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Abstract

This paper studies the effects of labour market reforms on the functional distribution of income in a DSGE model (Roeger et al., 2008) with skill differentiation, in which households supply three types of labour: low-, medium- and high-skilled. The households receive income from labour, tangible capital, intangible capital, financial wealth and transfers. We trace how structural reforms in the labour market affect these different types of income. The quantification of labour market reforms is based on changes in structural indicators that significantly reduce the gap of the EU average income towards the best-performing EU countries. We find a general trade-off between an increase in employment for a particular group and the income of the average group member relative to income per capita. Reforms that increase employment of low- and medium-skilled workers imply a trade-off between employment and wages in the low- and medium-skilled group, due to the increase in the skill-specific supply of labour. Capital owners generally benefit from labour market reforms, with an increasing share in total income. This can be attributed to limited entry into the final goods production sector, underlining the importance of product market reforms in addition to labour market reforms.

JEL-Codes: C330, D580, E250, J200.

Keywords: labour market reforms, dynamic general equilibrium modelling, income distribution, inequality.

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1. Introduction

The prolonged slowdown of GDP growth after financial crises has reinforced the need for structural reforms in the European Union. At the same time, *income* inequality remains at historically high levels in many countries (Keeley, 2015; OECD, 2011, 2015a, 2016). In particular, high-income households have benefited more than middle- and low-income ones from the post-crisis recovery. High unemployment and low wage growth have prevented a recovery of labour incomes at the bottom of the income distribution. In fact, the real labour income of the bottom 10% has declined in most EU Member States during 2010-2014, i.e. not only in countries in which average real labour income has declined. Rising primary income inequality has, furthermore, not been compensated by a (general) strengthening of redistribution through the tax and transfer system. Corresponding trends in the distribution of household *wealth* are summarised, e.g., in Murtin and Mira d'Ercole (2015).

The joint occurrence of slow growth and persistent inequality raises questions about causes and possible remedies. Potential drivers of inequality, which include skill-biased technological progress, the effects of globalisation, or the consequences of fiscal consolidation, have received widespread attention in the literature (see, e.g., Card and DiNardo, 2002; Agnello and Sousa, 2014; Keeley, 2015; Lopez Gonzalez et al., 2015). Less attention has been devoted to possible remedies, besides standard redistribution by taxes and transfers. This applies in particular to the role of structural reform and the question of complementarity ('inclusive growth') or incompatibility between the growth and equity objectives.

Traditionally, structural reforms have been assessed on the basis of their potential to increase productivity and GDP per capita. Their distributional impact is rarely addressed in the literature, as emphasised by Causa et al. (2016). This paper contributes to the emerging literature on the distributional impact of structural reforms. It studies the impact of structural reforms in the labour market on the functional distribution of income in the EU economy. The analysis uses a DSGE model of the EU economy (Roeger et al., 2008) in which households supply three types of labour, i.e. low-, medium- and high-skilled. Households receive income from labour, tangible capital, intangible capital, financial wealth, and transfers, and we trace how structural reforms affect these different types of income.

We rely on Varga and in 't Veld (2014) for a realistic quantification of structural reforms and apply a distance-to-frontier approach that calibrates the potential for reforms to a gradual and partial closure of the gap in labour market indicators vis-à-vis the average of the three best EU performers. More prcisely, the simulated structural reforms in this paper focus on increasing the labour market participation rate of the 55-65 age group, the low-skilled, and female workers and on raising (by education and training) the share of medium- and high-skilled workers in the labour force.

The results of the paper can be summarised as follows: There is a trade-off between employment and relative labour incomes. In general, reforms which aim at increasing the employment rate of low- and medium-skilled workers are associated with a fall of the respective wages relative to income per capita. This effect can be decomposed into wage distribution effects across skill groups, but the overall increase in the supply of labour also affects the distribution between labour income and other income categories, especially capital income. Capital owners generally benefit from labour market reforms, not only in the form of an absolute increase in capital income, but also in the form of an increasing share of capital in total income. The latter is due to a scale effect, associated with fixed costs of producing, in combination with limited entry into the final goods production sector. The increase in the capital income

share in response to labour market reforms can be reduced substantially only if we allow for entry in the goods market. This suggests that labour market reforms in combination with existing goods market rigidities can lead to undesired distributional effects. The result has some pararell to the argument in Blanchard and Giavazzi (2003) that labour market reform without product market reform redistributes product market rents from labour to capital, without lowering the total size of the rents. The paper analyses the effect of structural reforms on (functional) *income* inequality. It does not discuss the inequality in the distribution of *wealth*. Wealth (stock) inequality is at the same time a driver and a consequence of income (flow) inequality, as wealth generates income in the form of returns to assets, and higher income facilitates the accumulation of wealth.

Section 2 below provides a summary of existing literature in the field. Section 3 explains the functional definition of income categories in the model as applied in this paper. Section 4 presents and discusses the results for the impact of labour market reforms and human capital formation on different income categories. Section 5 summarises the findings and concludes.

2. Effects of structural reforms on the distribution of income

A substantial body of research has analysed the widening and persistence of income and wealth inequalities in recent years. Efforts of closing the knowledge gap with empirical and theoreticcal work have addressed causes and potential remedies. The distributional consequences of structural reforms, however, have received relatively little attention in the literature for a long time, with the exception of tax and benefit reforms. Examples of the latter are Cournède et al. (2013a, 2013b) who discuss the growth and equity impact of alternative fiscal consolidation strategies in the context of high and possibly unsustainable government debt and suggest that lowering (producer) subsidies and increasing corporate, personal income and property taxes reduce the inequality in disposable income. Higher social security contributions and lower government spending on health, education and social assistance, by contrast, counteract equity objectives.

Among policy institutions, the OECD has devoted particular attention to the role of a wide range of structural policies for inequality. Empirical work by the OECD has generally focused on the net real disposable household income across the distribution of households, i.e. real disposable household income after taxes and benefits. Causa et al. (2015a, 2015b), e.g., find that many policies can deliver higher income gains at the lower end of the income distribution. These policies include measures to strengthen competition in goods markets (reducing regulatory barriers, trade, and FDI), broader access to education, and active labour market policies (ALMP). A general reduction in the generosity of unemployment benefits is also found to raise relative incomes at the lower end of the income distribution, whereas reducing benefits to long-term unemployed lowers household disposable income at the lower end of the distribution. Other pro-growth policies may have opposite or ambivalent effects on low incomes as argued in OECD (2015b). Examples include the promotion of innovation that widens skill premia across workers. Policies that increase labour force participation particularly in the low-skilled sector may widen the wage dispersion, but have income-enhancing effects through higher employment, as argued in this paper.

Causa et al. (2016) broaden the analysis of income inequality by looking at the entire income distribution, instead of looking only at the bottom part, and by decomposing income effects of structural reforms into labour productivity and labour utilisation gains. Evidence for OECD countries covering the past three decades suggests that most reforms have had little impact on income inequality when the latter is defined by measures that emphasise the middle class,

whereas a high number of reforms have had significant effects on inequality (reducing or increasing) at the low end of the distribution. Trade-offs between growth and equity appear to be most common for reforms of social protection and labour market institutions. Reducing (the duration of) unemployment benefits and social assistance hurts low-income households in particular, which would call for complementary ALMP measures to accelerate a return to work. Lower rates of unionisation are also associated with higher income inequality. Lowering labour tax wedges is prone to a growth-equity trade-off in the absence of sufficient progressivity of the tax burden. The analysis in Causa et al. (2016) also confirms the Causa et al. (2015a, 2015b) result of complementarity between growth and equity effects for competition-promoting product market reform and higher government spending on education.

The work by De Serres and Murtin (2014) takes a different perspective and contrasts the long-term (average) employment effects of labour market policies with the policies' impact on the response of unemployment to adverse shocks, where the latter alludes to the concept of economic resilience to shock as discussed, e.g., in Duval and Vogel (2008). The empirical evidence for 19 OECD countries suggests trade-offs between long-term levels of employment and short-term employment and income stability during specific phases of the business cycle. In particular, less generous unemployment insurance, more ALMP, and lower minimum wages accelerate the exit of low-skilled workers from unemployment, but lower benefits and wage floors make them also more vulnerable to adverse income shock. Reducing the labour tax wedge avoids the trade-off between average employment gains and disposable income in downturns according to De Serres and Murtin (2014).

Ostry et al. (2018) present empirical evidence for broad indicators, a wide range of structural reforms, which also includes financial liberalisation and basic institutional reforms, and a large sample of advanced, emerging and developing economies. The study finds that domestic and external financial deregulation increase income inequality as measured by the Gini coefficient, a result discussed in more detail also in Larrain (2014) and Furceri et al. (2018) for external financial liberalisation. Contrary to the analysis of domestic market reforms, the distributional consequences of trade liberalisation have received widespread attention in the literature since Stolper and Samuelson (1941) already, including recently also Fajgelbaum and Khandelwal (2016). Institutional reforms that strengthen the legal system and the rule of law do not increase income inequality according to Ostry et al. (2018), whereas the liberalisation of network industries and, for low-income and middle-income countries, the decentralisation of wage bargaining tend to increase Gini-measured inequality. Focusing on labour market institutions in advanced economies, Jaumotte and Osorio Buitron (2015) find lower degrees of unionisation and lower minimum wages to be associated with higher income inequality.

The group of model-based studies on the distributional impact of structural reforms comprises micro-simulation studies and general-equilibrium analysis and has a particular focus on tax and benefit reforms. Micro simulation studies, such as Decoster et al. (2010), cover a lot of details of the income distribution, but tend to ignore the wider impact of reforms on prices and volumes and associated second-round effects on the income distribution, whereas general-equilibrium analyses, such as Burgert and Roeger (2014), tend to use simple household and firm structures to remain tractable and do, hence, not map a detailed household income distribution, but instead focus on the coherent modelling of different (functional) sources of income and incorporate the impact of price and quantity adjustments in goods and labour markets on the distribution of real disposable income.

This paper uses a general-equilibrium model to analyse distributional effects of labour market reforms. We show how policy affects different sources of income (wage income, benefits,

transfers, profits, and interest income) and proxy the income distribution of wage earners by distinguishing between low-, medium- and high skilled labour. The following section presents the definition of income sources in the model, focusing only on elements of the model that are crucial to understand the classification of income groups. Section 4 then discusses the distributional effects of labour market reforms, and section 5 concludes.

3. Functional income distribution

Our model economy is populated by households, final and intermediate goods producing firms, a research industry, a monetary and a fiscal authority. Firms in the final goods sector produce differentiated goods, which are imperfect substitutes for goods produced abroad. Final good producers use a composite of intermediate goods and three types of labour (low-, medium-, and high-skilled). Households own the economy's real and financial assets. They buy the patents of designs produced by the R&D sector and license them to the intermediate goods producing firms. The intermediate sector is composed of monopolistically competitive firms, which produce intermediate products from rented capital input, using the designs licensed from the household sector. The production of new designs takes place in research labs, employing high-skilled labour and making use of the existing stock of domestic and foreign ideas (Jones 1995, 2005). Technological change is modelled as increasing product variety in the tradition of Dixit and Stiglitz (1977). In this section we only discuss aspects of the model that are relevant for the understanding of how structural reforms affect the functional income distribution. The exposition of the model is simplified to focus on functional income categories, notably by presenting a consolidated version of the household sector and a tax structure. Appendix A instead provides a detailed description of the individual model elements and their calibration.

3.1 Households

The household sector supplies labour differented by skill (L_{kt}), with $k \in (L, M, H)$, holds tangible capital (K_t), intangible assets (patents) (A_t), and financial assets (B_t). The household sector receives wage income from labour at wage rate (W_{kt}), rental income form physical capital and intangible assets at rate (i_t^K) and (i_t^A), and interest income from financial assets at rate (i_t). Apart from the rental income on capital, the household sector also receives profits from the final goods production sector (PR_t^Y), from the *A* firms in the intermediate goods sector (PR_t^x), and from the research sector (PR_t^A). Finally, the household sector receives transfers, which are split into unemployment benefits (BEN_t) and other transfers (TR_t), mostly pensions, and it pays labour income taxes (t_t^k) and other (lump-sum) taxes (T_t). The total income received by the household sector in period t can be used for consumption (C_t) and gross savings, which are net purchases of financial assets, ΔB_t, tangible investment, J_t^K including depreciation, and investment in intangibles, J_t^A.

The households derive decision rules from maximising an intertemporal utility function:

$$max\ U_0 = E_0 \sum_{t=0}^{\infty} \beta^t (U(C_t) + V(POP_{kt}(1 - NP_{kt}) - L_{kt})), \quad (1)$$

which is additively separable in consumption and leasure of the three skill groups, and where β is the rate of time preference. POP_{kt} is the population share of skill group *k*, and NP_{kt} is the respective non-participation rate, which is determined by institutional factors, such as retirement age, years of schooling, availability of child care infrastructure, etc. The households' decision is constrained by a sequence of period budget constraints:

$$P_t^C C_t + \Delta B_t + P_t^K J_t^K + P_t^A J_t^A = i_{t-1} B_{t-1} + \sum_k (1 - t_t^k) W_{kt} L_{kt} + i_{t-1}^K P_t^K K_{t-1} + \int_{i=0}^{A_{t-1}} i_{it-1}^A P_{it}^A \, di + PR_t^Y + \int_{i=0}^{A_t} PR_{it}^x di + PR_t^A + BEN_t + TR_t - T_t \,, \quad (2)$$

and the asset accumulation constraints for tangible and intangible capital:

$$\Delta K_t = J_t^K + \delta^K K_{t-1}, \quad (3)$$

$$\Delta A_t = J_t^A + \int_{i=0}^{A_{t-1}} \delta^A di, \quad (4)$$

where δ^K and δ^A are the depreciation rates of tangible and intangible capital.

From the FOCs we obtain the arbitrage conditions for investment in tangible (5) and non-tangible (6) capital:

$$i_t^K = i_t - E_t \pi_{t+1}^K + \delta^K, \quad (5)$$

$$i_t^A = i_t - E_t \pi_{t+1}^A + \delta^A. \quad (6)$$

The (nominal) return on tangible capital exceeds the (nominal) return on financial assets by the rate of capital depreciation (δ^K). In case of expected capital valuation gains ($E_t \pi_{t+1}^K > 0$), arbitrage reduces i_t^K. Similarly, the rate of return on intangible assets differs from the risk free rate by an expected capital gain ($E_t \pi_{t+1}^A$) and the rate of depreciation (δ^A).

3.2 Firms

3.2.1 Final goods producers

The final goods producers (*j=1,…, n*) are buying capital services as intermediate input to production and hire labour. Final output, Y_{jt}, is produced with labour input, L_{Yjt}, intermediate capital inputs, $x_{m,t}$, and public capital, KG_t, where production is subject to general per-period fixed cost, FC_Y:

$$Y_{jt} = \left(L_{Yjt}\right)^{\alpha} \left(\int_{i=0}^{A_t} \left(x^i{}_{jt}\right)^{\theta} di\right)^{(1-\alpha)/\theta} KG_t^{\alpha_G} - FC_Y \quad (7)$$

Fixed costs in the production function are a common feature in structural macroeconomic models, including the prominent examples of Smets and Wouters (2003), Christoffel et al. (2008), and Ratto et al. (2009) for the Euro Area, and Christiano et al. (2005) for the US economy. As explained by Christiano et al (2005), the inclusion of fixed costs can account for the gap between significant price mark-ups, on the one side, and comparably low corporate profits, on the other side (Hall 1988, Rotemberg and Woodford 1999).

Labour is a CES aggregate of the three different skill types with:

$$L_{Yjt} = \left(\begin{array}{c} \Lambda_L^{\frac{1}{\mu}} \left(\chi_L L_{Ljt}\right)^{\frac{1-\mu}{\mu}} + \Lambda_M^{\frac{1}{\mu}} \left(\chi_M \left(L_{Mjt} - FC_{L,M}\right)\right)^{\frac{1-\mu}{\mu}} \\ + \Lambda_{HY}^{1/\mu} \left(\chi_{HY} L_{HYjt}\right)^{\frac{1-\mu}{\mu}} \end{array} \right)^{\frac{\mu}{1-\mu}}, \quad (8)$$

where $L_{L,t}$, $L_{M,t}$ and $L_{HY,t}$ denote the employment of low-, medium- and high-skilled workers in final goods production, respectively. A fixed number of workers with medium skills are employed as overhead labour, FC_L . Parameter Λ_z is the corresponding share parameter $z \in (L, M, HY)$, χ_z is the efficiency unit, and μ is the elasticity of substitution between different labour types.

The final goods producer j is a monopolistic competitor that maximises profits PR_t^Y net of a profit tax, t_t^P:

$$PR_{jt}^Y = (1 - t_t^P)(P_{jt}^Y Y_{jt} - (1 + ssc_t)W_t\, L_{Y,jt}) - A_t x_{jt} P_t^x \tag{9}$$

From the FOC w.r.t. labour, wage income in the final goods sector is given by:

$$\left(1 - mup_{jt}^Y\right)\alpha\left(Y_{jt} + FC_Y\right)P_t^Y = W_t L_{Yjt}, \tag{10}$$

where the mark-up mup_{jt}^Y is the inverse of the price elasticity of demand for final good j.

The FOC for the demand for intermediate capital good i yields:

$$\left(1 - mup_{jt}^Y\right)(1 - \alpha)\left(Y_{jt} + FC_Y\right)P_t^Y = P_{it}^x x_{ij} \tag{11}$$

Given the FOCs, profits of the final goods producing sector can be expressed as a positive function of the mark-up and depend negatively on fixed costs:

$$PR_{jt}^Y = mup_{jt}^Y P_{jt}^Y Y_{jt} - \left(1 - mup_{jt}^Y\right)P_{jt}^Y FC_Y - W_{t,M} FC_{L,M} \geq 0 \tag{12}$$

3.2.2 Intermediate production

Intermediate goods producers rent tangible and intangible capital. The technology has constant returns in tangible capital, whereas intangible capital is a fixed cost for the firm. The production technology is given by:

$$x_t^i = K_t^i \tag{13}$$

The profit of intermediate goods producer i (PR_{it}^x) is the difference between revenues and the rental price of physical capital, $i_t^K P_t^K$, and intangible capital, $i_t^A P_t^A$

$$PR_{it}^x = P_t^{x^i} x_t^i - i_t^K P_t^K K_t^i - i_t^A P_t^A, \tag{14}$$

where P_t^K is the price of the physical capital good, and P_t^A is the price of the patent. The intermediate goods producer maximises profits w.r.t. x_t^i, subject to the technology constraint (13) and the demand for intermediate goods that follows from equation (11). This yields the pricing rule:

$$P_t^{x^i} = \frac{i_t^K P_t^K}{\theta}, \tag{15}$$

where prices exceed marginal cost by a mark-up factor that is inversely related to the elasticity of substitution (θ) between varieties of intermediate inputs in final production. The free-entry condition implies that the capital cost from holding a patent is equal to current profits:

$$(i_t - E_t\pi^A_{t+1} + \delta^A)P^A_t = (P^{x^i}_t x^i_t - i^K_t P^K_t K^i_t) \quad (16)$$

Free entry and the arbitrage condition (6) imply zero profits for the intermediate goods firms:

$$PR^{x^i}_t = P^{x^i}_t x^i_t - i^K_t P^K_t K^i_t - i^A_t P^A_t = 0 \quad (17)$$

The zero-profit condition and the mark-up pricing rule for the intermediate goods firm give the following relationship between the capital cost for intangibles and the price for intermediate physical capital goods:

$$i^A_t P^A_t = P^{x^i}_t x^i_t - i^K_t P^K_t K^i_t = (1-\theta)P^{x^i}_t x^i_t \quad (18)$$

3.2.3 Research

The research sector creates new designs, using a (knowledge) production function with high-skilled labour as input:

$$\Delta A_t = \upsilon A^{\phi}_{t-1} L^{\lambda}_{HAt} \quad (19)$$

The modelling follows Jones (1995, 2005) semi-endogenous growth model in which υ is the total factor efficiency of R&D production, parameter ϕ ($0< \phi < 1$) measures the domestic spillover effects from the accumulated (i.e. existing) domestic knowledge stock (A_{t-1}) on further knowledge production, and λ measures the elasticity of R&D production w.r.t. the number of researchers (L_{HAt}). Note that setting ϕ < 1 implies the Jones-type semi-endogenous growth model, whereas ϕ = 1 would yield the strong scale effects with respect to the domestic level of knowledge that are part of endogenous growth models.

Maximising profits yields:

$$W^H_t L_{HAt} = \lambda P^A_t \Delta A_t, \quad (20)$$

and positive profits PR^A_t:

$$PR^A_t = (1-\lambda)P^A_t \Delta A_t \quad (21)$$

The ratio of wage and profit income in the research sector is a positive function of the elasticity of output w.r.t. labour in the research sector (λ).

3.3 Income shares

In this section we discuss how labour, capital and profit income shares are determined in this economy. Since the structural reform measures that we consider affect the supply of labour by skill, we also analyse how wage income of individual skill groups is affected. We also trace the response of income from tangible and intangible capital. The supply of skills also affects investment in tangibles and intangibles. Using the FOCs for intermediates and the pricing rule of the intermediate goods sector, we first determine the relationship between income from intangible capital and final output:

$$i^A_t P^A_t A_t = (1-\theta)(1-mup^Y_t)(1-\alpha)\left(Y_{jt} + FC_Y\right)P^Y_t \quad (22)$$

Using (11), one can express the rental income from physical capital as a function of final output:

$$i_t^K P_t^K A_t x_t = \theta(1 - mup_t^Y)(1 - \alpha)(Y_t + FC_Y)P_t^Y \tag{23}$$

Equations (22) and (23) show that the fractions θ and $1 - \theta$ of total capital income go to intangible capital and tangible capital, respectively, where the share going to intangible capital is a negative function of the elasticity of substitution (EoS) between intermediates in final good production. Relative income from intangible and tangible capital is entirely determined by this EoS and does not depend on the relative supply of labour with different skills. Combining income from tangible and intangible capital yields:

$$i_t^A P_t^A A_t + i_t^K P_t^K A_t x_t = (1 - mup_t^Y)(1 - \alpha)\big(Y_{jt} + FC_Y\big)P_t^Y \tag{24}$$

Now we are in a position to see what determines the wage, rental and profit income shares in the final goods sector. Wage, rental income and monopoly rents as share of final output:

$$\frac{W_t L_{Yt}}{P_t^Y Y_t} = (1 - mup_t^Y)\alpha\left(1 + \frac{FC_Y}{Y_t}\right) + \frac{W_t FC_L}{P_t^Y Y_t} \tag{25}$$

$$\frac{\left(i_t^A P_t^A A_t + i_t^K P_t^K A_t x_t\right)}{P_t^Y Y_t} = (1 - mup_t^Y)(1 - \alpha)\left(1 + \frac{FC_Y}{Y_t}\right) \tag{26}$$

$$\frac{PR_t^Y}{P_t^Y Y_t} = mup_t^Y - \frac{\left(1 - mup_t^Y\right)FC_Y}{Y_t} - \frac{W_t FC_L}{P_t^Y Y_t} \tag{27}$$

From the analysis so far we see that the share of labour, capital and profit income to final output depends on the presence of fixed costs and overhead labour. In the absence of fixed costs and overhead labour, the three income shares are entirely determined by the respective output elasticities w.r.t. the factors of production and by the price mark-up in the final goods sector. Any reform which affects the level of real final output does not affect the income shares as long as the price mark-up in the final goods sector remains constant. In the presence of fixed costs and overhead labour, to the contrary, structural reforms that affect output in the final goods sector positively increase the share of profits and reduce the share of wages and rental income from capital due to the presence of fixed costs. The effect of overhead labour on the income share of profits and wages is ambiguous. If the growth of real final output (Y_t) exceeds the increase in the real wage, $\frac{W_t}{P_t^Y}$ (expressed in terms of final goods), wage income declines (profit income increases), and vice versa.

There remains one other interesting case, namely mark-ups only cover fixed costs and profits are zero. Consider, first, the case with $FC_L = 0$. Now the zero-profit condition implies:

$$mup_t^Y Y_t = (1 - mup_t^Y)FC_Y \tag{28}$$

$$\frac{W_t L_{Yt}}{P_t^Y Y_t} = (1 - mup_t^Y)\alpha\left(1 + \frac{mup_t^Y}{1 - mup_t^Y}\right) = \alpha \tag{29}$$

$$\frac{i_t^A P_t^A A_t + i_t^K P_t^K A_t x_t}{P_t^Y Y_t} = (1 - mup_t^Y)(1 - \alpha)\left(1 + \frac{mup_t^Y}{1 - mup_t^Y}\right) = 1 - \alpha, \tag{30}$$

i.e. wage and capital income shares only depend on α. In the zero fixed-cost case ($FC_Y = 0$), we have:

$$mup_t^Y P_t^Y Y_t = W_t FC_L \tag{31}$$

$$\frac{W_t L_{Yt}}{P_t^Y Y_t} = (1 - mup_t^Y)\alpha + \frac{W_t FC_L}{P_t^Y Y_t} = (1 - mup_t^Y)\alpha + mup_t^Y = \alpha + mup_t^Y(1 - \alpha) \tag{32}$$

$$\frac{i_t^A P_t^A A_t + i_t^K P_t^K A_t x_t}{P_t^Y Y_t} = (1 - mup_t^Y)(1 - \alpha), \tag{33}$$

i.e. wage and capital income shares depend on α and mup_t^Y. Structural reforms that reduce the share of overhead labour in final output (because of rising output) would reduce the mark-up. In $FC_Y = 0$ case, the reduction in the mark-up goes along with a fall in the wage share, as the reason for the decline of the mark-up is the fall in the wage share of overhead labour in final output. A fall in the mark-up would in this case, however, increase the share of capital in final output.

Concerning wage income, even in the case of a constant labour income share the interesting question remains of how the increase in wage income in case of rising real (final) output, induced by an increase in the supply of labour, will be divided into changes in real wages and changes in employment. Providing an analytical decomposition throughout the adjustment path towards the new long-run equilibrium is difficult since it depends on the dynamic adjustment of the real interest rate. An answer can be provided, however, concerning the long-run evolution of the real wage (and employment). A second question that is especially relevant in the context of this paper is how the wage shares and the real wages of specific skill groups change in the long run in case of a permanent skill-specific labour supply shock. Appendix B to this paper provides an analysis of the wage response to general versus skill-specific labour supply shocks. The results can be summarised in the following two propositions:

Proposition 1: Labour market reform which increases the labour aggregate in the final goods production sector, $L_{Y,t}$, raises the capital stock until the initial capital-to-labour ratio is re-established. Since the post-reform *K*-L_Y ratio is unchanged, the post-reform marginal product of $L_{Y,t}$ is also unchanged, which supports an unchanged real wage index, W_t. The total wage share in nominal output also remains constant.

Proposition 2: An increase of employment of skill group *i* is associated with an increase in the wage share of of skill group *i* and a decline in the real wage of skill group *i* in terms of the final output deflator.

The strength of permanent wage effects in response to skill-specific labour supply shocks depends on the substitutability between different skills in production. The lower the elasticity of substitution between skill types, the stronger the trade-off in terms of negative wage effects becomes. If different skills are (nearly) perfect substitutes, the trade-off disappears. In a semi-endogenous growth model, the wage reduction is mitigated because labour market reforms also have positive TFP effects, either directly via an increase in the supply of high-skilled labour, or indirectly because of a reallocation of high-skilled workers from production to R&D.

The impact of a skill-specific labour supply expansion on skill-specific labour income, i.e. wage times employment, is illustrated in Figure 1, which shows the long-run effect of an expansion in the low-skilled work force for a given demand curve for low-skilled labour. The horizontal labour supply schedule in both panels corresponds to the case in which (relative) wages adjust fully, so that the expanded labour force is fully employed.

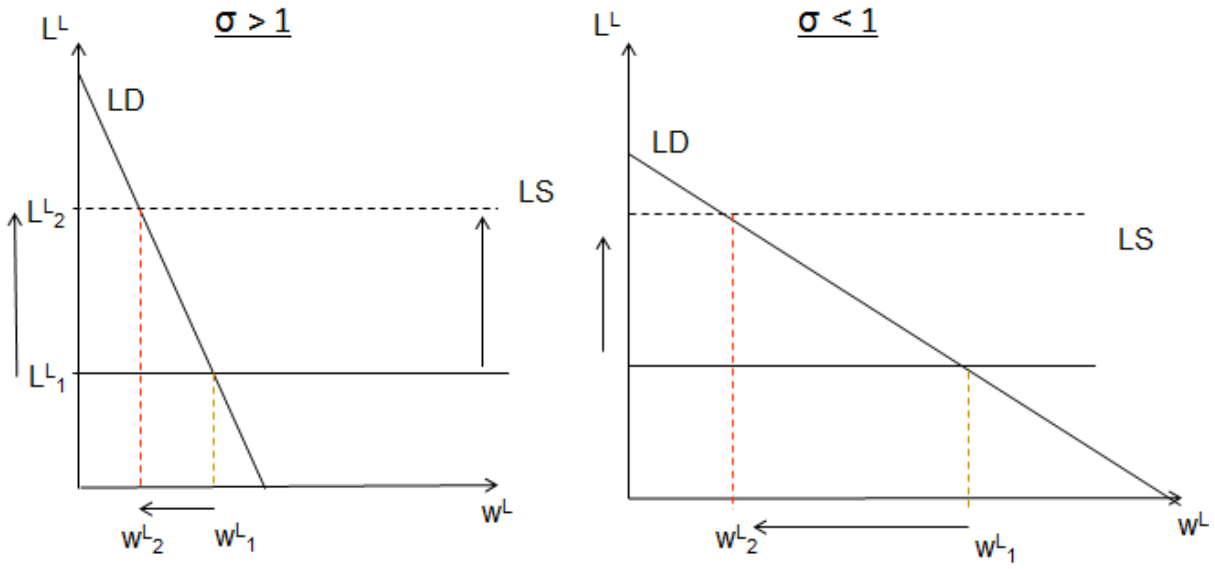

Figure 1: Wage and wage sum effects of an increase in low-skilled labour supply

The left panel of Figure 1 depicts the case, where the elasticity of substitution in the demand for labour between skill groups is above unity (σ>1). The low-skilled labour supply (LS) moves up from L_1^L to L_2^L. The low-skilled wage level falls from w_1^L to w_2^L. For the skill-specific labour demand elasticity above unity, the per-cent increase in low-skilled employment is larger than the per-cent decline in the wage, so that wage share of low-skilled workers increases ($w_2^L L_2^L > w_1^L L_1^L$).

The right panel of Figure 1, to the contrary, illustrates the situation in which the elasticity of substitution between skill groups in labour demand is below unity (σ<1). The low-skilled labour supply (LS) moves up from L_1^L to L_2^L as before, but it is now confronted with a flatter labour demand schedule LD(w^L), leading to a more pronounced wage decline from w_1^L to w_2^L. For the skill-specific labour demand elasticity below unity, the per-cent increase in low-skilled employment is smaller than the per-cent decline in the wage, so that wage share of low-skilled workers declines ($w_2^L L_2^L < w_1^L L_1^L$).

3.4 Calibration

The calibration of the model parameters is explained in detail in Appendix A to this paper. Here, we only emphasise the aspects of the calibration of the production block that are crucial for this exercise. We rely on sectoral mark-up estimates using EU KLEMS data. Aggregating mark-ups across sectors suggests aggregate mark-ups of around 13% in the final goods sector and around 10% in the intermediate production sector. The latter mark-up pins down the elasticity of substitution between intermediate goods ($1/\theta$) to 1.1. We determine the size of fixed costs such that the model can reconcile relatively large mark-ups with modest profit rates of around 1% of net disposable income. We choose steady-state rental rates of capital such that the model can generate a capital-output ratio of 3 and an R&D share of 2% at the EU-aggregate level. Information on the wage share and the final goods mark-up is used to pin down the output elasticity of labour (and by implication that of capital) in the production function as well as the level of overhead labour.

Since the labour market reforms discussed in this paper affect the skill composition of employment, special emphasis must be given to the skill parameters in production and the skill-

specific elasticity of labour supply. The consensus estimate for the elasticity of substitution between skilled labour and unskilled labour is in the range between 1.0 and 2.0 (Katz and Autor, 1999). Acemoglu and Autor (2011) recently updated the seminal reference of this elasticity parameter by Katz and Murphy (1992, "KM" hereafter). While KM estimated that the elasticity of substitution between skilled and unskilled labour is about 1.4, Acemoglu and Autor (2011) argue in favour of a somewhat higher value in the range of 1.6-1.8, using an extended version of the KM data sample (spanning 1963-2008 as opposed to 1968-1987). We use the middle value of this range, μ=1.7, for the simulations in section 4. Concerning labour supply, we set the average labour supply elasticity at 0.4, which is in the range of the estimates in the literature (Chetty, 2012).

4. The impact of labour market reforms on income categories

We consider two types of reforms: (1) an increase in the participation rate of low-skilled and medium-skilled workers, and (2) an increase in the share of medium- and high-skilled workers, associated with a decline in the share of low-skilled labour. The two reforms are implemented by giving (1) permanent negative shocks to NP_L and NP_M, and (2) positive shocks to POP_M and POP_H., respectively, where NP_L and NP_M are the shares of non-participants within, respectively, the low-skilled and medium-skilled working age population, and POP_M and POP_H are, respectively, the population shares of medium-skilled and high-skilled labour. Our focus is on the consequences of changing the structure of labour supply. In this paper we are not discussing concrete policy measures, but only consider exogenous shifts, because we want to avoid that specific revenue effects and financing needs attached to particular policy measures, particularly in the tax and benefit system, influence the results[1]. An increase in labour force participation, e.g., may be costly for the government if it results from an increased provision of child-care facilities or from lower taxes on labour. It could also go along with an increase in revenue, however, if implemented via a reduction of unemployment benefits. Government expenditure and transfers are kept constant in the simulations in real terms, and the government targets a constant debt-to-GDP ratio in the long run. Any additional revenue generated by the reform, notably via positive tax base effects, is rebated to households in the form of lump-sum transfers. This fiscal closure assures that the effects of structural reforms are not affected (mitigated or amplified) by second-round distortionary fiscal adjustment, which is a structural intervention itself.

Table 1: Structural indicators and benchmarks

Country	Medium-skilled non-participation	Low-skilled non-participation	Low-skilled share	High-skilled share
Best 3	11.2	25.4	6.3	10.3
E28	19.2	35.2	21.9	6.3
AT	19.3	37.9	14.7	7.7
BE	21.9	47.2	21.8	7.8
BG	18.1	44.6	17.4	4.9
CY	17.9	31.9	17.8	5.8
CZ	14.9	42.4	6.1	5.5
DE	15.3	33.3	13.4	6.8
DK	15.0	33.3	18.4	9.9
EE	15.6	28.5	10.8	6.3

[1] See Roeger et al (2018) for a more detailed discussion of specific policy measures.

EL	23.5	35.6	26.4	4.3
ES	17.7	27.8	39.9	5.2
FI	18.6	37.4	10.8	9.7
FR	19.9	38.2	20.6	5.2
HR	26.1	57.7	14.9	4.5
HU	19.2	37.6	15.1	4.7
IE	22.2	43.0	16.8	9.3
IT	22.6	39.3	38.3	3.2
LT	18.3	40.3	5.2	6.3
LU	23.5	34.9	21.4	7.9
LV	18.2	29.9	9.3	4.4
MT	12.9	36.3	46.7	5.7
NL	16.1	34.0	21.0	9.4
PL	26.9	52.5	7.6	5.9
PT	10.4	24.8	50.2	6.5
RO	23.7	41.2	21.5	5.0
SE	10.2	23.7	14.4	11.2
SI	19.9	43.8	11.9	6.6
SK	18.7	47.6	8.3	3.2
UK	17.1	30.9	19.6	9.7

Notes: Darker shades correspond to larger gap vis-à-vis the benchmark. Low-skilled corresponds to ISCED 0-2 categories, high-skilled corresponds to scientists and engineers (in natural science, mathematics, computing, manufacturing, or construction); the rest of the population is defined as medium-skilled.
Sources: Eurostat, 2018 or latest available.

For a realistic quantification of structural reforms and following Varga and in 't Veld (2014), we base the magnitude of each reform shock on a benchmarking exercise, which applies a distance-to-frontier approach to measure the potential for reforms by assuming a gradual and partial closure of the gap in labour market indicators vis-à-vis the (simple) average of the three best-performing EU Member States.[2] The first simulated structural reform scenario focuses on labour market reforms that increase the labour market participation rate for low-skilled, older, and female workers, respectively; the second scenario considers human capital investment raising the population share of the medium- and high-skilled labour force. Table 1 shows the corresponding indicators for each reform area, the targeted benchmark values ("Best 3") and the relative position of the various Member States with respect to the benchmark.The gaps for all Member States are then merged by taking a weighted average to obtain an EU-wide gap towards the three best performers for each indicator. Following Varga and in 't Veld (2014), we quantify the potential for reform as closing half of the gap vis-à-vis the three best performers for these indicators. To allow for realistic implementation lags, we phase in the reforms gradually over 20 years. For each reform scenario, the Figures below show the impulse response of selected marcoecnomic variables during the first 10 years, after 15 years and in the long run (LR), the change in income shares after 5, 10, 15 years and in the LR, and developments in wages and wage sums in the first 10 years, after 15 years, and in the LR. The discus-

[2] Varga and in 't Veld (2014) applies a benchmarking methodology to quantify the magnitude of structural reforms and assesses their aggregate economic effects through model-based simulations. The simulated shocks are based on a set of structural reform indicators covering a broad set of areas, including market competition and regulation, tax structure, and a wide range of labour market reforms. In this paper we focus on two elements of labour market reforms (participation and upskilling) and analyse their distributional effects.

sion in the text limits itself to the results in qualitative terms, i.e. without particular reference to the magnitude of the effects (which can, however, be inferred from the Figures).

4.1 Increasing low-skilled and medium-skilled labour force participation

Figure 2 shows the ouput, tangible capital, employment, and productivity effects of the participation reform. Rising low- and medium-skilled labour force participation increases GDP and therefore total income. Contrary to the standard neoclassical growth model with exogenous technological change, the increasing supply of low-skilled and medium-skilled labour leads to a small reallocation of high-skilled workers from final goods firms to the R&D sector, which is increasing TFP slightly.

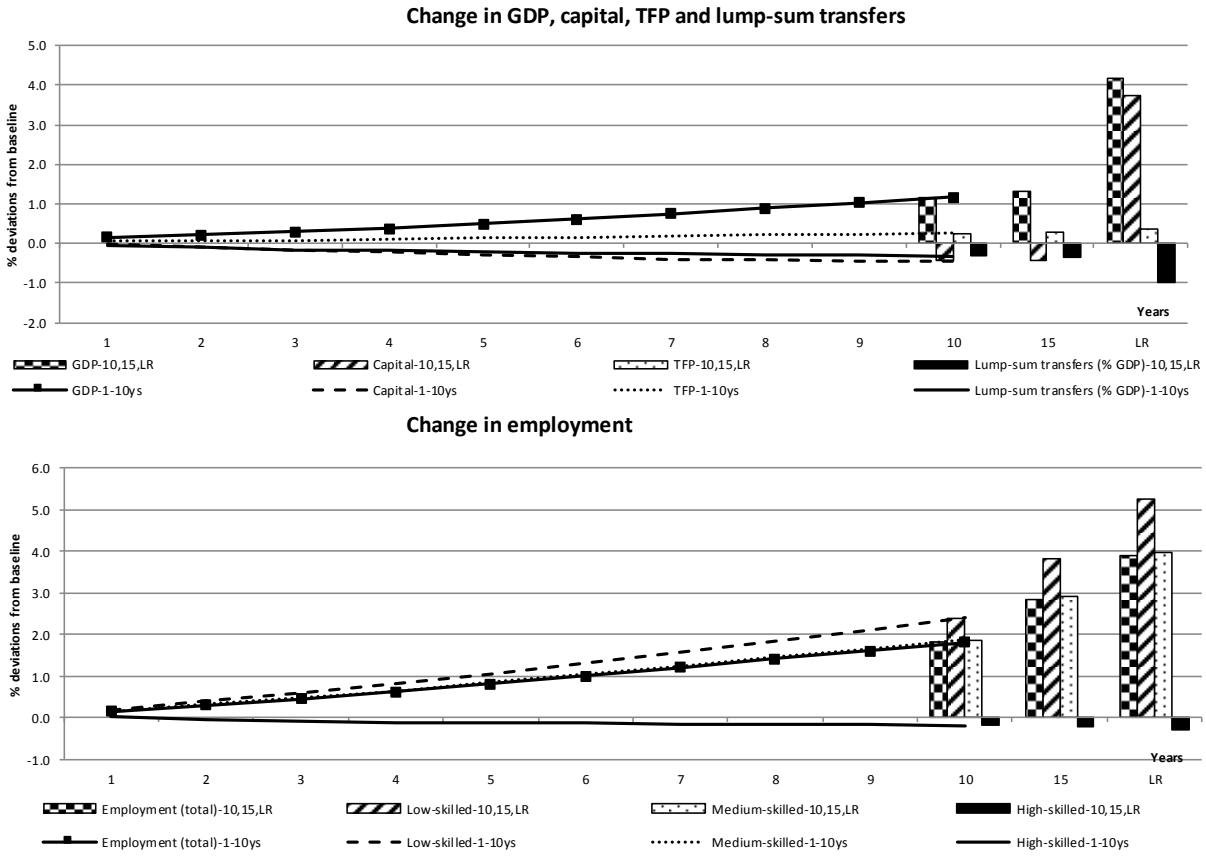

Figure 2: Macroeconomic effects of rising labour market participation

Figure 3 below shows the total effect of the two participation shocks (see Appendix C for a breakdown into increases in the participation rate of low-skilled labour and medium-skilled labour, respectively) on the income distribution. With the presence of fixed costs, the positive output effect reduces both the wage share and the rental income share, and it increases the share of profit income. The fact that the share of overhead labour income in total income declines reduces the wage share and increases the profit share even further as illustrated by the equations (25)-(27) in section 3.3 above. The increase of profits more than compensates capital owners for the decline in rental income from capital, so that the share of total capital income rises. The share of transfer income is falling, since transfers do not increase in real terms. The income from unemployment benefits increases because a higher participation rate also increases the number of unemployed workers (structural unemployment) in the labour force. Changes of income from financial wealth are small. Interest income from government

debt is slightly declining because governemt debt is a constant share of GDP. Interest income from abroad approaches its pre-reform level, since the net foreign asset (NFA) position returns to its pre-reform value in the long term and since the return on foreign assets is exogenous to the reform shocks.

Figure 3 also traces how the labour income and wage rates of the three income groups are evolving. The rise in participation increases net wage income across all skill categories, but more so for medium-skilled and low-skilled workers. The wage sum relative to net income is declining across all three skill groups, however. As shown by the bottom panel of Figure 3, the net real consumption wage rates (hourly wages) of both medium-skilled and low-skilled workers are declining, while it is increasing for high-skilled workers. The TFP increase associated with this type of reform in our semi-endogenous growth model is not strong enough to compensate for the efficiency loss associated with the change in the skill composition.

The restrictions imposed on government spending yield a 'reform dividend' in form of higher tax revenues, which is redistributed to all households in the form of lump-sum transfers (but which could also, e.g., be redistributed in the form of higher government services).[3] As can be seen from Figure 3, the share of lump-sum transfers amounts to slightly below 1.5 pp of total income, which is similar in order of magnitude to the fall in wage income. Note, however, that lump-sum rebates of tax revenue in the order of magnitude of the decline of the wage income share does not imply that loosers of the reform are (fully) compensated by this second-round effect. The wage share of high-skilled labour is also declining, but (as discussed in the previous paragraph) real wage income of high-skilled workers rises, although it increases less than average net income. Similarly, transfer income recipents do not need to be compensated, since their real income stays constant, but nevertheless would receive the lump-sum rebate.

In sum, distributional effects of reforms aiming to increase labour force participation of low- and medium-skilled workers are sizeable. According to our simulation results in this subsection, the share of wages in total income declines despite an increase in employment. This happens because of fixed costs and overhead labour. There exists a long-run trade-off between employment and wages which cannot be overcome by an endogenous increase in TFP given the relative strength of the channels. The government has sizeable reform dividend in the form of additional revenues available, however, to compensate those groups that suffer real wage losses. The reform dividend would, e.g., suffice to compensate low-skilled workers for a real wage loss of about 1% and medium-skilled workers for a real wage loss of about 0.75% in the long term. In addition, the scenario in this subsection should be seen as an upper bound concerning the decline in the wage share, because we are not considering a potential decline in the mark-up which, in models of endogenous market entry, could be associated with entry into the goods market in response to rising profits.

[3] 'Reform dividend' refers to lump-sum transfers (negative lump-sum taxes) that endogenously respond in the modelsimulation to stabilise the government debt-to-GDP ratio at its baseline levels. Hence, 'reform dividend' refers to the additional net government revenue that the reform delivers.

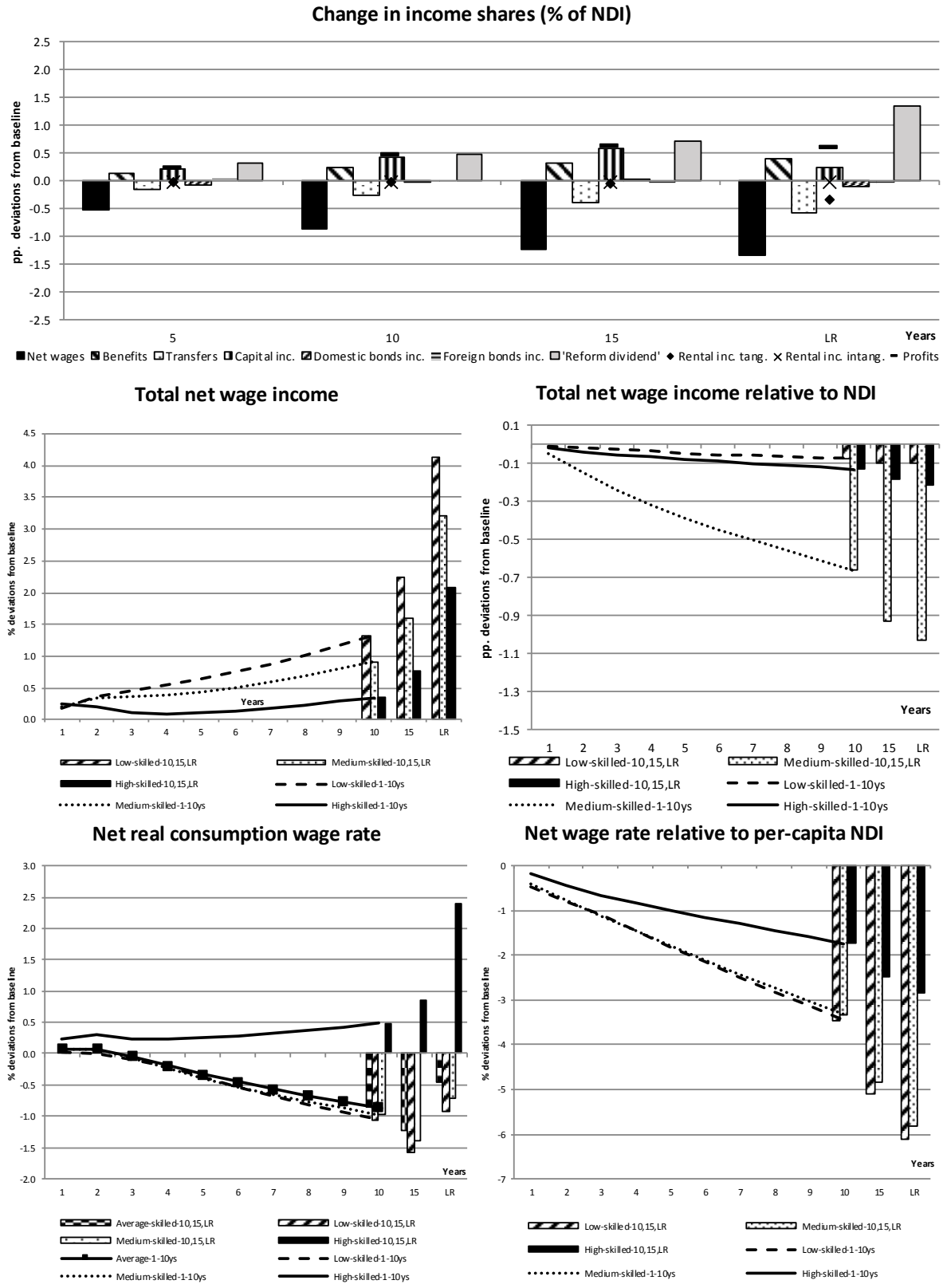

Figure 3: Distributional effects of rising labour market participation

Note: The first panel shows the changes of income shares as pp deviations from baseline; the second and third panels show the deviation of total net wages in absolute terms and in % of net disposable income, respectively. The fourth panel shows the consumption-price-deflated net wages, and the panel presents the GDP-deflated net wages relative to per-capita net disposable income. Results are shown in deviations from the no-reform baseline.

4.2 Increasing the share of medium-skilled and high-skilled labour

Figure 4 shows the output, tangible capital, employment and productivity (TFP) effects of a rising share of medium- and high-skilled workers, i.e. upskilling of the labour force 9education reform). Like in the previous reform scenario of increasing labour force participation, these shocks also yield positive GDP effects. Compared to the previous scenario, upskilling yields higher productivity effects, because the share of high-skilled workers (that can work in the R&D sector) in total employment increases.

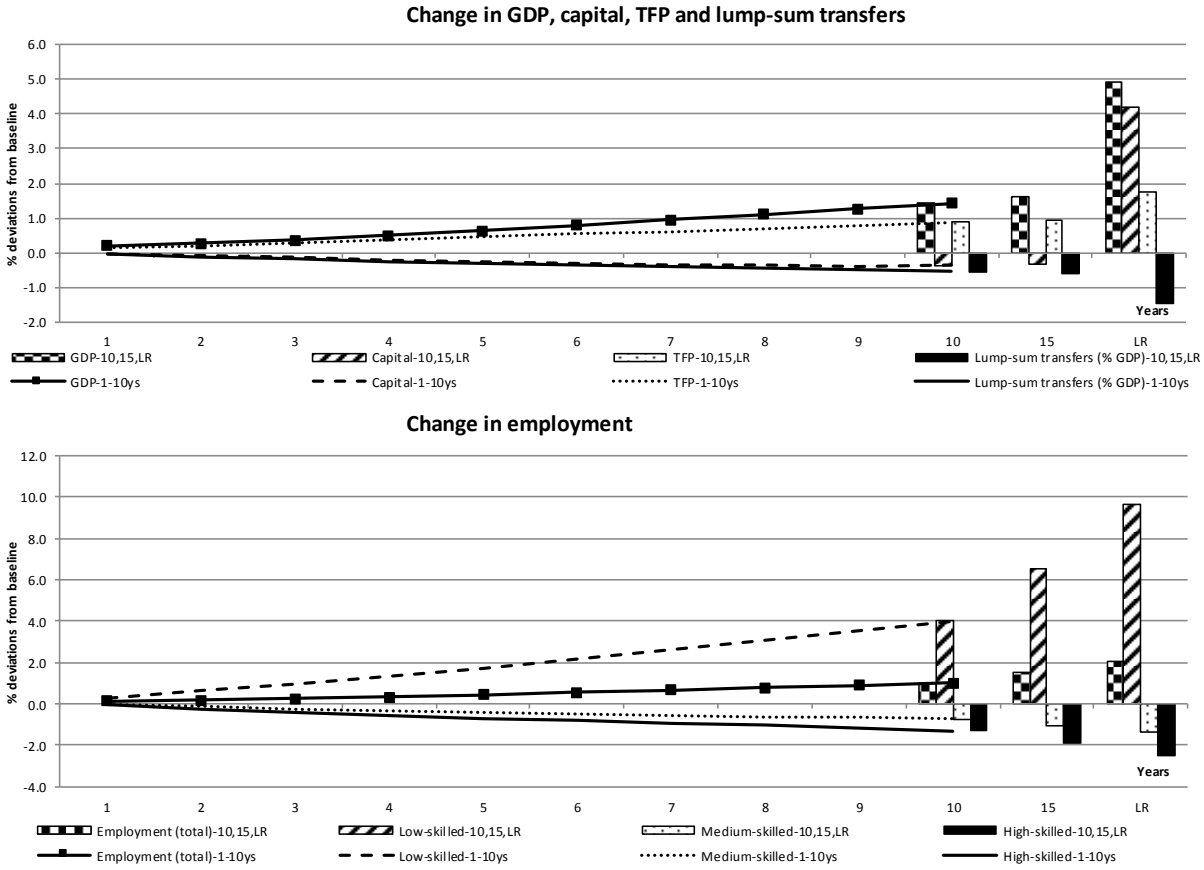

Figure 4: Macroeconomic effects of upskilling (education reforms)

Figure 5 portrays the distributional effects of the two skills-improving shocks together, i.e. increasing the share of medium-skilled versus low-skilled labour, and of high-skilled versus medium skilled labour. This skill shift has distributional effects that are similar to the effects of the increase in low- and medium-skilled labour force participation in the previous subsection. In particular, the increase of final output reduces the share of wages and of rental income from capital, and raises the profit share. Transfers, which are kept constant in real level terms, are declining as a share of income. Benefits, on the other hand, are slightly increasing, due to the fact that benefits are indexed to the skill-specific wage, so that the share of unemployed receiving higher benefits increases. As in the participation growth scenario in 4.1, profits rise sufficiently to compensate for the decline in the share of rental income from capital, so that the share of capital-related income (profits and interest income on capital) increases. Because of the productivity (TFP) gains associated with this scenario, upskilling is associated with higher government-revenue 'reform dividends' that can, in principle, be used for redistributive

purposes. Here this 'reform dividend' is reimbursed to all households in the form of an additional lump-sum transfer, which in the long run amounts to 2 pp of total income.

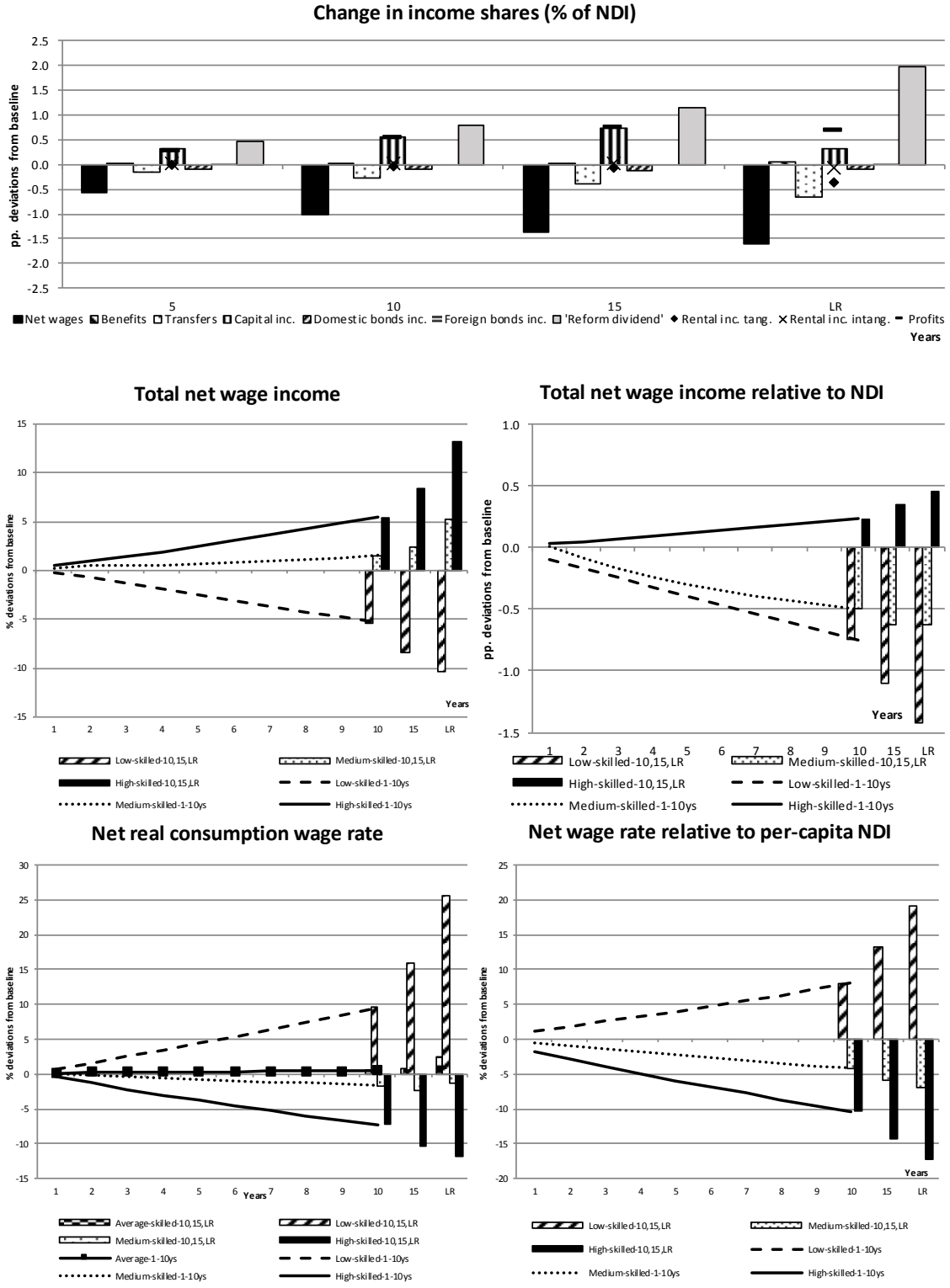

Figure 5: Distributional effects of upskilling (education reforms)

Note: The first panel shows the changes of income shares as pp deviations from baseline; the second and third panels show the deviation of total net wages in absolute terms and in % of net disposable income, respectively. The fourth panel shows the consumption-price-deflated net wages, and the panel presents the GDP-deflated net wages relative to per-capita net disposable income. Results are shown in deviations from the no-reform baseline.

Looking at the the evolution of wage income by skill group shows that the net wage income of high-skilled workers increases, whereas net wage income of low-skilled workers declines. The two scenarios have largely compensating effects for medium-skilled workers, instead. The fall in the low-skilled wage share and rise in the high-skilled wage share is associated with the change in group size. At the level of the wage rate (hourly wage), the shift in labour supply towards high- and medium-skilled workers reduces their real consumption wage, whereas the reduction in the supply of low-skilled workers leads to an increase in the real consumption wage of the remaining low-skilled workers (lower left panel of Figure 5). The same pattern holds for the net wage of the three skill groups relative to the increasing per-capita income (lower right panel of Figure 5). Hence, from the perspective of the wage rate, i.e. hourly wage income, incumbent high-skilled workers loose from the reform.

5. Conclusions

This paper has analysed the distributional impact of two alternative labour market reforms, namely (1) increased labour forced participation of the lower skill groups of the wage distribution, and (2) upskilling of the labour force, using a semi-endogenous growth model calibrated on the aggregate EU28 economy. The analysis builds on previous work that linked average income gaps, i.e. neglecting distributional implications, to differences in structural indicators across EU Member States and identified reforms with the potential of significantly narrowing the income gaps. The present paper has focused on reforms which would half the low-skilled labour force participation gap and the skill gap towards the three best-performing EU Member States in the long run.

Our analysis shows that the two reforms have positive GDP effects and generally increase total net wage income of those groups in the labour market that are directly affected ('treated') by the reform. There is a long-run trade-off between an increase of employment in the skill group that is targeted by the respective reform and its real wage rate. For the given strength of the endogenous growth channel in our model, this trade-off between employment and wage rate is only partly offset by an endogenous increase in TFP.

Because of this trade-off, labour market reforms that raise human capital also reduce the wage gap between low- and medium/high-skilled workers. A stronger distributional conflict may arise between wage earners and transfer recipients, however. In the scenarios presented in this paper, it has been assumed that transfer income is indexed (only) to inflation. Reforms which also increase productivity therefore increase the gap between wage and transfer income earners.

The analysis also shows that capital owners generally benefit from labour market reforms, not only in the form of an absolute increase in capital income, but also in the form of an increasing share of capital in total income. The increase in the (relative) income of capital owners is due to a scale effect arising from fixed costs and overhead labour in combination with limited entry into the final goods production sector. The increase in the capital income share associated with labour market reforms can be reduced substantially only if we allow for entry in the goods market, so that competition can lead to a decline in mark-ups and associated firm profits. The result suggests that labour market reforms combined with existing goods market rigidities can have undesired distributional effects. The result has some parallel to the argument by Blanchard and Giavazzi (2003) that labour market reform, which lowers the bargaining power of workers, without product market reform at the same time redistributes product market rents from labour to capital, without lowering the total size of the rents.

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Appendix A: The model

This appendix provides a detailed description of the underlying model, i.e. without the simplifications introduced in the main text for the clarity of exposition. The model economy is populated by households, final and intermediate goods producing firms, a research industry, a monetary authority, and a fiscal authority. Firms in the final goods sector produce differentiated goods which are imperfect substitutes for goods produced abroad. Final good producers use a composite of intermediate goods and three types of labour: low-, medium-, and high-skilled. Non-liquidity constrained households buy the patents of designs produced by the R&D sector and license them to the intermediate goods producing firms. The intermediate sector is composed of monopolistically competitive firms which produce intermediate products from rented capital input using the designs licensed from the household sector. The production of new designs takes place in research labs, employing high skilled labour and making use of the commonly available domestic and foreign stock of knowledge. Technological change is modelled as increasing product variety following Jones (1995, 2005) semi-endogenous growth framework with endogenous R&D.

A.1 Households

The household sector consists of a continuum of households $h \in [0,1]$. A share $(1-\varepsilon)$ of these households is not liquidity constrained and indexed by $i \in [0, 1-\varepsilon]$. They have access to financial markets where they can buy and sell domestic assets (government bonds), accumulate physical capital which they rent out to the intermediate sector, and they also buy the patents of designs produced by the R&D sector and license them to the intermediate goods producing firms. The remaining share ε of households is liquidity constrained and indexed by $k \in (1-\varepsilon, 1]$. These households cannot trade in financial and physical assets and consume their disposable income each period. For each skill group we assume that households (liquidity and non-liquidity constrained) supply differentiated labour services to unions which act as wage setters in monopolistically competitive labour markets. The unions pool wage income and distribute it in equal proportions among their members. Nominal rigidity in wage setting is introduced by assuming that the households face adjustment costs for changing wages.

A.1.1 Non liquidity-constrained households

Non-liquidity constrained households maximise an intertemporal utility function in consumption and leisure subject to a budget constraint. These households make decisions about consumption

($C_{i,t}$), and labour supply ($L_{i,s,t}$), the purchases of investment good ($J_{i,t}$) and government bonds ($B_{i,t}$), the renting of physical capital stock ($K_{i,t}$), the purchases of new patents from the R&D sector ($J_{A,i,t}$), and the licensing of existing patents ($A_{i,t}$), and receive wage income ($W_{s,t}$), unemployment benefits ($BEN_{s,t}$), transfer income from the government ($TR_{i,t}$), and interest income (i_t, $i_{K,t}$ and $i_{A,t}$). Hence, non-liquidity constrained households face the following Lagrangian:

$$\max_{\substack{\{C_{i,t},L_{i,s,t},B_{i,t}\\ J_{i,t},K_{i,t}\\ J_{A,i,t},A_{i,t}\}_{t=0}^{\infty}}} V_{i,0} = E_0 \sum_{t=0}^{\infty} \beta^t \left(U(C_{i,t}) + \sum_{s\in\{L,M,H\}} V(1-L_{i,s,t}) \right)$$

$$-E_0 \sum_{t=0}^{\infty} \lambda_{i.t} \frac{\beta^t}{P_t} \left(\begin{array}{c} (1+t_{C,t})P_{C,t}C_{i,t} + B_{i,t} + P_{I,t}\left(J_{i,t} + \Gamma_J(J_{i,t})\right) + P_{A,t}J_{A,i,t} \\ -(1+i_{t-1})B_{i,t-1} \\ -\sum_s \left(\begin{array}{c} (1-t_{w,s,t})W_{s,t}L_{i,s,t} - BEN_{s,t}(1-NPART_{i,s,t}-L_{i,s,t}) \\ -(1-t_K)(i_{K,t-1}-rp_K)P_{I,t-1}K_{i,t-1} - t_K\delta_K P_{I,t-1}K_{i,t-1} \\ -(1-t_K)(i_{A,t-1}-rp_A)P_{A,t-1}A_{i,t-1} - t_K\delta_A P_{A,t-1}A_{i,t-1} \\ -TR_{i,t} - PR^Y_{i,t} - PR^X_{i,t} \end{array} \right) \end{array} \right)$$

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

$$-E_0 \sum_{t=0}^{\infty} \lambda_{i,t}\psi_{i,t}\beta^t\left(A_{i,t} - J_{A,i,t} - (1-\delta_A)A_{i,t-1}\right) \qquad \text{(A1)}$$

where *s* is the index for the corresponding low- (*L*), medium- (*M*) and high-skilled (*H*) labour type respectively ($s \in \{L,M,H\}$). The budget constraints are written in real terms with the price for consumption, investment and patents ($P_{C,t}$, $P_{I,t}$, $P_{A,t}$) and wages ($W_{S,t}$) divided by GDP deflator (P_t). All firms of the economy are owned by non-liquidity constrained households who share the total profit of the final and intermediate sector firms, $PR^Y_{i,t}$ and $PR^X_{i,t}$. As shown by the budget constraints, all households pay consumption taxes ($t_{C,t}$), wage income taxes ($t_{w,s,t}$) and t_K capital income taxes less tax credits (τ_K and τ_A) and depreciation allowances ($\tau_K\delta_K$ and $\tau_A\delta_A$) after their earnings on physical capital and patents. When investing into tangible and intangible capital the household requires premium rp_K and rp_A in order to cover the increased risk on the return related to these assets. $NPART_{i,s,t}$ stands for the share of non-participants (inactives) and 1- $NPART_{i,s,t}$- $L_{i,s,t}$ is the number of unemployed per skill group.

The utility function is additively separable in consumption ($C_{i,t}$) and leisure (1-$L_{i,s,t}$). We assume log-utility for consumption and allow for habit persistence.

$$U(C_{i,t}) = (1-habc)\log\left(C_{i,t} - habcC_{t-1}\right) \qquad \text{(A2)}$$

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

$$V(1-L_{i,s,t}) = \frac{\omega_s}{1-\kappa}(1-L_{i,s,t})^{1-\kappa}, \qquad \text{(A3)}$$

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

$$\Gamma_J(J_{i,t}) = \frac{\gamma_K}{2}\frac{\left(J_{i,t}\right)^2}{K_{i,t-1}} + \frac{\gamma_I}{2}(\Delta J_{i,t})^2. \tag{A4}$$

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

$$\frac{\partial V_0}{\partial C_{i,t}} => U_{C,i,t} - \lambda_{i,t}(1+t_{C,t})\frac{P_{C,t}}{P_t} = 0 \tag{A5a}$$

$$\frac{\partial V_0}{\partial B_{i,t}} => -\lambda_{i,t} + E_t\left(\lambda_{i,t+1}\beta(1+i_t)\frac{P_t}{P_{t+1}}\right) = 0 \tag{A5b}$$

$$\frac{\partial V_0}{\partial K_{i,t}} => E_t\left(\lambda_{i.t+1}\frac{\beta P_{I,t}}{P_{t+1}}\left((1-t_K)(i_{K,t}-rp_K)+t_K\delta_K\right)\right) - \lambda_{i,t}\xi_{i,t} + E_t\left(\lambda_{i,t+1}\xi_{i,t+1}\beta(1-\delta_K)\right) = 0 \tag{A5c}$$

$$\frac{\partial V_0}{\partial J_{i,t}} => -\left(\left(1+\gamma_K\left(\frac{J_{i,t}}{K_{i,t-1}}\right)+\gamma_I\Delta J_{i,t}\right)-\tau_K\right) + E_t\left(\frac{1}{1+i_t}\frac{P_{I,t+1}}{P_{I,t}}\gamma_I\Delta J_{i,t+1}\right) + \xi_{i,t}\frac{P_t}{P_{I,t}} = 0. \tag{A5d}$$

Non-liquidity constrained households buy new patents of designs produced by the R&D sector ($I_{A,t}$) and rent their total stock of design (A_t) at rental rate $i_{A,t}$ to intermediate goods producers in period t. Households pay income tax at rate t_K on the period return of intangibles and they receive tax subsidies at rate τ_A. Hence, the first order conditions with respect to R&D investments are given by:

$$\frac{\partial V_0}{\partial A_{i,t}} => E_t\left(\lambda_{i.t+1}\frac{\beta P_{A,t}}{P_{t+1}}\left((1-t_K)(i_{A,t}-rp_A)+t_K\delta_A\right)\right) - \lambda_{i,t}\psi_{i,t} + E_t\left(\lambda_{i,t+1}\psi_{i,t+1}\beta(1-\delta_A)\right) = 0 \tag{A6a}$$

$$\frac{\partial V_0}{\partial J_{A,i,t}} => -\frac{P_{A,t}}{P_t}(1-\tau_A) + \psi_{i,t} = 0\,. \tag{A6b}$$

Therefore, the rental rate can be obtained from (6a), (6b) and (5b):

$$i_{A,t} = E_t\left(\frac{(1-\tau_A)(i_t - \pi_{A,t+1} + \delta_A + \delta_A\pi_{A,t+1}) - t_K\delta_A}{1-t_K}\right) + rp_A \tag{A6c}$$

where $1+\pi_{A,t+1} = \frac{P_{A,t+1}}{P_{A,t}}$.

Equation (A6c) states that households require a rate of return on intangible capital which is equal to the nominal interest rate minus the rate of change of the value of intangible assets and also covers the cost of economic depreciation plus a risk premium. Governments can affect investment decisions in intangible capital by giving tax incentives in the form of tax credits and depreciation allowances or by lowering the tax on the return from patents.

A.1.2 Liquidity-constrained households

Liquidity constrained households do not optimise but simply consume their current income at each date. Real consumption of household k is thus determined by the net wage income plus

benefits and net transfers:

$$(1+t_{C,t})P_{C,t}C_{k,t} = \sum_{s\in\{L,M,H\}}\left((1-t_{w,s,t})W_{s,t}L_{k,s,t} + BEN_{s,t}(1-NPART_{k,s,t}-L_{k,s,t})\right) + TR_{k,t}. \quad \text{(A7)}$$

A.1.3 Wage setting

Within each skill group a variety of labour services are supplied which are imperfect substitutes to each other. Thus, trade unions can charge a wage mark-up ($1/\eta_{s,t}$) over the reservation wage. The reservation wage is given as the marginal utility of leisure divided by the corresponding marginal utility of consumption. The relevant net real wage to which the mark up adjusted reservation wage is equated is the gross wage adjusted for labour taxes, consumption taxes and unemployment benefits, which act as a subsidy to leisure. Thus, the wage equation is given as:

$$\frac{U_{1-L,h,s,t}}{U_{C,h,s,t}}\frac{1}{\eta_{s,t}} = \frac{W_{s,t}(1-t_{w,s,t}-b)}{P_{C,t}(1+t_{C,t})} \text{ for } s\in\{L,M,H\}, \quad \text{(A8)}$$

where b is the benefit replacement rate.

A.1.4 Aggregation

The aggregate of any household specific variable $X_{h,t}$ in per capita terms is given by:

$$X_t = \int_0^1 X_{h,t}dh = (1-\varepsilon)X_{i,t} + \varepsilon X_{k,t}. \quad \text{(A9)}$$

Hence, aggregate consumption and employment is given by:

$$C_t = (1-\varepsilon)C_{i,t} + \varepsilon C_{k,t} \quad \text{(A10)}$$

and

$$L_t = (1-\varepsilon)L_{i,t} + \varepsilon L_{k,t}. \quad \text{(A11)}$$

A.2 Firms

A.2.1 Final output producers

Since each firm produces a variety of the domestic good which is an imperfect substitute for the varieties produced by other firms, it acts as a monopolistic competitor facing a demand function with a price elasticity given by σ_d. Final output (Y_t) is produced using A_t varieties of intermediate inputs ($x_{m,t}$) with an elasticity of substitution $1/(1-\theta) > 1$. The final good sector uses labour aggregate ($L_{Y,t}$) and intermediate goods in a Cobb-Douglas technology, subject to overhead labour FC_L and fixed costs FC_Y:

$$Y_t = (L_{Y,t})^{\alpha}\left(\int_0^{A_t}(x_{m,t})^{\theta}dm\right)^{\frac{1-\alpha}{\theta}} KG_t{}^{\alpha_G} - FC_Y \quad \text{(A12)}$$

with

$$L_{Y,t} = \left(\Lambda_L^{\frac{1}{\mu}} \left(\chi_L L_{L,t}\right)^{\frac{\mu-1}{\mu}} + \Lambda_M^{\frac{1}{\mu}} \left(\chi_M \left(L_{M,t} - FC_{L,M}\right)\right)^{\frac{\mu-1}{\mu}} + \Lambda_{HY}^{\frac{1}{\mu}} \left(\chi_{HY} L_{HY,t}\right)^{\frac{\mu-1}{\mu}} \right)^{\frac{\mu}{\mu-1}} \quad \text{(A13)}$$

$L_{L,t}$, $L_{M,t}$ and $L_{HY,t}$ denote the employment of low, medium and high-skilled in final goods production respectively. Parameter Λ_z is the corresponding share parameter, $\left(z \in \{L, M, HY\}\right)$, χ_z is the efficiency unit, and μ is the elasticity of substitution between different labour types. Note that high-skilled workers can work in the final goods and the R&D sector as well, therefore the total number of high-skilled ($L_{H,t}$) should be equal to the number of high-skilled employed in the final goods ($L_{HY,t}$) and in the R&D sector respectively ($L_{RD,t}$):

$$L_{H,t} = L_{HY,t} + L_{RD,t}. \quad \text{(A14)}$$

We account for the productivity-enhancing effects of infrastructure investment via a production function where the public capital stock ($K_{G,t}$) enters externally.

In a symmetric equilibrium, the demand for labour and intermediate inputs is given by:

$$\alpha \frac{Y_t + FC_Y}{L_{Y,t}} \left(\frac{L_{Y,t}}{L_{z,t}}\right)^{\frac{1}{\mu}} \Lambda_z^{\frac{1}{\mu}} (\chi_L)^{\frac{\mu-1}{\mu}} \eta = W_{z,t}, z \in \{L, HY\} \quad \text{(A15a)}$$

$$\alpha \frac{Y_t + FC_Y}{L_{Y,t}} \left(\frac{L_{Y,t}}{L_{M,t} - FC_L}\right)^{\frac{1}{\mu}} \Lambda_M^{\frac{1}{\mu}} (\chi_M)^{\frac{\mu-1}{\mu}} \eta = W_{M,t} \quad \text{(A15b)}$$

$$px_{m,t} = \eta(1-\alpha)(Y_t + FC_Y) \left(\int_0^{A_t} \left(x_{m,t}\right)^{\theta} dm\right)^{-1} \left(x_{m,t}\right)^{\theta-1} \quad \text{(A16)}$$

where $\eta = 1 - 1/\sigma_d$ and $px_{m,t}$ is the price of intermediate goods.[4]

A.2.2 Intermediate goods producers

The intermediate sector consists of monopolistically competitive firms which have entered the market by licensing a design from domestic households and by making an initial payment FC_A to overcome administrative entry barriers. Capital inputs are also rented from the household sector for a rental rate of $i_{K,t}$. Firms which have acquired a design can transform each unit of capital into a single unit of an intermediate input. In a symmetric equilibrium, the respective inverse demand functions of intermediate goods producing firms are given as (A16), therefore the first order condition is:

$$\theta\eta(1-\alpha)(Y_t + FC_Y) \left(\int_0^{A_t} \left(x_{m,t}\right)^{\theta} dm\right)^{-1} \left(x_{m,t}\right)^{\theta-1} = i_{K,t}. \quad \text{(A17)}$$

Intermediate goods producers set prices with a mark-up over marginal cost. Therefore intermediate goods prices are given by:

$$px_{m,t} = \frac{i_{K,t}}{\theta}. \quad \text{(A18)}$$

A.2.3 R&D sector

[4] Note that η is inversely related to the net mark-ups in the final goods sector (mkp_f): $\eta = 1/(1 + mkp_f)$.

Innovation corresponds to the discovery of a new variety of producer durables that provides an alternative way of producing the final good. The R&D sector hires high-skilled labour ($L_{RD,t}$) and generates new designs according to the following knowledge production function:

$$\Delta A_t = \nu A^{*}_{t-1}{}^{\omega} A^{\varphi}_{t-1} \left(L_{RD,t}\right)^{\lambda}. \tag{A19}$$

In this framework we allow for international R&D spillovers following Bottazzi & Peri (2007). Parameters ω and φ measure the foreign and domestic spillover effects from the aggregate international and domestic stock of knowledge (A^*_t and A_t) respectively. Negative value for these parameters can be interpreted as the "fishing out" effect, i.e. when innovation decreases with the level of knowledge, while positive values refer to the "standing on shoulders" effect and imply positive research spillovers. Note that φ=1 would yield the strong scale effect feature of endogenous growth models with respect to the domestic level of knowledge. Parameter ν can be interpreted as total factor efficiency of R&D production, while λ measures the elasticity of R&D production on the number of researchers ($L_{RD,t}$). The international stock of knowledge grows exogenously at rate g_{A^*}. We assume that the R&D sector is operated by a research institute which employs high skilled labour at their market wage, $W_{H,t}$. We also assume that the research institute faces an adjustment cost (γ_A) of hiring new employees and maximises the following discounted profit-stream:

$$\max_{L_{RD,t}} \sum_{t=0}^{\infty} d_t \left(P_{A,t}\Delta A_t - W_{H,t} L_{RD,t} - \frac{\gamma_A}{2} W_{H,t} \left(\Delta L_{RD,t}\right)^2 \right) \tag{A20}$$

where d_t is the discount factor. High-skilled are paid the same wages across sectors: $W_{H,t}=W_{HY,t}$.

A.3 Policy

On the expenditure side we distinguish between government consumption (G_t), government investment (IG_t), government transfers (TR_t) and unemployment benefits (BEN_t), where:

$$BEN_t = \sum_{s\in\{L,M,H\}} BEN_{s,t}(1 - NPART_{s,t} - L_{s,t}). \tag{A21}$$

The government provides subsidies (SUB_t) on physical capital and R&D investments in the form of a tax-credit and depreciation allowances:

$$SUB_t = t_K \left(\delta_K P_{I,t-1} K_{i,t-1} + \delta_A P_{A,t-1} A_{i,t-1}\right) + \tau_K P_{I,t} J_{i,t} + \tau_A P_{A,t} J_{A,i,t}. \tag{A22}$$

Government revenues R_t^G are made up of taxes on consumption as well as capital and labour income. Government debt (B_t) evolves according to:

$$B_t = (1+i_t) B_{t-1} + G_t + IG_t + TR_t + BEN_t + SUB_t - R_t^G. \tag{A23}$$

Lump-sum transfers (TR_t) control the debt to GDP ratio according to the following rule:

$$\Delta TR_t = \tau_B \left(\frac{B_{t-1}}{Y_{t-1}} - b^T\right) + \tau_{DEF} \Delta \left(\frac{B_t}{Y_t}\right) \tag{A24}$$

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

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

$$i_t = \gamma_{ilag} i_{t-1} + (1-\gamma_{ilag})(r_{EQ} + \pi_{TAR} + \gamma_{\inf}(\pi_{C,t} - \pi_{TAR}) + \gamma_{ygap}\hat{y}_t). \quad \text{(A25)}$$

The central bank has a constant inflation target (π_{TAR}) and it adjusts interest rates whenever actual consumer price inflation ($\pi_{C,t}$) deviates from the target and it also responds to the output gap $(\hat{y}_t)$ via the corresponding $\gamma_{\inf}$ and γ_{ygap} coefficients. There is also some inertia in nominal interest rate setting over the equilibrium real interest rate r_{EQ} determined by γ_{ilag}. Output gap is defined as deviation of capital and labour utilisation from their long run trends.

A.4 Trade

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

$$Z_t = \left((1-\rho)^{\frac{1}{\sigma_{im}}} Z_{d,t}^{\frac{\sigma_{im}-1}{\sigma_{im}}} + \rho^{\frac{1}{\sigma_{im}}} Z_{f,t}^{\frac{\sigma_{im}-1}{\sigma_{im}}} \right)^{\frac{\sigma_{im}}{\sigma_{im}-1}}. \quad \text{(A26)}$$

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

A.5 Calibration

We calibrate our model in a two-country setting with EU28 and the rest of the world. We select behavioural and technological parameters such that the model can replicate important empirical ratios such as labour productivity, investment, consumption to GDP ratios, the wage share, the employment rate and the R&D share, given a set of structural indicators describing market frictions in goods and labour markets, tax wedges and skill endowments.

Goods Market:

We identify the intermediate sector as the investment goods' sector (mostly R&D intensive subsectors of manu-facturing) and the final goods sector as the aggregate of all remaining market sectors. The investment goods' sector resembles the intermediate sector along various dimensions. First, this sector is more R&D and patent intensive, second, a large fraction of these manufacturing sectors supply innovative goods (in the form of invest-ment goods but also innovative consumer goods). Final goods sectors, including services, on the other hand are typically not subject to large (patented) innovations but rely on organisational changes possibly in relation to new technologies supplied by the investment goods'sector sector. Also the two sectors differ in the degree of competition, with manufacturing showing smaller mark ups compared to final goods sectors. Our calibration of mark ups is based on Roeger (1995) and Canton and Thum-Thysen (2015). Using the most recent EU KLEMS databank the average mark-up for manufacturing is 10%, while for final goods/service sector it is around 13% in the EU28. Concerning entry barriers we rely on estimates provided by the Doing Business Database.

Knowledge production technology:

Empirical evidence on output elasticities has been provided by Bottazzi and Peri (2007) and Pessoa (2005). The growth rate of ideas was obtained from Pessoa (2005) with the assumption of a 5% obsolescence rate. In our model the R&D elasticity of research labour (λ) is determined by the wage cost share in the total R&D spending. We rely on Bottazzi and Peri (2007) to calibrate the knowledge elasticity parameters w. r. t. domestic and foreign knowledge capital. The authors do not estimate directly φ and ω, only the ratio between these coefficients and λ. These estimates together with the long-run growth rate of intangible capital and λ pin down the corresponding elasticities.

Labour market and the skill composition of the labour force:

We rely on Ratto et al. (2009) to calibrate the adjustment parameters of the labour market. Labour force is disaggregated into three skill-groups: low-, medium- and high-skilled labour. We define high skilled workers as that segment of labour force that can potentially be employed in the R&D sector, i.e. engineers and natural scientists. Our definition of low-skilled corresponds to the standard classification of ISCED 0-2 education levels and the rest of the labour force is considered as medium-skilled. Data on skill-specific population shares, participation rates and wages are obtained from the Labour Force Survey, SES, and the Science and Technology databases of EUROSTAT. The elasticity of substitution between different labour types (μ) is one of the major parameters addressed in the labour-economics literature. We rely on Acemoglu and Autor (2011) which updated the seminal reference for this elasticity parameter by Katz and Murphy (1992). Acemoglu and Autor (2011) argues for estimates in the range of 1.6-1.8 on the extended data sample, therefore, we take 1.7 as our baseline value. Low-skilled wages are obtained from the annual earnings of employees with low educational attainment (ISCED 0-2) irrespective of their occupation. High-skilled wages are approximated by the annual earnings of scientists and engineers with tertiary educational attainment employed as professionals or associate professionals in physical, mathematical, engineering, life science or health occupations (ISCO-08 occupations 21, 22, 31, 32). Earnings data of employees with tertiary educational attainment not working as scientists and engineers and employees with medium educational attainment (ISCED 3-4) irrespective of their occupation are taken to calculate wages for our medium-skilled in the model.

Fiscal, monetary and trade variables:

We use EUROSTAT for the breakdown of government spending into consumption, investment and transfers and we use effective tax rates on labour, capital and consumption to determine government revenues. In addition we use estimates of R&D tax credits from OECD (2015c). Monetary policy parameters are adopted from Ratto et al. (2009) while the bilateral trade data is obtained from the EUROSTAT/COMEXT database.

Income shares

The initial income shares correspond to the calibrated values of our income categories in Section 3. Net wages are based on labour compensation data adjusted by labour taxes (EUROSTAT, 2018 data). Unemployment benefits are obtained by multiplying the 2017 value of benefit replacement rates (OECD) with the skill-specific wages. Transfers and domestic bond income are derived using 2018 national accounts data (EUROSTAT), while final, intermediate goods and R&D profits are pinned down by the model equations using the underlying wage and capital stock data (EUROSTAT). The rental rate of capital and equity premiums are

set in line with the low profit rates in the model.

Table A.1. Calibration of income shares

Income shares	%
Net wages	**62.38**
Benefits	**1.14**
Transfers	**10.72**
Lump sum tax	**0**
Domestic bond inc.	**5.92**
Foreign bond inc.	**0**
Capital inc. (total)	**19.84**
- Rent inc. tang.	*15.83*
- Rent inc. intang.	*1.73*
- Profits-final goods	*1.02*
- Profits-R&D	*1.26*
Total	**100**

Source: Authors' calculations

Note that fixed costs are a standard feature of current macroeconomic models. See, for example, Smets and Wouters (2003), the ECBs Area Wide Model (Christoffel et al., 2008) or the Commission's QUEST model (Ratto et al., 2009) for the Euro Area, and Christiano et al. (2005) for the US. Fixed costs are needed in order to reconcile relatively high mark up estimates with low profit rates. For a discussion see for example Hall (1988) or Rotemberg and Woodford (1999). From the first-order conditions (10) and (11) in the main text, it follows that profits in the final goods producing sector can be expressed as a positive function of the mark up and they depend negatively on fixed costs and the overhead labour costs.

$$PR_{jt}^{Y} = mup_{jt}^{Y} P_{jt}^{Y} Y_{jt} - \left(1 - mup_{jt}^{Y}\right) P_{jt}^{Y} FC_{Y} - W_{t,M} FC_{L,M} \geq 0 \qquad \text{(A27)}$$

In line with the QUEST model estimate of Ratto et al. (2009), the share of overhead labour ($FC_{L,M}$) is set to 10%. Given the high mark-ups (13%) and the low profit rate, equation (A27) implies a fixed cost (FC_Y) of about 3% of output.

Appendix B: The wage response to general versus skill-specific labour market reforms

In a standard macro model with a CRS technology and infinitely lived households it is fairly well understood that the capital labour ratio is determined by the rate of time of preference and the depreciation rate and the capital labour ratio in turn determines the real wage. Therefore, a labour market reform leads to an increase in employment and a fall in wages in the short run but in the long run wages return to their pre reform baseline level while employment remains higher permanently. Thus, labour market reforms generate a trade-off between wages and employment in the short run but in the long run such a trade-off does not exist. In this appendix we show that for a skill specific labour market reform the trade-off between (skill specific) wages and employment exists both in the short and the long run.

Since we want to emphasize the difference between an aggregate and skill specific labour market reform we choose the simmlest possible model, namely Cobb-Douglas production function for capital and labour and in a second step we represent labour input by a CES ag-

gregate of skill specific labour inputs. We further assume zero price mark ups and we only consider the case without fixed costs and overhead labour. Before proceeding to the case with a CES labour aggregate we first discuss the case with homogenous labour.

B.1 Aggregate labour market reform

We consider a long-run equilibrium, where firms operate under perfect competition where labour is inelastically supplied and capital is elastically supplied at real interest rate r and δ is the depreciation rate of capital. The price is normalised to one. The technology is given by a Cobb Douglas production function:

$$Y = UK^{1-\alpha}L^{\alpha} \tag{B1}$$

From the first order condition for capital and labour:

$$\frac{\partial Y}{\partial K} = (1-\alpha)\frac{Y}{K} = (1-\alpha)\left(\frac{L}{K}\right)^{1-\alpha} U = r + \delta \tag{B2}$$

$$\frac{\partial Y}{\partial L} = \alpha\frac{Y}{L} = \alpha\left(\frac{K}{L}\right)^{\alpha} U = W \tag{B3}$$

one can see immediately that capital cost determines the capital labour ratio in the long run. From this we can derive the following proposition.

Proposition 1A: Labour market reform which increases employment increase the capital stock until the initial capital labour ratio is re-established. Since the post reform capital labour ratio is unchanged, the post reform marginal product of labour is also unchanged which supports an unchanged real wage. The wage share in total output remains constant.

B.2 Aggregate labour market reforms in the case of skill-specific labour

Now we allow that output is produced with capital and different types of labour. And labour input is combined in a CES aggregator L_Y:

$$Y = UK^{1-\alpha}L_Y^{\alpha}, \tag{B4}$$

where:

$$L_Y = \left[\sum_i \; s_i^{\frac{1}{\sigma}} L_i^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \text{ with } \sigma > 1. \tag{B5}$$

And there is a CES wage index W such that:

$$WL_Y = \sum_i \; W_i L_i \tag{B6}$$

FOCs w. r. t. K and the labour aggregate L_Y :

$$\frac{\partial Y}{\partial K} = (1-\alpha)\frac{Y}{K} = (1-\alpha)\left(\frac{L_Y}{K}\right)^{1-\alpha} U = r + \delta \tag{B7}$$

$$\frac{\partial Y}{\partial L_Y} = \alpha\frac{Y}{L_Y} = \alpha\left(\frac{K}{L_Y}\right)^{\alpha} U = W \tag{B8}$$

The same logic applies in the disaggregated labour case as long as we consider only variations of L_Y.

Proposition 1B: Labour market reform which increases the labour aggregate L_Y, raises the capital stock until the initial capital output ratio is re-established. Since the post reform *K*-L_Y ratio is unchanged, the post reform marginal product of L_Y is also unchanged which supports an unchanged real wage index *W*. Also, the total wage share in nominal output remains constant.

B.3 Skill-specific labour market reform

Now consider the case where only labour supply of a specific skill group *i* is increased.

$$\frac{\partial Y}{\partial L_Y}\frac{\partial LCES}{\partial L_i} = \alpha \frac{Y}{L_Y} s_i^{\frac{1}{\sigma}} \left(\frac{L_Y}{L_i}\right)^{\frac{1}{\sigma}} = W s_i^{\frac{1}{\sigma}} \left(\frac{L_Y}{L_i}\right)^{\frac{1}{\sigma}} = W_i \tag{B9}$$

W remains constant as shown above. But the constancy of *W* (in the long run) generates a trade-off between the increase of the $\frac{L_i}{L_Y}$ ratio and a fall in W_i. This fall in skill specific wages is due to a fall in the marginal efficiency of L_i as measured by a declining marginal productivity of L_i ($\frac{\partial^2 L_Y}{\partial L_i^2} < 0$). The efficiency loss is inversely related to the elasticity of substitution (σ) and goes to zero as the elasticity of substitution goes to zero.

Rearranging the FOC yields an expression for the wage share of skill group *i*

$$\frac{W_i L_i}{W L_Y} = s_i^{\frac{1}{\sigma}} \left(\frac{L_i}{L_Y}\right)^{1-\frac{1}{\sigma}} \tag{B10}$$

This shows that an increase in relative employment of skill group *i* increases the share of wages of skill group *i* in total wages. Since the share of total wages in output remains constant, this implies an increase of the wage share of skill group *i* in total (nominal) output. This can be summarised in the following proposition

Proposition 2: An increase of employment of skill group *i* is associated with an increase in the wage share of skill group *i* and a decline in the real wage of skill group *i*.

Appendix C: Detailed results by reform areas

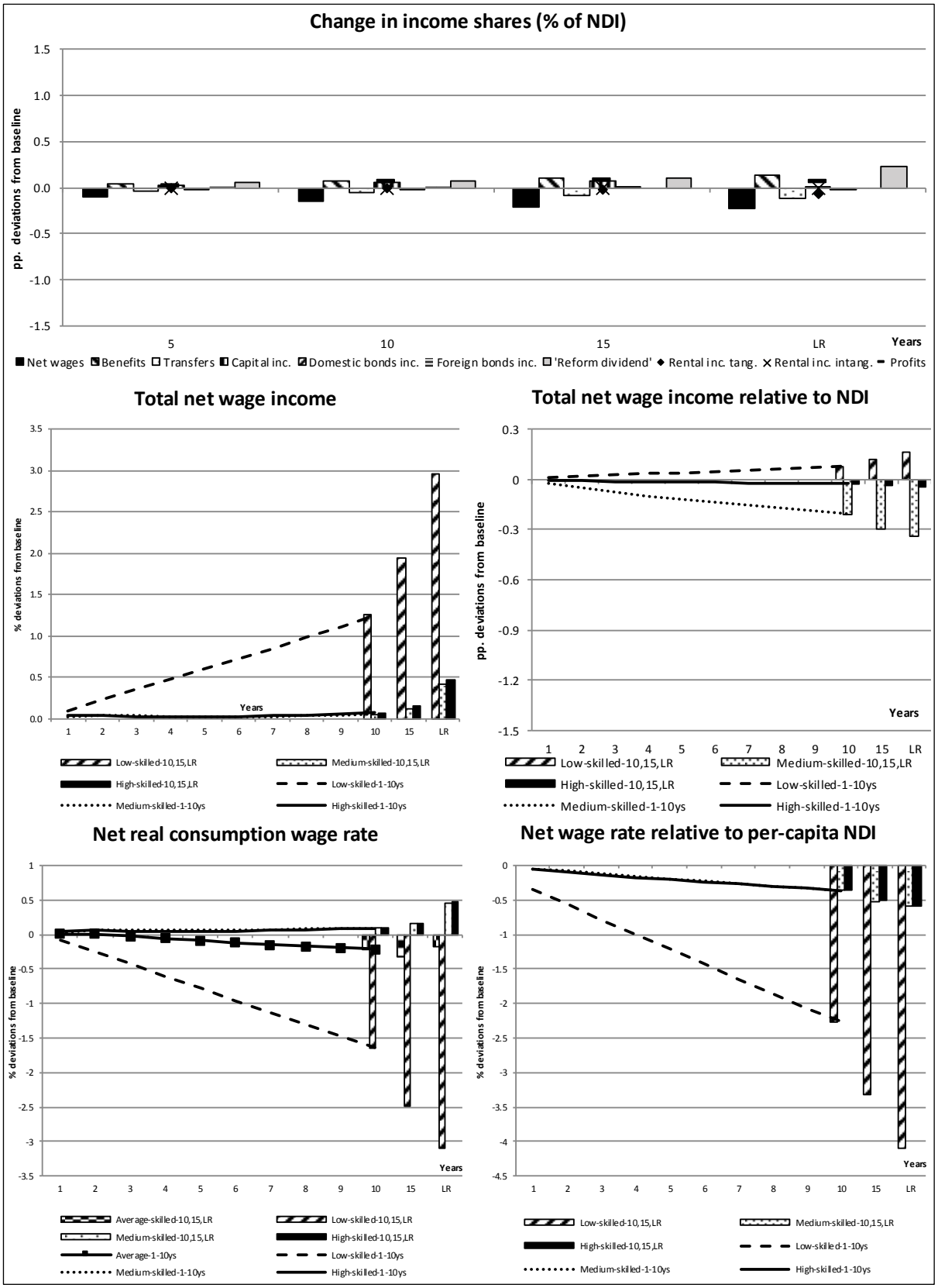

Figure C.1. Increasing low-skilled participation
Source: Model simulations

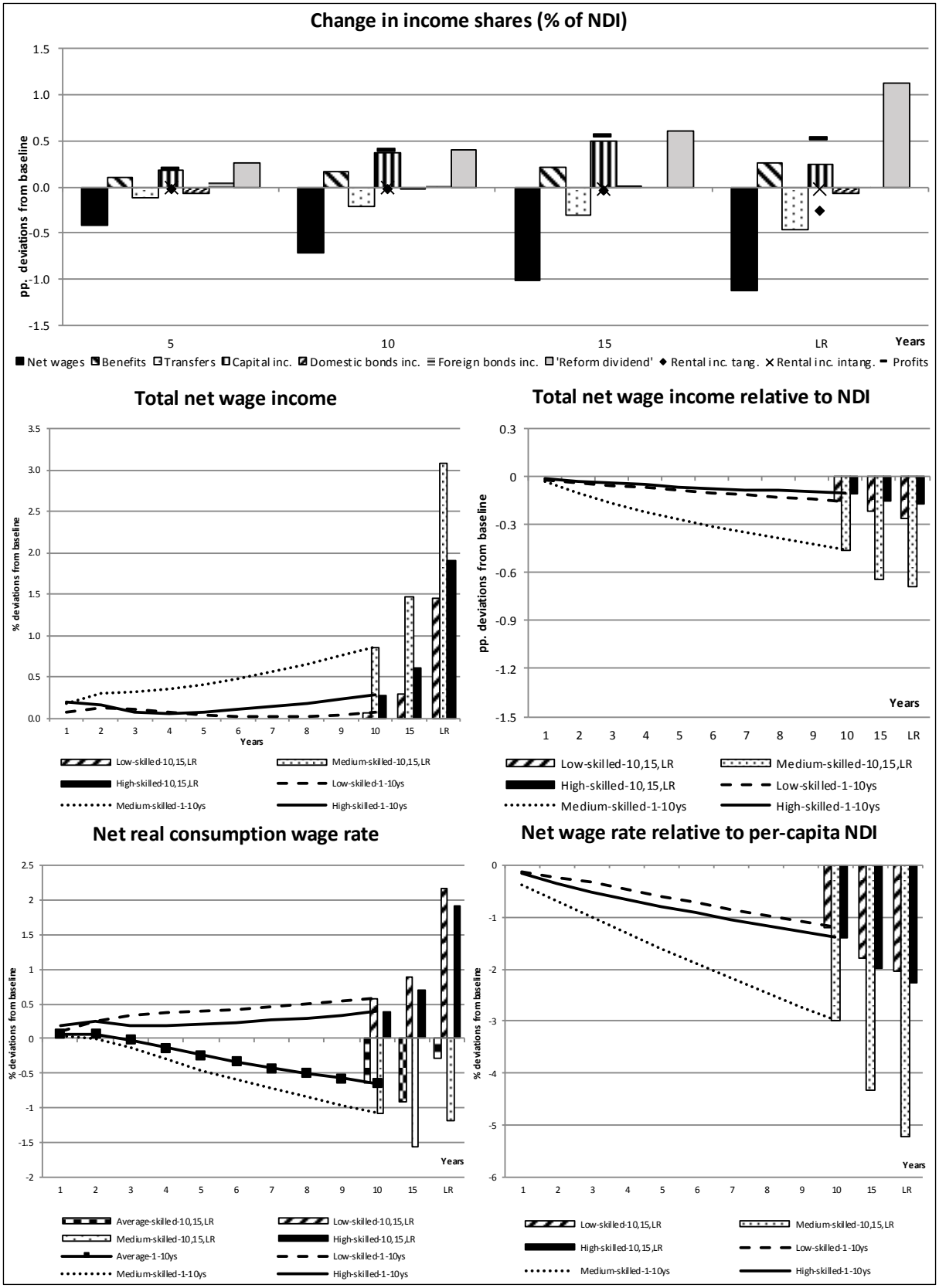

Figure C.2. Increasing medium-skilled participation
Source: Model simulations

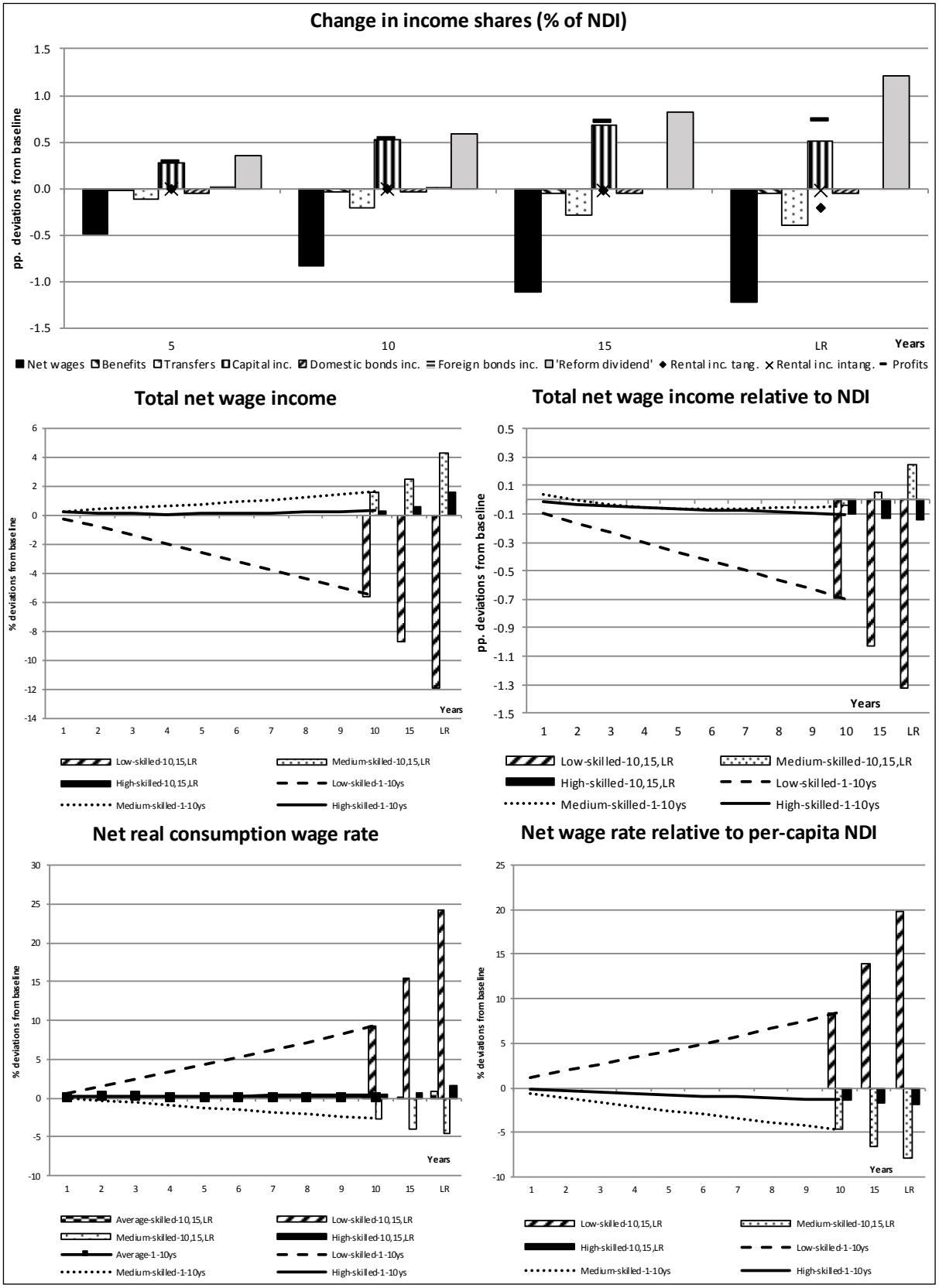

Figure C.3. Shift from low- to medium-skilled population
Source: Model simulations

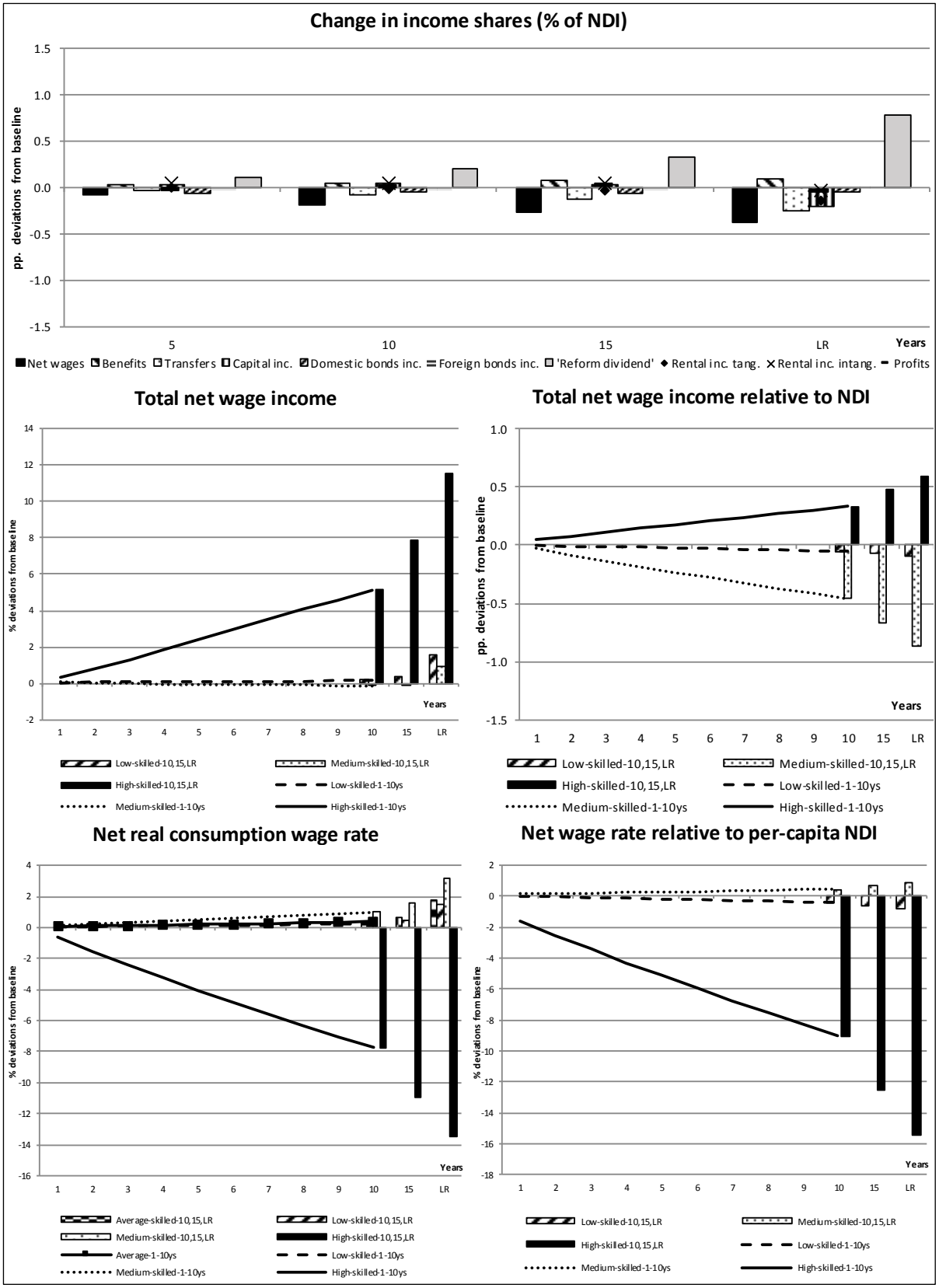

Figure C.4. Shift from medium- to high-skilled population
Source: Model simulations