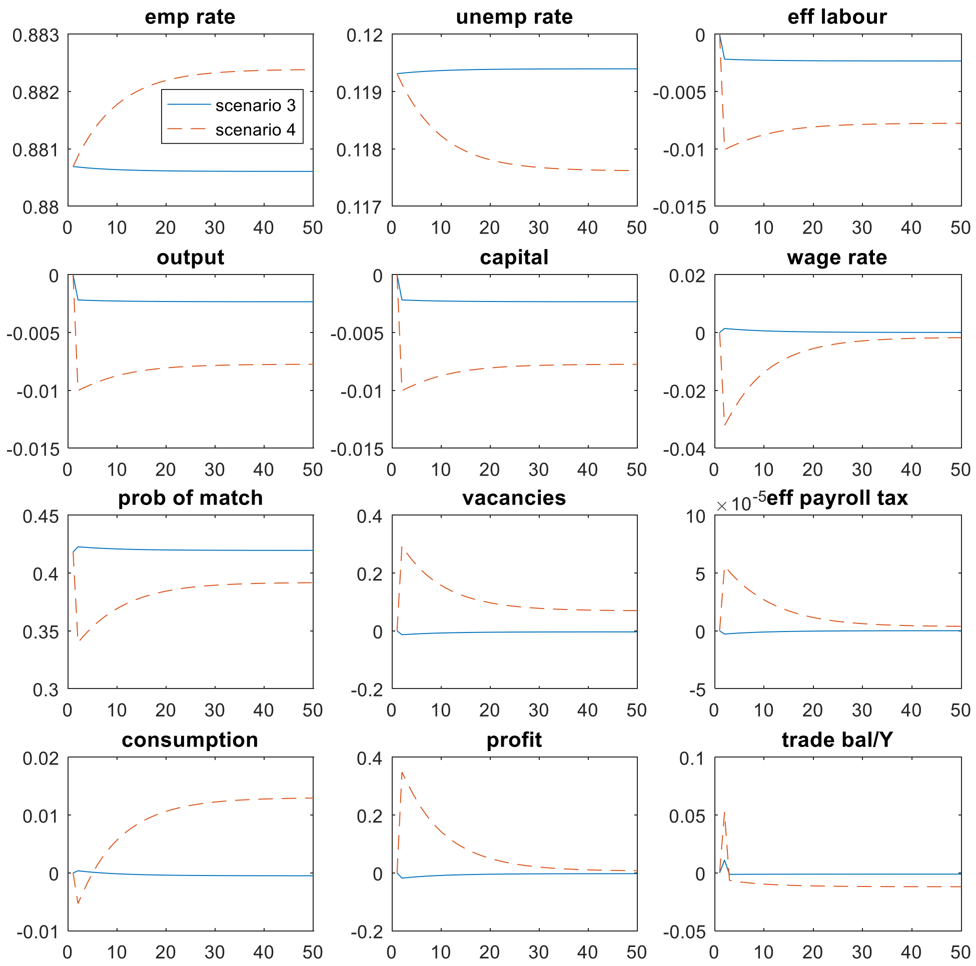
The tax systems simulated in the third and fourth scenarios are constructed to be approximately fiscally neutral in a static simulation. The long run effects are therefore more interesting. Under scenario 3, we see a significant drop in personal income tax and the related social insurance contributions. 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.

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



Notes: The employment and unemployment rates, and the probability of a match are reported in levels. The responses of effective labour, output, capital, the wage rate, vacancies, consumption and profit are reported in percentages of initial steady-state values. The effective payroll rate, the trade balance-to-output ratio are reported as a percentage-point difference relative to the initial steady state. On the horizontal axes, we have units of time in quarters.

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



Notes: The employment and unemployment rates, and the probability of a match are reported in levels. The responses of effective labour, output, capital, the wage rate, vacancies, consumption and profit are reported in percentages of initial steady-state values. The effective payroll rate, the trade balance-to-output ratio are reported as a percentage-point difference relative to the initial steady state. On the horizontal axes, we have units of time in quarters.

Figure 3 The distribution of the labour supply response in the final steady state

Scenario 3	Scenario 4

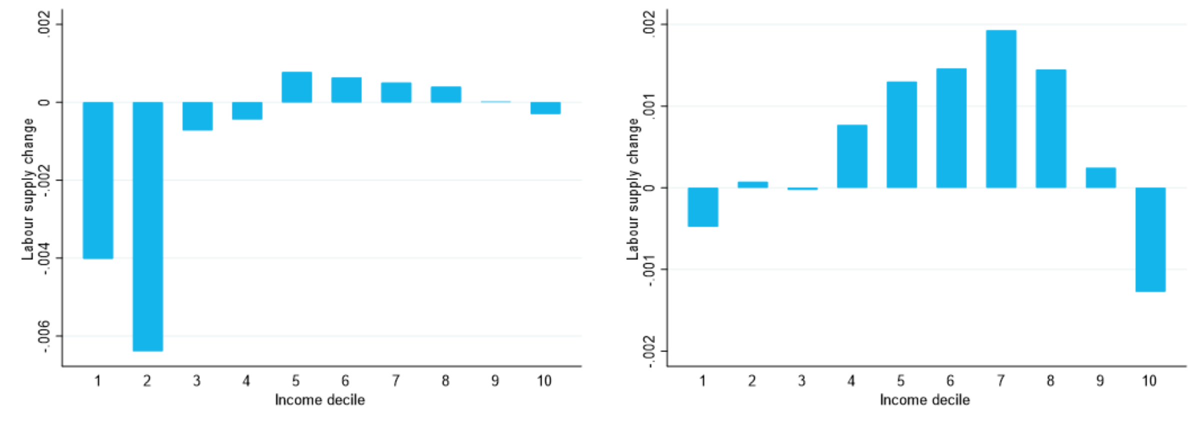


Table 1 Percentage change in fiscal variables under different scenarios

	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 contributions	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 contributions	0.2	0.0	-1.0	-4.1
Social benefits	-0.2	-0.2	0.7	-0.4

In principle, one could compute the fiscal effects for any or all periods along the whole transition path based on the path for the probability of employment and the real wage rate. The real wage rate tends to undershoot its long-run level in three out of the four scenarios considered. In those cases, the transitional fiscal effects are likely to be worse than the long-run outcomes.

Further fiscal implications can be derived from the macroeconomic model. Assuming constant effective tax rates, the tax intake will mimic the dynamics of the tax bases. In the scenarios in which consumption undershoots its final steady-state level, indirect taxation will act to worsen the budget balance in transition. By contrast, in scenario 4, net-asset-financed increases in consumption and a rise in corporate profits will act to compensate for the shortfall in personal income taxation.

Table 2 Comparison of steady-state results under two methodologies (in %)

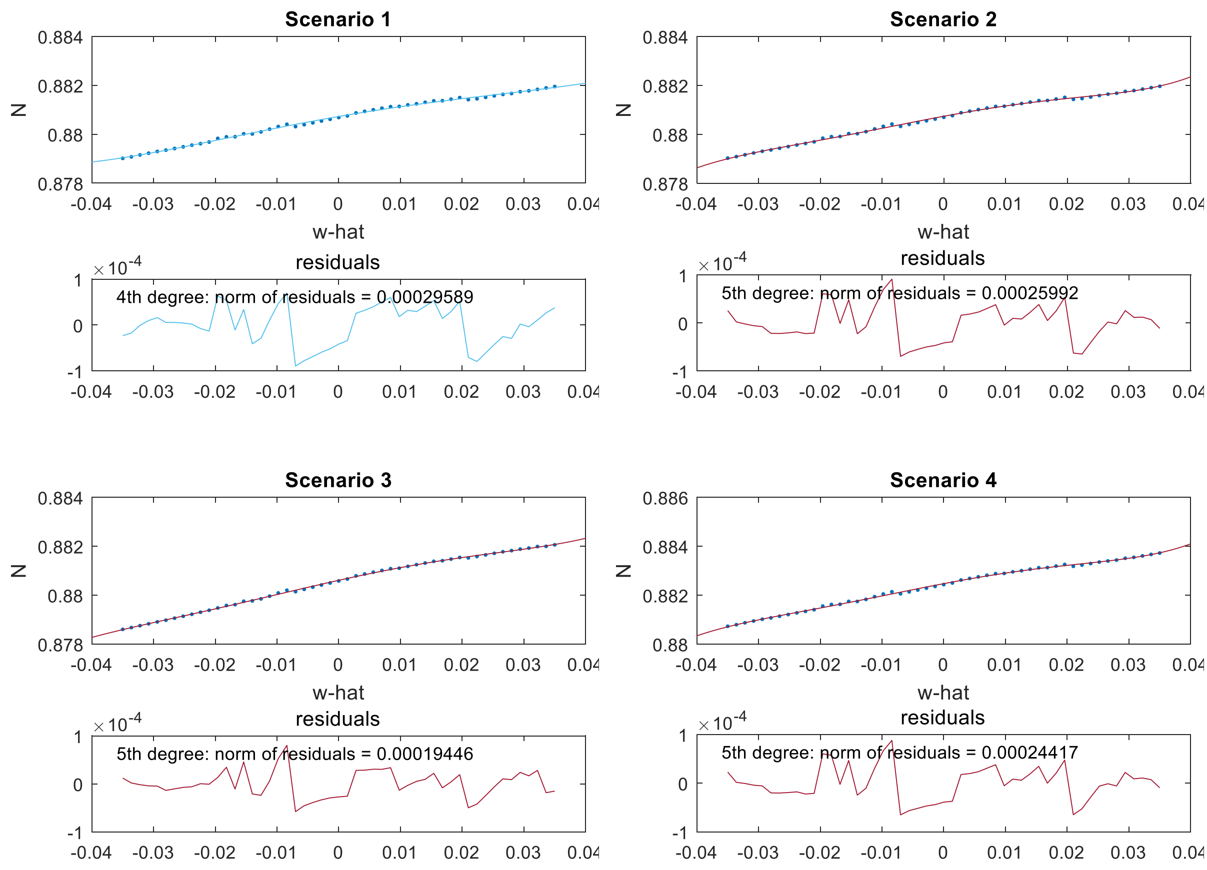
	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Employment rate	0.004	0.005	0.003	0.005 (2.598)
Effective labour	0.002	0.001	0.000	0.000 (0.005)
Gross wage rate	0.003	0.003	0.002	0.004 (2.426)
Output	0.002	0.001	0.000	0.000 (0.005)
Vacancy rate	0.155	0.156	0.101	0.182 (2.702)

Notes: The numbers in the table give the absolute value of the difference in the solutions for the final steady-state value of the respective variables using our methodology versus the iterative procedure of Savard (2003) as a percentage of the initial steady-state value of the respective variable. The values are in percentages with 1 denoting 1 percent. The values in the brackets in the last column normalise the same absolute difference by the absolute value of the change in the variable between the two steady states.

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. In Table 2, we report two normalised measures of the distance between the two solutions. The main measure reported for all four scenarios is the absolute value of the difference in the solutions for the final steady-state value of the respective variables using our methodology versus the iterative procedure of Savard (2003) expressed as a percentage of the initial steady-state value of the respective variable (1 in the table corresponds to 1 percent deviation).

For scenario 4, we also report the same absolute difference in the solution for the final steady state across the two methodologies expressed as a percentage of the absolute value of the change in the value of the respective variable from one steady state to another. Clearly, this latter measure is more relevant, as it better captures the intuitive notion of accuracy one would like to achieve in these simulation exercises. This measure can, however, provide disproportionately large values if the magnitude of the change across steady states (the denominator) is very small which is the case in our scenarios 1 to 3. Reassuringly, both measures indicate very small differences in the case of scenario 4.

Figure 4 Employment-wage relationship: Accuracy of polynomial approximations



Notes: The dots in the top panels in the figures show the aggregate labour supply responses corresponding to different wage levels under a given scenario obtained from the behavioural microsimulation exercise. The solid lines show the polynomial providing the best fit. The bottom panels plot the residuals from the estimation of the polynomial.

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 4 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.

5. Sensitivity checks and extensions

In the macroeconomic module of the model, we rely extensively on calibration. The parameter values used in the baseline version were based on observed or estimated values for Slovakia. Nevertheless, it is interesting to explore the consequences of alternative values, especially for the speed of transition from one steady state to another following a policy change. In this section, therefore, we explore the sensitivity of the baseline results to some key parameter values.

We also extend the model to include more real rigidity to see how transition from one steady state to another is affected. Specifically, we introduce capital adjustment costs, and explore the consequences of their presence for the speed of adjustment in the labour market.

We could also consider habit persistence in consumption - a commonly used features of DSGE models. Note, however, that the macro model can be solved in two separate blocks with (3), (4), (5), (6), (7), (10), (11) and the relevant polynomials for N, L and τ_w representing a self-standing system determining adjustment in the labour market. Hence, adding habit persistence in consumption would only affect the dynamic of aggregate consumption in this model. Nevertheless, this extension could be a useful extension to improve the performance of the model vis-à-vis data.

In an analysis in which labour market dynamics play a central role, it comes as natural to raise the potential role for (real) wage rigidity. In our framework, the interaction between employers and job seekers/employees is fully dealt with in the empirical section. The estimations that underlie our reduced-form labour supply schedule described in section 2 are all based on a static optimization problem. The clean way of introducing wage rigidity would be to consider their dynamic version. This is a major task and would be a significant self-standing contribution to the empirical literature too.

We also tried introducing convex costs of adjustment in (effective) employment levels in the spirit of Nickell (1986) to inject more dynamics into labour demand, and to account for costs related to employment fluctuation not accounted for by matching frictions. While such modification has the potential to affect dynamics in the model, the level of costs (as a percentage of aggregate output) that have to be assumed to generate a significant deviation from the baseline results is unrealistically large.

In what follows, we shall demonstrate the effects of alternative parameter values and the extension to the model on Scenario 4 given that the magnitude of the effects induced by the policy change is largest, and hence the consequences of parametric changes are likely to be most visible.

5.1. Alternative parameter values

In all our alternative calibrations, we have to make sure the initial steady state of the model is consistent with the (un)employment rates, aggregate productivity ω, the vacancy rate, and the effective employers' contribution rate τ_w observed in the empirical sample. We achieve this by adjusting the parameter μ in the matching function to an appropriate value.

We consider three alternative parameterisations to the baseline version of the model. First, the world real return is doubled to two percent quarterly. Second, parameter λ driving exogenous job separation in the labour market is increased from approximately 0.004 to 0.006. Finally, elasticity of matching χ is increased from 0.8 to 0.9.

Such parametric changes have a notable impact on the speed of adjustment in the model. By contrast, we have found our results in terms of dynamics to be fairly robust to the parameters of the production function.

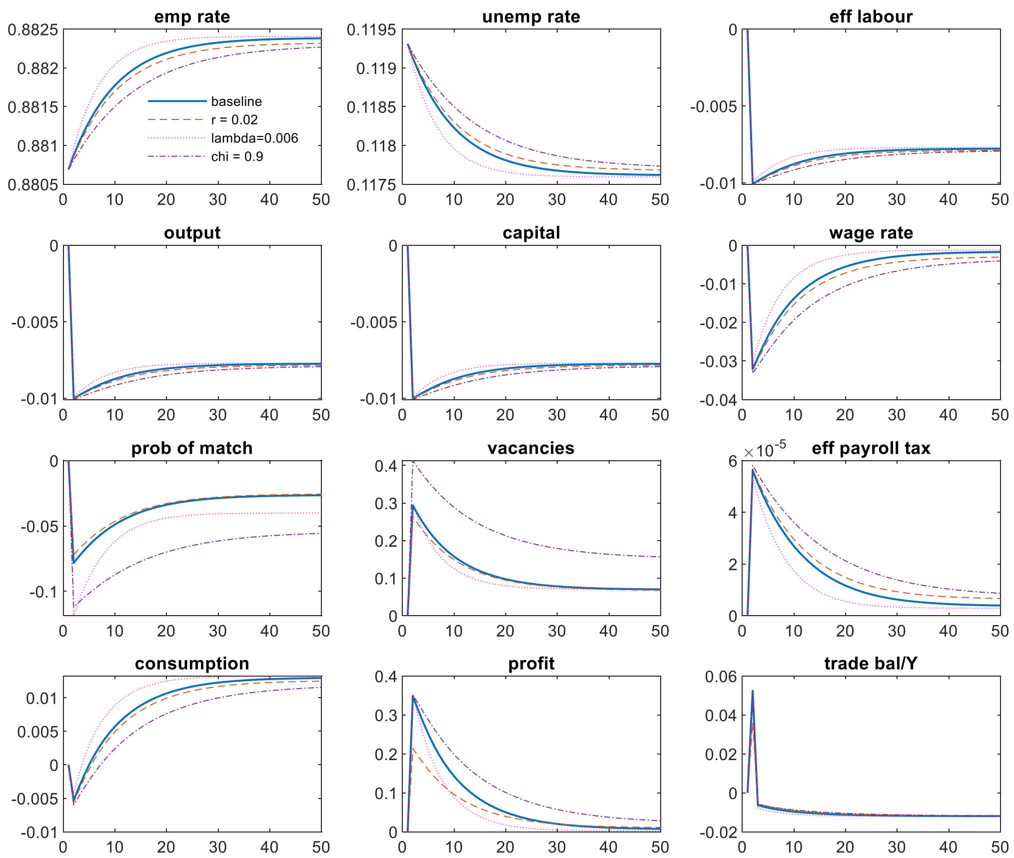
Figure 5 displays the consequences of the mentioned parametric changes for dynamics in the model economy.

The world real rate of return is intrinsically linked to the rate of time preference in this framework. Doubling it is equivalent to increasing the rate of time preference of agents or reducing their discount factor. As firms discount the gains from continuation of a match in the labour market more heavily, fewer such matches happen, and the (un)employment rate adjusts more gradually too.

Increasing the exogenous separation rate leads to a faster adjustment on the extensive margin in the labour market. About half of the adjustment in employment now happens within just 5 quarters as opposed to 7 quarters in the baseline version. This has obviously implications for the evolution of vacancies and the probability of finding a match. As consumption is non-separable from labour in our model, consumption dynamic follows the same pattern. By contrast, effective labour driven also by the adjustment on the intensive margin is affected to a lesser extent.

On the other hand, if vacancies are turned into a match less effectively, the adjustment takes longer. With $\chi = 0.9$, it takes 10 quarters for employment to achieve half of the adjustment.

Figure 5 Sensitivity analysis (scenario 4)



Notes: The employment and unemployment rates are reported in levels. The responses of effective labour, output, capital, the wage rate, vacancies, consumption and profit are reported in percentages of initial steady-state values. The effective payroll rate, the probability of a match and the trade balance-to-output ratio are reported as a percentage-point difference relative to the initial steady state. On the horizontal axes, we have units of time in quarters.

5.2. A model with capital adjustment costs

We model capital adjustment costs following Mendoza (1991).[21] The firms' production function (2), and the profit function get augmented for a cost term of the following form: $\frac{\varphi}{2}(K_{t+1} - K_t)^2$ with φ being a small positive parameter. As a consequence, the aggregate resource constraint (12) becomes

$$Y_t - cv_t - \frac{\varphi}{2}(K_{t+1} - K_t)^2 = C_t + I + G_t + tb_t, \tag{18}$$

while the firms' first-order condition with respect to capital is modified to

$$\alpha K_t^{\sigma-1}[\alpha K_t^{\sigma} + (1-\alpha)L_t^{\sigma}]^{\left(\frac{1}{\sigma}-1\right)} + \beta\varphi(K_{t+1} - K_t) - \beta^{-1}\varphi(K_t - K_{t-1}) = \frac{r}{(1-\tau_F)}. \tag{19}$$

In Figure 6, we plot the response of the macroeconomy in the baseline model together with the response in the extended version in which firms pay a three-percent capital adjustment cost ($\varphi = 0.03$) which is a value close to the value used in Mendoza (1991).

The main consequence of introducing capital adjustment costs is a slower adjustment in capital, and a more subdued improvement in the external balance, as demand for investment contracts less sharply. Dynamics elsewhere in the economy remain largely unaffected. As in Mendoza (1991), this form of rigidity can improve the model's ability to better match investment volatility in the model economy with observed volatility in the data.

6. Concluding remarks

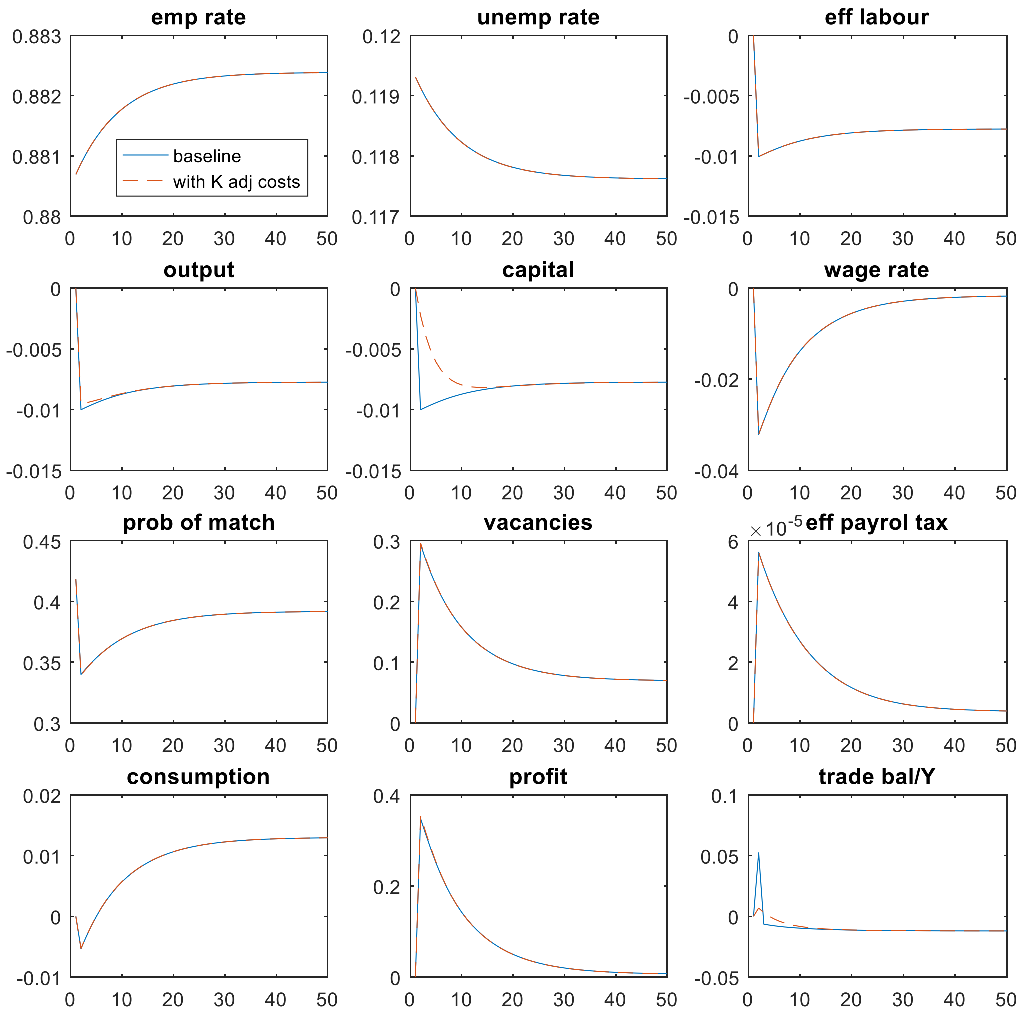
We have introduced a novel way of linking microsimulation models with dynamic general equilibrium frameworks. Our modelling approach allows us to consider the impact of a wide range of finely-tuned tax and benefit reforms range of effects on important aggregate and cross-sectional indicators, including 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

[21] Investment adjustment costs à la Christiano et al. (2005) could be a somewhat more elaborate alternative. We prefer the approach that naturally extends our simple baseline framework.

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.

Figure 6 The response of the macro variables under scenario 4 with and without capital adjustment costs



Notes: The employment and unemployment rates, and the probability of a match are reported in levels. The responses of effective labour, output, capital, the wage rate, vacancies, consumption and profit are reported in percentages of initial steady-state values. The effective payroll rate is given in percentage point differences while the trade balance-to-output ratio is reported as a percentage-point difference relative to the initial steady state. On the horizontal axes, we have units of time in quarters.

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.

References

Aaberge R. and Colombino, U., 2014, Labour Supply Models, in: O'Donoghue, C., (ed.), Handbook of Microsimulation Modelling, Contributions to Economic Analysis, vol. 293, 167-221, Emerald Group Publishing Limited.

Altig, D., Auerbach, A.J., Koltikoff, L.J., Smetters, K.A. and Walliser, J., 2001, Simulating Fundamental Tax Reform in the United States, American Economic Review, 91(3), 574-595.

Anagnostopoulos, A., Atesagaoglu, O.E. and Carceles-Poveda, E., 2014, On the Double Taxation of Corporate Profits, Mimeo., Stony Brook University.

Azacis, H. and Gillman, M., 2010, Flat tax reform: The Baltics 2000-2007, Journal of Macroeconomics, 32(2), 692-708.

Bakos, P., Benczur, P. and Benedek, D., 2008, The elasticity of taxable income: Estimates and flat tax predictions using the Hungarian tax changes in 2005, National Bank of Hungary Working Paper 2008/7.

Bargain, O., Caliendo, M., Haan, P., Orsini, K., 2010, Making work pay in a rationed labour market, Journal of Population Economics, 23(1), 323-351.

Barrios, S., Dolls, M., Maftei, A., Peichl, A., Riscado, S., Varga, J. and Wittneben, C., 2017, Dynamic Scoring of Tax Reforms in the European Union, Zew Discussion Paper No. 17-017.

Bencik, M. 2008, Methods for Detecting Disequilibrium in the real Economy of Slovak Republic. NBS Working Paper 2008/2, National Bank of Slovakia.

Benczur, P., Katay, G., Kiss, A., 2018, Assessing the economic and social impact of tax and benefit reforms: A general-equilibrium microsimulation approach applied to Hungary, Economic Modelling (forthcoming).

Benczur P., Katay G., Kiss A., Racz O., 2014, Income Taxation, Transfers and Labour Supply at the Extensive Margin, Working Papers 487, Banque de France.

Blanchard, O.J., Galí, J., 2010, Labor markets and monetary policy: A New Keynesian model with unemployment, American Econmic Journal: Macroeconomics. 2 (2), 1–30.

Blanchard, O.J., Kahn, C.M., 1980, The Solution of Linear Difference Models under Rational Expectations, Econometrica, 48(5), 1305-1311.

Bourguignon F., Robilliard, A.S. and Robinson, S., 2005, Representative versus real households in the macro-economic modelling of inequality, in: Kehoe, T.J., Srinivasan, T.N. and Whalley, J. (eds): Frontiers in Applied General Equilibrium Modeling: In Honor of Herbert Scarf, Cambridge University Press, Chapter 10.

Cassou, S.P. and Lansing, K.J., Growth Effects of Shifting from a Graduated-rate Tax System to a Flat Tax, Economic Inquiry, 42(2), 194-213.

Chetty, R., Guren, A., Manoli D., S. and Weber, A., 2013, Does Indivisible Labor Explain the Difference Between Micro and Macro Elasticities? A Meta-Analysis of Extensive Margin Elasticities, in Acemoglu, D., Parker, J. and Woodford, M. (eds.), The NBER Macroeconomics Annual, 27, 1-56.

Christiano, L.J., Eichenbaum, M. and Evans, C.L., 2005, Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy, Journal of Political Economy, 113 (1), 1-45.

Cockburn J., Savard, L. and Tiberti, J., 2014, Macro-Micro Models, in Cathal O'Donoghue (ed.), Handbook of Microsimulation Modelling, Contributions to Economic Analysis, vol. 293, 275-304, Emerald Group Publishing Limited.

Colombo, G., 2010, Linking CGE and Microsimulation Models: A Comparison of Different Approaches, International Journal of Microsimulation, 3(1), 72-91.

Conesa, J.C., Kitao, S. and Krueger, D., 2009, Taxing Capital? Not a Bad Idea after All!, American Economic Review, 99(1), 25-48.

Diamond, P. and Saez, E., 2011, The Case for a Progressive Tax: From Basic Research to Policy Recommendations, Journal of Economic Perspectives, 25(4), 165-90.

Diaz-Gimenez, J. and Pijoan-Mas, J., 2006, Flat Tax Reforms In The U.S.: A Boon For The Income Poor, Working Papers wp2006_0611, CEMFI.

Duncan D., Sabirianova Peter, K., 2010, Does Labour Supply Respond to a Flat-tax?, Economics of Transition, 18 (2), 365 – 404.

European Commision, 2013, Labour market developments in Europe, 2013. European Economy 6/2013.

Fair, R.C. and Taylor, J.B., 1983, Solution and Maximum Likelihood Estimation of Dynamic Nonlinear Rational Expectations Models, Econometrica, 51 (4), 1169-1185.

Farmer, R.E.A., 2013, Animal Spirits, Financial Crises and Persistent Unemployment, The Economic Journal, 123 (May), 317-340.

Farmer, R.E.A., 2016, The Evolution of Endogenous Business Cycles, Macroeconomic Dynamics, 20(2), 544-557.

Fuest, C., Peichl, A. and Schaefer, T., 2008, Is a flat tax reform feasible in a grown-up democracy of Western Europe? A simulation study for Germany, International Tax and Public Finance, 15(5), 620-636.

Gruber, J. and Saez, E., 2002, The elasticity of taxable income: evidence and implications, Journal of Public Economics, 84, 1–32.

Hall, R.E. and Rabushka, A., Low Tax, Simple Tax, Flat Tax, 1983, McGraw Hill.

Hausman, J.A., 1981, Labor Supply. How Taxes Affect Economic Behavior, in H. Aaron and J.Pechman (eds.), The Brookings Institution, Washington D.C., 27-72.

Heathcote, J. and Tsujiyama, H., 2015, Optimal Income Taxation: Mirrlees Meets Ramsey, Federal Reserve Bank of Minneapolis, Research Department Staff Report 507.

Holter, A.H., Krueger, D. and S. Stepanchuk, 2015, How Does Tax Progressivity and Household Heterogeneity Affect Laffer Curves?, NBER Working Paper No. 20688

Ivanova, A., Keen, M. and Klemm, A., Pestieau, P. and Velasco, A., 2005, The Russian Flat Tax Reform, Economic Policy, 20(43), 397+399-444.

Keen, M., Kim, Y. and Varsano, R., 2008, The "Flat Tax(es)": Principles and Experience, International Tax and Public Finance, 15(6), 712-756.

Kiss, A. and Mosberger, P., 2015, The elasticity of taxable income of high earners: evidence from Hungary, Empirical Economics, 48 (2), 883-908.

Krajcir, Z. and Odor, L., 2005, Prvy rok danovej reform alebo 19% v akcii [The first year of the tax reform or 19 percent in action], Financial Policy Institute, Economic Analysis No. 8.

Marcet, A., Obiols-Homs, F. and Weil, P., 2007, Incomplete markets, labor supply and capital accumulation, Journal of Monetary Economics, 54, 2621-2635.

Magnani, R. and Mercenier, J., 2009, On linking microsimulation and computable general equilibrium models using exact aggregation of heterogeneous discrete-choice making agents, Economic Modelling, 26, 560-570.

Mankiw, N.G., Weinzierl, M.C. and Yagan, D.F., 2009, Optimal taxation in theory and practice, Journal of Economic Perspectives, 23(4), 147-174.

Mendoza, E. G., 1991, Real Business Cycles in a Small Open Economy, American Economic Review, 81(4), 797-818.

McClelland, R. and Mok, S., 2012, A Review of Recent Research on Labor Supply Elasticities, Congressional Budget Office.

Mirrlees, J.A., 1971, An Exploration in the Theory of Optimal Income Taxation, Review of Economic Studies, 38, 175-208.

Nemec, D., 2013, Investigating Differences Between the Czech and Slovak Labour Market Using a Small DSGE Model with Search and Matching Frictions, Czech Economic Review 7, 21-41.

Nickell, S.J., 1986, Dynamic Models of Labour Demand, in: Ashenfelter, O. and Layard, R. (eds.): Handbook of Labor Economics, Elsevier, Chapter 9, pp. 473-522.

O'Donoghue, C., 2014, Handbook of Microsimulation Modelling, in Cathal O'Donoghue (ed.) Handbook of Microsimulation Modelling (Contributions to Economic Analysis, Volume 293) Emerald Group Publishing Limited.

Peichl, A., 2009, The Benefits and Problems of Linking Micro and Macro Models – Evidence from a Flat Tax Analysis, Journal of Applied Economics, 12(2), 301-329.

Peichl, A., 2016, Linking Microsimulation and CGE models, International Journal of Microsimulation, 9(1), 167-174.

Savard, L., 2003, Poverty and income distribution in a CGE-household micro-simulation model: top-down/bottom up approach', CIRPEE Working Paper 03-43, Laval University.

Senaj M., Siebertova Z., Svarda N., Valachyova J., 2016, Labour force participation elasticities and the move away from a flat tax: the case of Slovakia, IZA Journal of European Labor Studies, Volume 5

Siebertova Z., Svarda N., Valachyova J., 2016, Improving the validity of microsimulation results: lessons from Slovakia, International Journal of Microsimulation, 9(2), 77–105

Tuomala, M., 1984, Optimal Degree of Progressivity under Income Uncertainty, Scandinavian Journal of Economics, 86(2), 184-193.

Tuomala, M., 1990, Optimal Income Tax and Redistribution, Oxford University Press.

Ventura, G., 1999, Flat tax reform: A quantitative exploration, Journal of Economic Dynamics and Control, 23, 1425-1458.

Zelenak, L. and Moreland, K., 1999, Can the Graduated Income Tax Survive Optimal Tax Analysis, Tax Law Review, 53, 51-93.

Zeleznik, M., 2012, Labour Market in Central European Countries: Small Search and Matching DSGE Model, Biatec, 20 (10), 12-16.

Appendix

As mentioned in the text, the macro model can be solved in two separate blocks with (3), (4), (5), (6), (7), (10), (11) and the relevant polynomials for $N, L \; and \; \tau\_w$ representing a self-standing system determining adjustment on the production side. Given our assumptions about income pooling at the household level and the small open economy setting, the dynamics of the other variables describing the rest of the economy can then be easily solved based on the solution to this system.

Here, we provide a linear approximation to this inner core of the economy to demonstrate that the solution to the equilibrium is locally unique and stable in the neighbourhood of the model's steady state.

The nonlinear system of (3), (4), (5), (6), (7), (10), (11) and the relevant polynomials for $N, L \; and \; \tau\_w$ can be approximated to the first order as follows:

$$\widehat{\omega}_t = \widehat{L}_t - \widehat{N}_t$$

$$\widehat{N}_t = (1-\lambda)\widehat{N}_{t-1} + \frac{qv}{N}(\widehat{v}_t + \widehat{q}_t)$$

$$\widehat{m}_t = \xi \widehat{u}_t + (1-\xi)\widehat{v}_t$$

$$\widehat{u}_t = -\frac{N}{u}\widehat{N}_t$$

$$\widehat{q}_t = \widehat{m}_t - \widehat{v}_t$$

The first-order approximation to (10) implies

$$\widehat{K}_t = \widehat{L}_t$$

This, in turn, simplifies the approximation to (11) to

$$\widehat{q}_t = (1-\lambda)\beta E_t \widehat{q}_{t+1} + \frac{(1+\tau_w)w\omega q}{c}\widehat{w}_t + \frac{\tau_w w\omega q}{c}\widehat{\tau}_{wt} + [(1-\lambda)\beta - 1]\widehat{\omega}_t.$$

Finally, we have $\widehat{x}_t = \frac{\alpha_{1,x}}{\alpha_{0,x}}\widehat{w}_t$ for $x = L, N, \tau_w$.

In these equations, the symbol '^' denotes percentage deviations from steady state of a given variable.

This system can be reduced to a linear dynamic system of two equations and two unknowns:

$$A\begin{pmatrix} \widehat{w}_t \\ E_t\widehat{q}_{t+1} \end{pmatrix} = B\begin{pmatrix} \widehat{w}_{t-1} \\ \widehat{q}_t \end{pmatrix}$$

with

$$A = \begin{pmatrix} \frac{\alpha_{1,N}}{\alpha_{0,N}}(1+\frac{qv}{u}) & 0 \\ [1-(1-\lambda)\beta]\left(\frac{\alpha_{1,L}}{\alpha_{0,L}} - \frac{\alpha_{1,N}}{\alpha_{0,N}}\right) + \frac{w\omega q}{c}\left(1+\alpha_{0,\tau_w}+\alpha_{1,\tau_w}\right) & (1-\lambda)\beta \end{pmatrix}$$

and

$$B = \begin{pmatrix} (1-\lambda)\frac{\alpha_{1,N}}{\alpha_{0,N}} & \frac{qv}{N}(1-\xi^{-1}) \\ 0 & 1 \end{pmatrix}.$$

To check if the Blanchard-Kahn (1980) conditions are satisfied, we need to inspect the eigenvalues of $A^{-1}B$. Given that we have one predetermined and one jump variable, we need one eigenvalue to be inside and one outside the unit circle in order for the system to have a unique and stable solution in the neighbourhood of the steady state.

Table A1 below shows that the eigenvalues for the four scenarios examined in the main part of the paper satisfy this requirement. Hence, for initial values in the neighbourhood of the (final) steady state, the system converges to the steady state along a unique equilibrium path.

Table A1 Eigenvalues

	Scenario 1	**Scenario 2**	**Scenario 3**	**Scenario 4**
Eigenvalues	0.8855	0.8856	0.8934	0.8896
	1.1080	1.1079	1.0982	1.1024