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Abstract in English

This paper describes a labour market extension for the CGE model "WorldScan". The labour market module features endogenous labour supply at two margins: participation and hours of work. Involuntary unemployment is captured through a collective bargaining ("right to manage") set-up. The paper explains how these two labour market mechanisms interact and how they are calibrated to empirical elasticities. Illustrative simulations that can be placed in the context of the "double dividend" literature show the working mechanisms of the module.

Keywords: WorldScan, computable general equilibrium model, labour market, labour supply, involuntary unemployment

JEL Code: C68, D58, J20, J50

Abstract in Dutch

Dit document beschrijft de arbeidsmarktextensie voor het algemeen-evenwichtsmodel 'WorldScan'. In de arbeidsmarktmodule is het arbeidsaanbod in twee opzichten endogeen: de participatie en het aantal gewerkte uren. Onvrijwillige werkloosheid wordt meegenomen in de vorm van een model van collectieve loononderhandelingen ('right to manage approach'). In dit paper wordt de wisselwerking tussen deze twee arbeidsmarktmechanismen uitgelegd, evenals de manier waarop empirische elasticiteiten kunnen worden gebruikt om het model te ijken. De werkwijze van de module wordt met illustratieve simulaties gedemonstreerd. Deze kunnen in de context van de discussie over een mogelijk 'dubbel dividend' van klimaatbeleid worden geplaatst.

Contents

Preface

Government policies may affect labour market participation and involuntary unemployment. To be able to assess these policy impacts with the Computable General Equilibrium model WorldScan a labour market extension of the model was required. This extension is described in this document. The labour market module features endogenous labour supply at two margins: participation and hours of work. Involuntary unemployment is captured through a collective bargaining ("right to manage") set-up. The authors explain how these two labour market mechanisms interact and how they are calibrated to empirical elasticities. Selected policy simulations illustrate the working mechanisms of the module.

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Coen Teulings

Director

Summary

We present a labour market module for WorldScan in which labour supply and unemployment are endogenous variables, not exogenous parameters, which they were in the previous set-up. Labour supply at the intensive margin (hours of work) results from the optimising consumption-leisure choice of a representative household. Labour supply at the extensive margin (participation) is modelled as the comparison of the expected utility of participation with a fixed cost of taking up work, which varies between households. Wages and unemployment are determined through collective bargaining between firms and a trade union in a representative sector of each economy.

These modelling choices produce interaction effects, which are integrated in the model as far as possible. Labour supply at the two margins has different consequences for unemployment: Without labour demand reactions, an additional participating worker increases unemployment, whereas an additional hour of an already participating worker does not. Unemployment, in turn, affects labour supply at the extensive margin, because the households consider the expected value of participation in their decision and high unemployment rates have a discouraging effect. Finally, bargained wages feed back to the individual hours-of-work decision, which then co-determines employment in persons.

Interaction effects turn out to be intricate and are not always resolved in a completely consistent way in WorldScan. Most prominently, the empirical parameters of the Linear Expenditure System are not in all cases compatible with empirical wage differentials and replacement rates. Second, there remains a ambiguity between personal and functional income distribution in the disaggregated household accounting. And finally, the wage bargaining equation is not calibrated to empirical wage curve elasticities. However, we think that these weak points of the current set-up are not dominant as drivers of the model's basic reactions to policy shocks. Nevertheless, they must be kept in mind when interpreting the simulation results.

1 Policy analysis with WorldScan

The applied general equilibrium model WorldScan is used for assessing the consequences of a broad spectrum of European policy measures, e.g. liberalisation of trade in services (De Bruijn et al., 2008), R&D stimulation (Gelauff and Lejour, 2006) or greenhouse gas emission trading in the context of the Kyoto protocol (Boeters et al., 2007). While the modelling of international trade, sectoral interdependencies and consumption demand can be considered state of the art in applied general equilibrium modelling, labour market mechanisms have received less attention. This can be defended as long as one is primarily interested in the consequences for the international trade structure, productivity growth or the carbon price. However, once we start to engage in an encompassing impact assessment of policy measures, the labour market is a core issue, particularly in those European countries where involuntary unemployment remains one of the most pressing economic problems.

In the context of the Framework 6 project "MODELS", the labour market representation in WorldScan has therefore undergone a thorough revision. The most important outcome is that labour supply and involuntary unemployment have turned from exogenous parameters into endogenous variables. This paper documents the changes that were necessary to implement this general strategy. It covers both the core equations for labour supply and unemployment and a number of auxiliary refinements of the model structure.

We proceed as follows. Section 2 sketches our point of departure, the labour market set-up of WorldScan in the version documented by Lejour et al. (2006). Section 3 lays out the general modelling principles for the new labour market representation. These are explained in more detail in Sections 4, 5 (labour supply) and 6 (collective wage bargaining and unemployment). We document auxiliary changes in the model set-up (Sections 7 and 8) and remaining problems (Section 9). Section 10 presents a series of illustrative simulations of an energy tax reform with different tax revenue recycling schemes. Section 11 draws conclusions about the applicability of the labour-market-extended model.

2 Previous labour market set-up

Our point of departure is the labour market module of WorldScan as documented in Chapter 4 (p. 39 – 52) of Lejour et al. (2006). In this set-up, the labour market behaviour is almost completely determined by exogenous parameters. Essentially, we have a single labour market equation per skill group (low skilled / high skilled) and region:

$$L_D(\mathbf{Y}, \mathbf{p}) = (1 - \bar{u})\bar{L}_S, \tag{2.1}$$

where L_D is labour demand (as a function of the vectors of sectoral outputs, $\mathbf{Y}$, and prices, $\mathbf{p}$, including wages), u is unemployment, and L_S is labour supply. Labour supply and unemployment are determined outside the model, indicated by bars above the variables in equation (2.1), through the following steps.

- Labour supply (in persons) per region is given as an exogenous projection. This projection has been calculated by decomposing total population into age groups and applying age-group specific participation rates, yielding the average participation rate of the population. Both total population and participation rates can be varied exogenously as a part of a scenario (e.g. simulating the effects of increasing participation of certain groups of the population). However, they do not respond endogenously to variations in other parameters (productivity, tax rates). Working time per person is assumed to be constant, so that labour supply in persons translates into labour supply in hours by simple scaling.
- The same approach is taken for the split of total labour supply into low and high skilled workers. The split is governed by a share parameter derived from GTAP and additional ILO data. This parameter can be exogenously varied, if we want to analyse the consequences of more schooling in a specific region, but it does not adjust endogenously to other changes in the model. The approach of an exogenous variation of labour market parameters has been followed in Jacobs (2005).
- Finally, also involuntary unemployment (in contrast to non-participation, which is assumed to be voluntary) enters the model through an exogenous parameter. Unemployment rates are taken from OECD sources and held fixed both over time and in the scenario analyses. (The split between high and low skilled unemployment is ad hoc in a way that the low skilled unemployment rate is considerably higher.)

Under these assumptions, the wage forming mechanism is basically a competitive labour market with fixed labour supply. Total employment does not depend on the model mechanisms and can simply be calculated as exogenous labour supply less exogenous unemployment. In the model, the wage endogenously adjusts so that labour demand equals employment and the labour market clears.

This previous labour market set-up in WorldScan has obvious shortcomings, which we can classify with regard to the type of policy that we want to analyse:

- If we analyse non-labour market policies (e.g. stimulation of R&D, an emission-trading system or the liberalisation of trade), we are also interested in the endogenous adjustment of labour market variables other than the wage: To what extent will labour supply adjust? Will changes in labour supply smoothly be absorbed through labour demand, or will there be changes in the unemployment rate? What are the wage reactions if the role of the wage is more complex than simply the clearing of the labour market?
- Labour market effects become particularly important when we operate in a setting of a revenue-neutral tax reform (e.g. analysing the consequences of recycling the revenue of an emission tax). The most prominent candidate for a welfare-enhancing recycling of a budget surplus are labour taxes, because here distortions are considered to be particularly high. If labour supply is fixed, however, the labour tax is completely non-distortionary, and it is not interesting at all to analyse it as a revenue-recycling instrument.
- In the context of assessing the EU “Lisbon” targets, we might also be interested in policy measures that are designed to directly stimulate labour supply. With the previous model set-up, the only thing we can do is *assume* that the labour market stimulation is successful and trace out the consequences of this (Gelauff and Lejour, 2006). In such an approach, neither the instruments of labour market policy are specified, nor can the costs of labour market policy be determined.

3 General modelling principles

In the light of the shortcomings listed at the end of the previous section, the principal aim of the model revision undertaken in the labour market work package of the "MODELS" project is to develop a labour market module where both labour supply and unemployment are endogenous. Given the CGE set-up of WorldScan, the multi-country approach and the time restrictions of the project, we opt for a modelling strategy at the level of representative households. This means that any labour market behaviour that is at the level of specific aspects of household heterogeneity is not covered (see the summarising discussion in Section 11). The microeconomic foundation of the model is maintained. This means that representative households are modelled as utility-maximising agents, and that the wage and unemployment generating process is seen as the product of the interaction of utility-maximising agents as well. This is necessary if we do not restrict ourselves to assessing observable outcomes at the labour and other markets, but also want to perform a welfare analysis of policy scenarios.

Making labour supply and unemployment endogenous, *in isolation*, are two straightforward exercises. There exist blueprint models that can in principle directly be implemented in any CGE model like WorldScan. Endogenising labour supply and unemployment *at the same time* is more demanding than simply "adding up" a labour supply and an unemployment module, because interaction effects emerge:

- In a model without involuntary unemployment, basic labour market related questions can be answered at the level of a representative household with a simple labour-leisure choice, i.e. with a single margin of labour supply. Such a set-up compounds the reaction at the intensive margin (hours of work) and at the extensive margin (participation). As long as each supplied unit of labour is actually employed, the additional insights of splitting the two margins of labour supply are limited.
  The situation completely changes once there is involuntary unemployment. Now it is of utmost importance whether, say, an additional one percent labour supply is one percent more hours of the same number of persons, or one percent more persons with the same hours of work. Without, or before, any adjustment of labour demand, the latter would translate into higher unemployment, whereas the former would not. This difference is both interesting in itself (the unemployment rate is the most important indicator of labour market inefficiency) and because of its implications for the wage level (unemployment puts pressure on the wage) and the public budget (unemployed persons receive some kind of unemployment compensation, unemployed hours do not).
- A second aspect that makes the distinction between the two margins of labour supply relevant, is the presence of non-proportional taxes on labour. The reactions on the two margins depend on different tax indicators. At the intensive margin, the household compares the actual (optimal)

situation with slightly more or slightly less hours of work. Here it is the marginal after-tax wage that counts, and high marginal tax rates are likely to produce a particularly strong distortion. At the extensive margin, in contrast, the household does not face a marginal, but a discrete choice: working or not working at all. Consequently, the marginal tax rate has no particular role to play. What counts is the after-tax income in the case of working, which is compared to the utility of not working. This after-tax income is most directly determined by the *average* tax rate. The marginal rate only plays an indirect role by influencing the hours of work *conditional* on a positive participation decision, which are also one of the determinants of the after-tax income.

- While the first point in this list was about the consequences of labour supply for unemployment, there is also an important consequence in the other direction. In its participation decision, households are likely to take the labour market situation into account. If involuntary unemployment is high, searching for a job is costly and expected income is low, so that participation is discouraged. One might also speculate about unemployment consequences for the intensive margin of labour supply, but this is only plausible if households decide over hours of work before the labour market uncertainty is resolved and unemployment rates differ by labour market segment (part-time vs. full time). There is some plausibility in both, but unemployment seems to be most important for the extensive margin; so we limit our attention to this aspect.

In the following three sections, we work out the consequences of these general modelling guidelines in detail. Section 4 is about the intensive margin of labour supply and its calibration to empirical labour supply elasticities, Section 5 is the analogue for the extensive margin, and Section 6 explains our approach to unemployment (collective wage bargaining).

4 Labour supply: hours of work

In this section, we present the hours of work choice of a representative household, where hours of work are chosen as the result of maximising a utility function that comprises consumption of goods and leisure. Except for some normalisations and auxiliary variables, we follow as closely as possible the equations that are implemented in the WorldScan GAMS code. However, we suppress skill, sector and country indices for expositional clarity. The WorldScan names of the variables are listed in Appendix A.

Our point of departure is the extended income of the employed worker household, Y_E, which includes labour earnings, $wL(1-t_a)$, non-labour income, Y_0, and leisure, which is valued at the marginal wage: $w(T-L)(1-t_m)$.

$$Y_E = w\left[L(1-t_a)+(T-L)(1-t_m)\right]+Y_0$$

T is time endowment, L is hours worked. Both are expressed as multiples of labour supply in the base year[1] ($\bar{L}=1$). w is the wage per initial hours package. t_a and t_m are the average and marginal labour tax rate, respectively. *Disposable* extended income, Y_D, results if we subtract basic consumption[2], C_0.

$$Y_D = Y_E - C_0,$$

where basic consumption is calculated from its components

$$C_0 = \sum_i \gamma_i p_i^c,$$

with γ_i and p_i^c denoting basic consumption and price per consumption commodity category. The spending of Y_D is determined by the maximisation of a CES utility function[3] with leisure and (disposable) consumption (of goods) as its arguments and elasticity of substitution σ:

$$U_e = \left[\theta_C\left(\frac{C_D}{\bar{C}_D}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_C)\left(\frac{F}{\bar{F}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}},$$

where F is leisure,

$$F = T - L,$$

and C_D is disposable consumption,

$$C_D = \frac{\left[wL(1-t_a)-C_0\right]}{p_C},$$

[1] All variables with an upper bar denote base year values.

[2] See Chapter 6 of Lejour et al. (2006) for the details of the consumption structure (Linear Expenditure System).

[3] We use the “calibrated share form” of the CES function, see Rutherford (1998).

with p_C as an appropriately defined consumption price index normalised to $\bar{p}_C = 1$:

$$p_C = \prod_i \left(\frac{p_i^c}{\bar{p}_i^c} \right)^{\theta_i}$$

$$\theta_i = \frac{\bar{p}_i^c \left(\bar{C}_i - \gamma_i \right)}{\bar{C}_D}$$

θ_C is the initial share of disposable consumption in disposable extended income:

$$\theta_C = \frac{\bar{C}_D}{\bar{Y}_D} \tag{4.1}$$

As Y_D can be expressed as $Y_D = p_C C_D + w(1 - t_m)F$, we have

$$1 - \theta_C = \frac{\bar{w}(1 - \bar{t}_m)\bar{F}}{\bar{Y}_D}$$

In WorldScan, the CES utility is implemented as an expenditure function and corresponding demand functions:

$$p_U = \left[\theta_C p_C^{1-\sigma} + (1 - \theta_C) \left(\frac{w(1 - t_m)}{\bar{w}(1 - \bar{t}_m)} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} \tag{4.2}$$

$$\frac{C_D}{\bar{C}_D} = U_e \left(\frac{p_U}{p_C} \right)^{\sigma} \tag{4.3}$$

$$\frac{F}{\bar{F}} = U_e \left(p_U \frac{\bar{w}(1 - \bar{t}_m)}{w(1 - t_m)} \right)^{\sigma}, \tag{4.4}$$

where p_U is the necessary expenditure for one unit of utility, so that the utility level can be calculated as

$$U_e = \frac{Y_D}{p_U}$$

In the following two subsections, we describe how labour supply at the intensive margin is calibrated to empirical labour supply elasticities.

4.1 Income elasticity of labour supply

Originating from a homothetic CES function, the demand functions are homogeneous of degree one in disposable extended income. We thus have[4]

$$\frac{\varepsilon F}{\varepsilon Y_D} = 1$$

From this we can derive the income elasticity of labour supply. To be precise, we calculate the per cent change of labour supply with respect to an exogenous variation of the non-labour

[4] We use $\varepsilon x / \varepsilon y$ as a shorthand for the elasticity $\partial \log x / \partial \log y$.

income, Y_0, that would increase $Y = wL(1-t_a)+Y_0$ by one percent, if labour supply did not react.[5]

$$\eta_{LY} := \frac{\varepsilon L}{\varepsilon Y} = \frac{\varepsilon L}{\varepsilon Y_0}\frac{Y}{Y_0} = \frac{\varepsilon L}{\varepsilon F}\frac{\varepsilon F}{\varepsilon Y_D}\frac{\partial Y_D}{\partial Y_0}\frac{Y}{Y_D}$$

We have

$$\frac{\varepsilon L}{\varepsilon F} = -\frac{T-L}{L} \tag{4.5}$$

$$\frac{\varepsilon F}{\varepsilon Y_D} = \frac{\partial Y_D}{\partial Y_0} = 1 \tag{4.6}$$

and therefore

$$\begin{aligned}\eta_{LY} &= -\frac{T-L}{L}\frac{Y}{Y_D} \\ &= -\frac{T-L}{L}\frac{wL(1-t_a)+Y_0}{w\left[L(1-t_a)+(T-L)(1-t_m)\right]+Y_0-C_0}\end{aligned}$$

We treat η_{LY} as a parameter that we can (approximately) observe empirically, and use it to determine T, the (unobservable, disposable) time endowment. Solving for T, as a multiple of initial labour supply, gives

$$\begin{aligned}\frac{T}{L} &= \frac{[wL(1-t_a)+Y_0]-\eta_{LY}\left(w\left[L(1-t_a)-L(1-t_m)\right]+Y_0-C_0\right)}{[\eta_{LY}wL(1-t_m)]+wL(1-t_a)+Y_0} \\ &= 1-\frac{\eta_{LY}\left[wL(1-t_a)+Y_0-C_0\right]}{\eta_{LY}wL(1-t_m)+wL(1-t_a)+Y_0}\end{aligned} \tag{4.7}$$

For small, negative values of η_{LY} (we consider -0.1 a reasonable value[6]), $T > L$ is warranted. At the same time, small absolute values of η_{LY} will result in a small amount of disposable leisure. In the simplified benchmark case with $Y_0 = C_0 = 0$ and proportional taxes ($t_m = t_a = t$), (4.7) reduces to

$$\frac{T}{L} = 1-\frac{\eta_{LY}}{1+\eta_{LY}} = \frac{1}{1+\eta_{LY}} \tag{4.8}$$

For our preferred value of $\eta_{LY} = -0.1$, we thus arrive at $T \approx 1.1$. This may seem overly little: only 4 hours disposable leisure in relation to a standard work week of 40 hours. In ad-hoc specifications, one rather finds values between 1.5 and 2. However, this would lead to income elasticities of labour supply which are far beyond what we empirically observe. This point has forcefully been made by Ballard (2000).

In our numerical specification, we rely on equation (4.7). We assume η_{LY} to be uniformly -0.1 across all regions. Differences in the calibrated disposable time endowment, T/L, are then caused by country-specific values of basic consumption, C_0, and in the tax rates, t_m and t_a (see Section 7.2). Appendix B contains a list of the calibration results by country.

[5] The case is not completely clear. Do we ask: What would happen to labour supply if we gave the household one percent of its current income as an additional exogenous transfer? Or do we ask: What would happen to labour supply if we gave the household so much additional exogenous income that, *after adjustment*, his income is one percent higher? – Our reading of the empirical estimates is that the first interpretation is more appropriate.

[6] Here we follow Ballard (2000): "Based on my reading of the literature, a value of -0.1 would not be unreasonable."

4.2 Wage elasticity of labour supply

With the time endowment determined by the income elasticity of labour supply, we proceed with calibrating the value of the elasticity of substitution between consumption and leisure, using the wage elasticity of labour supply as empirical basis. This elasticity (of labour supply with respect to the marginal after-tax wage), η_{Lw}, can be calculated as

$$\eta_{Lw} = \frac{\varepsilon L}{\varepsilon \tilde{w}} = -\frac{T-L}{L}\frac{\varepsilon F}{\varepsilon \tilde{w}},$$

where $\tilde{w} = w(1-t_m)$. The elasticity of leisure demand with respect to the marginal after-tax wage can be routinely decomposed into a substitution effect and an income effect. The income effect deserves attention, because we need the effect of the wage on the disposable extended income, Y_D.

$$\eta_{Lw} = -\frac{T-L}{L}\left[-\sigma\theta_C - (1-\theta_C) + \frac{w(1-t_m)T}{Y_D}\right]$$

Solving for σ gives

$$\sigma = \frac{\eta_{Lw} - \frac{T-L}{L}\left((1-\theta_C) - \frac{w(1-t_m)T}{Y_D}\right)}{\frac{T-L}{L}\theta_C}, \tag{4.9}$$

which is our calibration equation. To get a feeling for magnitudes, we again consider the special case with $Y_0 = C_0 = 0$ and $t_m = t_a$. Then we have

$$\frac{w(1-t_m)T}{Y_D} = 1$$

and (4.9) simplifies to

$$\sigma = \frac{\eta_{Lw} + \frac{T-L}{L}\theta_C}{\frac{T-L}{L}\theta_C} = 1 + \frac{\eta_{Lw}}{\frac{T-L}{L}\theta_C} \tag{4.10}$$

Further simplification of (4.10) is achieved by observing that in this case

$$\theta_C = \frac{L}{T},$$

which yields[7]

$$\sigma = 1 + \frac{T}{T-L}\eta_{Lw}$$

Finally, we insert (4.8), which leaves us with

$$\sigma = 1 - \frac{\eta_{Lw}}{\eta_{LY}}$$

This shows that the inclusion of η_{LY} in the calibration makes the outcome for σ more volatile. With an exogenous, relatively large T/L ratio, a small value of η_{Lw} would have warranted a small

[7] This is also what you obtain in Rutherford (1998) if you leave out the upper nest with the consumption-savings decision (assuming that the savings ratio is zero).

deviation of σ from one.[8] With η_{LY} additionally appearing in the equation, σ can easily assume much higher values. Our preferred elasticity values, $\eta_{Lw} = 0.1$ and $\eta_{LY} = -0.1$, produce $\sigma = 2$.

Alternatively, it would be possible to calibrate the model with the compensated and the uncompensated elasticity of labour supply. Ballard and Fullerton (1992) use values of 0.2 and 0 for their benchmark calibration.

In our numerical specification, we use (4.9). $\eta_{Lw} = 0.1$ is assumed uniformly for all countries. Country differences in σ are produced through differences in the calibrated time endowment, T, and the tax rates, t_m and t_a, which both directly appear in (4.9) and indirectly through θ_C (calculated according to (4.1)). The numerical outcome of the calibration by region can be found in Appendix B.

[8] We follow Sørensen (1999) and assume a value of 0.1 for η_{Lw}. The meta study of Evers et al. (2005) suggests a somewhat higher elasticity, but it is difficult to distil a “core” value from this study.

5 Labour supply: participation

Households are assumed homogeneous with respect to their labour-leisure choice (intensive margin of labour supply), but they differ with respect to their participation decision. This is caused by heterogeneity in their fixed cost of taking up work, which produces the split between participating and non-participating individuals (extensive margin of labour supply). Those with low fixed costs enter the labour market, whereas those with high fixed costs stay at home.[9] We do not try to specify the precise nature of these "fixed costs". They may consist of costs that are caused by the difficulties of family coordination if both partners have a paid job, commuting costs between home and work, or simply some kind of "labour market attachment", an inherent utility from interacting with others in a productive environment.

The two step labour-supply decision (participation, hours of work) is solved backwards: First the individuals determine the optimal choice of hours *assuming* that they participate, then they compare this optimal outcome with the fixed cost of working. Things become slightly more complicated through the presence of involuntary unemployment. We assume that individuals take the (unemployment-weighted) expected utility of supplying labour for comparison with their respective fixed costs. A straightforward calculation of utility in the case of unemployment gives (with index "u" for "unemployed")

$$U_u = \left[\theta_C \left(\frac{C_D^u}{\bar{C}_D} \right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_C) \left(\frac{T}{\bar{F}} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \tag{5.1}$$

where disposable consumption in the case of unemployment, C_D^u, is income less basic income

$$C_D^u = Y^u = rwL(1-t_a) + Y_0^u - C_0.$$

Here we assume that unemployment benefits are a fixed replacement rate, r, times the after-tax income of the employed workers. The straightforward formulation (5.1), however, produces a problem. All relevant variables for this equation are fixed, either institutionally (r, t_a) or through the calibration of the labour supply decision of the employed workers (θ_C, σ, T). For a reasonable unemployment model, we must have $U_u < U_e$, which is not automatically warranted. In fact, for some WorldScan regions, U_u turns out to be larger than U_e. Various factors play a role here: As an outcome of the calibration (see Sections 4.1 and 4.2), $\bar{F}$ is only a small share of T, and the elasticity of substitution, σ, is considerably larger than one. This both works in the direction of a high utility level of the unemployed. On the other hand, we have basic consumption, C_0, which makes the relative difference between C_D^u and $\bar{C}_D$ larger than simply given by the replacement rate. However, for those countries with the highest replacement rates (France, Germany, Great Britain, Sweden), we nevertheless end up with a "utility reversal".

[9] See Kleven and Kreiner (2006) for a general discussion of this approach.

Finding a solution to this problem would require further explorations in the value of involuntarily unemployed time, which seems to be an unresolved question in labour economics.[10] The model can in principle easily be adjusted to allow for more flexibility. As it stands, the parameters of the utility function have been calibrated *locally* at the point where the employed workers supply labour. However, there are no strong reasons to assume that the outcome of the calibration is also informative about the utility *difference* between two distant points, $U_e - U_u$. We approach the problem of the previous paragraph in an ad-hoc fashion by introducing an additional parameter. This parameter allows for the possibility that unemployed cannot consume their total time endowment, T, as leisure. We can think of different reasons for this: Searching for a job requires time, even more so if the unemployed are expected to attend active labour market measures. A correction factor for disposable leisure could also capture effects of the social embeddedness that the work sphere supplies. However, it is particularly difficult to quantify this effect.[11] Our ad-hoc approach consists in the assumption that a given fraction δ of the additional non-working time of the unemployed does not count as "leisure". This gives

$$U_u = \left[\theta_C \left(\frac{C_D^u}{\bar{C}_D} \right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_C) \left(\frac{T - \delta \bar{L}}{\bar{F}} \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} .$$

Our default choice for δ is $\delta = 0.5$. Obviously, this is an important candidate for sensitivity analysis.

Given U_u, including the implied difficulties, we can calculate the expected utility of supplying labour, U_l,

$$U_l = (1-u)U_e + uU_u ,$$

which is the same for all individuals. They compare it with their idiosyncratic fixed cost of supplying labour, U_0, and supply labour if $U_l > U_0$.

The distribution of the U_0's over the population must be calibrated. We have the actual participation rate and the elasticity of labour supply at the extensive margin as our empirical basis. This is sufficient to calibrate the distribution of the fixed costs locally (at the point of actual participation), but not globally. The rest of the distribution must be fixed by some functional assumption. We assume that fixed costs are uniformly distributed between U_0^- and U_0^+. For fixing the values of these bounds, we first have to calculate the change in U_l produced by an exogenous variation in the wage. We consider an isolated change in the wage of an employed individual. In this case, the unemployment rate and the utility in case of

[10] Jenkins and Montmarquette (1979) is a coarse trial to find indirect ways for evaluating unemployed time.

[11] A possible line of investigation would be whether there are time-use studies that inform us about how much time the unemployed actually spend on searching.

unemployment remain constant.[12] In terms of elasticities, we then have

$$\frac{\varepsilon U_l}{\varepsilon w} = \frac{(1-u)U_e}{U_l}\frac{\varepsilon U_e}{\varepsilon w} = \frac{(1-u)U_e}{U_l}\left(\frac{\varepsilon Y_D}{\varepsilon w} - \frac{\varepsilon p_U}{\varepsilon w}\right)$$
$$= \frac{(1-u)U_e}{U_l}\left(\frac{wT(1-t_m)}{Y_D} - \frac{wF(1-t_m)}{Y_D}\right)$$
$$= \frac{(1-u)U_e}{U_l}\frac{wL(1-t_m)}{Y_D}$$

The elasticity of labour supply at the extensive margin (N is the number of participating persons) can be calculated as[13]

$$\eta_{Nw} = \frac{\varepsilon N}{\varepsilon U_l}\frac{\varepsilon U_l}{\varepsilon w} = h\frac{(1-u)U_e}{N}\frac{wL(1-t_m)}{Y_D},$$

where h is the density of the fixed cost distribution. Solved for h, we get

$$h = \eta_{Nw}\frac{NY_D}{(1-u)U_e wL(1-t_m)}. \tag{5.2}$$

This is evaluated at the initial point, with η_{Nw} set to 0.2, following Kleven and Kreiner (2006).[14] h is then treated as a constant in the counterfactual simulations. This means that the elasticity at the extensive margin is precisely reproduced only for the initial point; off the initial situation, it is endogenous.

The bounds of the uniform distribution for h can be determined as

$$U_0^- = \bar{U}_l - \frac{\bar{N}}{h}$$
$$U_0^+ = \bar{U}_l + \frac{N_0 - \bar{N}}{h}$$

where N_0 is the total population and $\bar{N}$ is initial participation.[15] Finally, counterfactual participation can be calculated as

$$N = \bar{N} + h(U_l - \bar{U}_l) \tag{5.3}$$

[12] This would not be the case for a general change in the wage, which applies to all individuals.

[13] Again (compare Footnote 5), the interpretation of empirical estimates is not without problems. Usually, in labour supply studies, the reaction of labour supply on the net wage is estimated, and the net wage is, in turn, calculated as the net labour income divided by the hours of work, i.e. the average after-tax wage. This would require a correction for the degree of tax progressivity.

[14] Kleven and Kreiner (2006, p.18-20) survey the current state of empirical evidence on the elasticity at the extensive margin. It is particularly difficult to calibrate a model with a representative agent to these elasticities, because they differ considerably by household type. The value of 0.2 is the aggregate average in Kleven and Kreiner's core scenario.

[15] As a matter of practical convenience, U_0^- and U_0^+ are not implemented in the model code. Given that the labour supply elasticity at the extensive margin is small, the bounds are almost certainly not relevant for actual policy simulations (see Table B.6 in Appendix B).

6 Collective wage bargaining

Involuntary unemployment in WorldScan is based on a model of collective wage bargaining between an employers' organisation and a representative trade union. The parties bargain over the skill-specific hourly wage. Once the wage is fixed, individuals choose optimal hours of work and firms choose the number of employed persons, given the wage and individual hours ("Right to manage model").[16]

An alternative set-up would have been that collective bargaining is not over wages alone, but also about hours of work (as in Sørensen, 1999). However, this would have produced considerably more complicated bargaining equations if combined with the CES utility functions in our approach. Sørensen (1999) uses an additively separable utility function instead. In this case, the quantitative discrepancy between bargaining over the wage only and bargaining over both wages and hours is small. If hours of work were subject to collective bargaining as well, we would end up with actual hours being less than individually desired hours. This also would complicate the calibration of the labour supply elasticities, because then the employed households are quantity restricted as well.

Wage formation is conceptualised as the maximisation of a Nash function, Ω, where trade unions are represented by a utility mark-up over the fallback option, $U_e - \bar{U}_l$ and firms by profits, π. The relative bargaining power of the trade union, λ, is an unobservable parameter to be determined in the calibration. Bargaining takes place separately for both skill groups, and we drop the skill index (as well as sector and country indices) to keep notation simple.

$$\max_{w} \quad \Omega = (U_e - \bar{U}_l)^{\lambda} \pi \tag{6.1}$$

The fallback option of the union, $\bar{U}_l$, is composed of possible employment in another sector (with a probability that equals the employment rate) and unemployment (receiving unemployment benefits, see Section 5):

$$\bar{U}_l = (1-u)\bar{U}_e + uU_u$$

The fallback option is exogenous for the sectoral wage bargain, so that the first-order condition of the maximisation of the Nash function is given as

$$\lambda \frac{dU_e/dw}{U_e - \bar{U}_l} + \frac{d\pi/dw}{\pi} = 0$$

Both firms and employed workers make optimal choices, conditional on the bargained wage. This allows us to apply the envelope theorem and express the first-order condition in terms of

[16] We restrict our discussion to the options within the collective bargaining approach. Other possible mechanisms of involuntary unemployment are efficiency wage and search-and-matching models (see Pissarides (1998) or Sørensen (1999) for comparisons). Our basic reason for choosing the collective bargaining model is that it most clearly captures the view that at least a part of involuntary unemployment is an inefficiency that could in principle be avoided.

partial effects:

$$\lambda \frac{\partial U_e/\partial w}{U_e - \bar{U}_l} + \frac{\partial \pi/\partial w}{\pi} = 0$$

The individual parts of this expression can be evaluated as follows:

$$\frac{\partial U_e}{\partial w} = \frac{\partial U_e}{\partial C_D}\frac{\partial C_D}{\partial w} = \theta_C \frac{U_e}{C_D}\frac{L(1-t_m)}{p_C}$$

$$\frac{\partial \pi}{\partial w} = -E$$

where E is total employment, $E = LN(1-u)$. The first order condition thus becomes

$$\lambda \frac{\theta_C U_e L(1-t_m)}{p_C C_D\,(U_e - \bar{U}_l)} - \frac{E}{\pi} = 0. \tag{6.2}$$

λ is a parameter that cannot directly be observed. Its value is determined in the calibration through inverting (6.2) and solving for λ, given the values of all the other variables in the base year.

In deriving (6.2), we have used the assumption of a small representative sector. When the collective parties bargain over the wage, they consider the macroeconomic variables as beyond their control. Most importantly, this applies to the unemployment rate, u, the wage that can be earned in other sectors (which enters $\bar{U}_e$ and therefore $\bar{U}_l$) and the tax rates. Given the sectoral structure of production in WorldScan, it would have been possible to model sector-specific bargaining. However, experiments with such a set-up showed that most of the sectoral differences are compensated in the calibration through bargaining-power parameters varying by sector, so that no interesting sector-specific results are generated. We have therefore opted for a set-up with a representative sector that has the characteristics of aggregate production in each region.

The Nash bargaining equation (6.1) requires positive profits for the firms to have something to bargain over. However, in the basic version of WorldScan there is perfect competition on the product markets and therefore profits are zero. We solve this problem by an ad-hoc adjustment, assuming that profits are a fixed share of the production value. This would be the outcome if we modelled product markets as monopolistic competitive with a fixed number of product varieties, which is a set-up often found in collective bargaining models. As long as the share of profits in output value is constant, its precise level is irrelevant, because a different level of profits would be exactly compensated by an adjusted level of the bargaining-power parameter in the calibration. We assume ad-hoc that profits are 10% of output value.[17]

The specification of the Nash maximand (6.1) can be characterised as an “insider model”. The trade union cares about the mark-up of the utility of an employed worker above the fallback

[17] We plan to integrate the labour market module with the imperfect competition version of WorldScan, which makes a more consistent formulation possible. This will most probably not change the quantitative outcomes significantly.

option $\bar{U}_l$, but not about the number of employed persons. A common, alternative formulation is the utilitarian union, which would result in the Nash maximand

$$\max_{w} \quad \tilde{\Omega} = \left[(U_e - \bar{U})N(1-u)\right]^{\lambda} \pi.$$

There are also versions of this equation in the literature where individual utility and employment get different weights (e.g. in MIMIC, see Graafland et al., 2001, ch. 7). With such an approach, the first-order condition of wage bargaining would contain the elasticity of labour demand. Then we are left with two options, again. Either we treat this elasticity as a constant, which it is under Cobb-Douglas production. This is the approach of Sørensen (1999), who uses labour demand elasticities from Symons and Layard (1984) for calibration. In WorldScan, the value-added nest is almost Cobb-Douglas (CES with an elasticity of substitution close to unity), but the rest of the production structure is not. This leaves the case unclear. Böhringer et al. (2005) work with a formulation where the elasticity of labour demand is endogenous. However, it turns out that the endogenous variation of the value of the labour demand elasticity are so small that it hardy matters for the quantitative results.

If we treat the labour demand elasticity as a constant, we are back in the situation that we already encountered several times: Different values of the labour demand elasticity are almost perfectly compensated through the calibration of the bargaining power parameter. This is because a trade union that puts a very high weight on employment is observationally indistinguishable from an insider union with very low bargaining power. For this reason we opted for the simpler insider model.

It would be desirable to calibrate the wage bargaining system to empirical estimates of the wage curve elasticities. However, this is difficult to carry out, because the exact match between model results and empirical estimates is not easy to determine (see Section 9.3). As a first step for an empirical validation, we report some general equilibrium effects in Appendix C. We simulate an isolated one percentage point increase of the average tax rate, the marginal tax rate and the replacement rate. The tables in Appendix C report the effects of these variations on the wage and several employment indicators.

7 Further changes

The model changes described so far (endogenisation of labour supply and unemployment) make a number of further model adjustments necessary and lead to additional data requirements. In contrast to the version of Lejour et al. (2006), the household sector is disaggregated (Section 7.1), OECD data have been used as empirical basis for tax rates and labour market institutions in the model (Section 7.2), and the value split between high and low skilled workers has been revised using ILO and UBS data (Section 7.3).

7.1 Household sector disaggregation

In the previous set-up of WorldScan all consumptive spending was by a single representative household. After subtracting savings from total income, the remaining consumption was allocated to specific goods according to a Linear Expenditure System (LES). With endogenous labour supply and unemployment, the representative household must be split up for a number of reasons:

- There are differences between the consumption structures of high and low skilled workers, because the wage of the low skilled is lower and, as a consequence, they have a higher share of basic consumption.
- The same applies for employed and unemployed workers per skill group.
- Income of the unemployed is determined by applying the replacement rate to the income of the employed. This requires both separation of the two skill groups and per capita accounting.
- Through the endogenous participation decision, the total number of workers is not constant any more, but adjusts endogenously. The total amount of basic consumption moves in line with this.
- Government consumption has a different structure than private consumption. (This split is available in the GTAP data, but was not used in the previous WorldScan set-up.)
- Government consumption is less than total tax revenue. The residual (most conveniently interpreted as transfers) must be dealt with in the model.

Led by these requirements, we end up with the following structure of the household sector: There are four worker households: high and low skilled, employed and unemployed. The employed workers receive their wage income, the unemployed workers receive unemployment benefits.[18] The four worker households consume according to the LES, where basic consumption per commodity per capita is the same across households. The government collects

[18] In the WorldScan model code, the unemployed households are split one again in those that receive wage-indexed unemployment insurance payments and those that receive consumption-price indexed welfare benefits. This split is suppressed in the present model description.

all tax revenue and spends money for publicly provided goods. This leaves us with two residual income categories: capital income and transfers (which are calculated as the difference between tax revenue and public consumption). The problem with these income categories is that we do not know how they are distributed between the different worker households and non-working households (except for the unemployment benefits). Therefore we collect income from these sources in a residual household account. Here we subtract savings, which are computed by applying an econometrically estimated macro savings function (as in the previous set-up). The remaining income is spend according to a Cobb-Douglas utility function. As we do not know the number of persons that are represented by this residual household, we cannot apply the LES. This modelling of the residual income categories is clearly a loose end of the current approach (for further discussion see Section 9.2).

7.2 OECD data for calibration

The relevance of reliable tax rate information as an input for the model calibration is more pressing than in the former set-up for two reasons. First, we now have a separate government budget accounting, and tax revenue, together with government consumption, determines transfers. Second, tax rates are an important factor in the determination of the wage bargaining outcome. It has been pointed out that there are many instances of problematic tax rates in the GTAP data set (Gurgel et al., 2007). We therefore follow Gurgel et al. (2007) in reconstructing macroeconomic tax rates from OECD sources. In addition, we need tax rates separately for low and high skilled workers, as well as the replacement rate and an indicator of tax progressivity. In particular, we use the following data sources:

- Effective average tax rates on consumption, labour and capital income are constructed from OECD “Annual National Accounts of OECD countries, Vol. 2”, Issue 2005, and OECD “Revenue Statistics”, Issue 2004 for the GTAP base year 2001. They are calculated as proposed in Mendoza et al. (1994) and further developed by Gurgel et al. (2007). In order to better fit the tax bases identified in the model of this paper, we have used the gross instead of the net capital income as basis for the capital tax. This gives substantially lower capital tax rates than those reported in the papers cited.
- Skill specific average tax rates are constructed by assuming that the relation for low and high skilled workers corresponds to those between the household types “Single, no child, earning 67% of average production worker” and “Single, no child, earning 167% of average production worker” in OECD “Taxing Wages”, Issue 2004. We take entry “144. Total tax wedge including employer’s social security contributions (Average rate in %)” and rescale it, holding the ratio constant, so that in total the average tax rate from the OECD macro sources is met.
- Skill specific marginal tax rates: Again we use OECD “Taxing Wages”, Issue 2004, “Single no

child earning 67% (167%) of average production worker (APW)", entries "144" and "153. Total tax wedge: Principal earner (marginal rate in %)". We first calculate tax progressivity, expressed as the "CRIP", the coefficient of residual income progression, where CRIP $= (1-t_m)/(1-t_a)$. Then t_m is calculated by applying CRIP to the re-scaled value of t_a.

- The replacement rates are taken from OECD "Benefits and Wages", Issue 2004, Table 3.3a. (p. 102) "Average of Net Replacement Rates over 60 months of unemployment 2001, for four family types and two earnings levels, in per cent", entry "without social assistance, no children, single person". Here, no skill-specific information is available, so we assume that the same replacement rate applies to both skill types.[19]

7.3 Revision of the high/low skilled value split

Combining the value shares of high and low skilled labour in GTAP with additional information about the number of high and low skilled workers produces an implicit ratio of high to low skilled wages. Because the precise mechanism that led to the GTAP skill-specific value shares is not easily recovered, it is difficult to find appropriate volume data to be combined with the GTAP values. For volume data from independent sources, the wage ratio turns out to be unreasonable in many cases (including cases where the low skilled are better paid than the high skilled).

These difficulties, and the observation that the empirical foundation of the GTAP skill shares is relatively narrow and dated, led us to a complete revision of the skill share information in WorldScan. Basically, the procedure is as follows: (1) We derive sectoral high-to-low skilled worker shares from ILO statistics. (2) We take a high-to-low skilled wage ratio from UBS statistics and assume that it is uniform across sectors. (3) From this we calculate sectoral high-to-low skilled value ratios, which are used to split the value share of labour in GTAP. (4) By assuming that wages of the skill groups are uniform across sectors – the only assumption that is, although counterfactual, compatible with labour mobility across sectors –, we can calculate a macroeconomic split of the total working population into high and low skilled.

In particular, we use the following data sources:

- Data for high-to-low ratio of employed persons are taken from: ILO, the LABORSTA internet site, Yearly Statistics (http://laborsta.ilo.org/). We use table 1E ("Economically active population, by industry and occupation"), and choose for each country a sample year as close as possible to 2001. These tables show the distribution of the economically active population by industry, cross-classified by occupation.
- Data for high-to-low skilled wage ratio are calculated form: Union Bank of Switzerland, Prices and Earnings, A comparison of purchasing power around the globe / 2006 edition, Appendix:

[19] Plausibly, the low skilled have a higher replacement rate.

Earnings and working hours of professions. We assume the following classification: Low skilled are “car mechanics, building labourer, skilled industrial worker, factory worker, bus driver, cook, personal assistant, sales assistant, call centre agent and bank credit officer”. High skilled are “engineers, department heads, product managers and primary school teacher”. We use unweighted arithmetic averages over the occupations.

Details of the skill-split calculations can be found in Van Leeuwen and Boeters (2009).

8 Welfare computations

A welfare assessment of policy counterfactuals is performed by computing equivalent variation (EV) in income, i.e. the exogenous change in income that would have produced the same utility change as the reform under consideration. Aggregate EV results from the summation over household-specific EV. When we interpret EV as a welfare measure, the usual caveat applies: A positive EV of a policy reform means that *if lump-sum redistribution between households is possible*, then a Pareto improvement compared to the initial situation *can* be generated. Such a redistribution is not necessarily feasible, and, if feasible, cannot be assumed to actually take place. Without redistribution, EV is only valid as a welfare measure if utility of different households is commensurable and marginal utility of income is the same for all households. This must be kept in mind when interpreting the welfare results.

In the calculation of EV, we must account for the fact that the number of individuals per representative household is not constant, because there are status changes. This applies both to individuals that change between unemployment and employment, and between participation and non-participation. We first calculate EV for all possible status combinations (transitions as well as non-transitions), and then sum up with appropriate weights. The split between high and low skilled workers remains exogenous and produces no additional problems. It is therefore suppressed in the equations below.

- Households that are employed and remain employed:

$$EV_{EE} = \bar{p}_U \left(U_e - \bar{U}_e\right)$$

- Households that switch from employment to unemployment:

$$EV_{EU} = \bar{p}_U \left(U_u - \bar{U}_e\right)$$

- Households that are unemployed and remain so. These households are subject to a demand constraint ($F = T - \delta\bar{L}$, see section 5). Therefore we can restrict the welfare calculation to the consumption part of the utility function:

$$EV_{UU} = \bar{p}_C \left(C_D^u - \bar{C}_D^u\right)$$

- Households that switch from unemployment to employment. Here, again, we have no dual formulation of the utility function and must calculate equivalent income directly by solving the following equation for $\tilde{C}_D^u$:

$$U_e = \left[\theta_C \left(\frac{\tilde{C}_D^u}{\bar{C}_D}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_C)\left(\frac{T-\delta\bar{L}}{\bar{F}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

Then EV can be calculated as

$$EV_{UE} = \bar{p}_C \left(\tilde{C}_D^u - \bar{C}_D^u\right)$$

Observe that the treatment of switches into and out of employment is asymmetrical, by the very nature of EV calculations. In the case of unemployed persons, we ask "What amount of money would compensate them, given their labour supply constraint, for being unemployed?" and in the case of employed persons: "Which income loss, given the possibility of optimal adjustment of labour supply, would make them indifferent to being unemployed?"

- Households with a CD utility structure and without labour supply. These are the residual household who receives capital and transfer income, and, if revenue neutrality of the policy reform is not imposed, the public household.

$$EV_{CD} = \bar{p}_C \left(C - \bar{C}\right)$$

- Households that switch from non-participation to participation. These households face idiosyncratic fixed cost of taking up work (see Section 5), which must be accounted for in the welfare calculation. We discuss the two cases of increasing and decreasing participation apart.[20]

If the expected utility from participation goes up, participation increases, and we have $N > \bar{N}$. The worker that was the marginal participant in the initial situation reaps the full gain, i.e.

$$EV_{\bar{N}}^{+} = U_l - \bar{U}_l = \frac{N - \bar{N}}{h}.$$

The new marginal participant has a welfare gain of zero, because she is just indifferent compared to her previous non-participation. Integrating EV between these two points under the assumption of a uniform distribution gives

$$EV_P^{+} = \int_{\bar{N}}^{N} \frac{N - n}{h} dn = \frac{\left(N - \bar{N}\right)^2}{2h}. \tag{8.1}$$

In the opposite case we have expected utility from participation, and therefore participation itself, going down $(N < \bar{N})$. Then the originally marginal participant has no utility loss, because she was indifferent to switching to non-participation. The worker who is indifferent in the new situation, by contrast, suffers the full utility loss.

$$EV_N^{-} = U_l - \bar{U}_l = \frac{N - \bar{N}}{h}.$$

Integrating gives

$$EV_P^{-} = \int_{N}^{\bar{N}} \frac{n - \bar{N}}{h} dn = -\frac{\left(N - \bar{N}\right)^2}{2h},$$

which can be consolidated with (8.1) to become

$$EV_P = \operatorname{sign}(N - \bar{N}) \frac{\left(N - \bar{N}\right)^2}{2h}.$$

[20] It is possible to integrate the two cases in common expressions, but this does not help to illuminate the situation.

Finally, we add up all these effects

$$
\begin{aligned}
EV = {} & \min(\bar{N}, N) \cdot [\min(1-u, 1-u_0) \cdot EV_{EE} + \min(u, u_0) \cdot EV_{UU} \\
& + \max(0, u_0 - u) \cdot EV_{UE} + \max(0, u - u_0) \cdot EV_{EU}] \\
& + EV_P + EV_{CD}
\end{aligned}
$$

9 Remaining difficulties

The labour market module of WorldScan described in this paper integrates different pieces of labour market theory, which are only found treated separately in the theoretical literature. It comes as no surprise that such an integration approach produces difficulties and loose ends, which we weren't able to solve in a completely consistent way. These are discussed in the following sections.

9.1 Basic consumption in the LES

The first problem arises with the calibration of the LES demand system when we have skill-specific wages and unemployment. The cross-country estimates from aggregate consumption data used in GTAP (and adopted in WorldScan) imply an almost 40 percent share of basic, non-disposable consumption in the EU-15 countries. (This corresponds to a "Frisch parameter" of about -1.6.) For countries with a lower GDP, this share is even larger. We assume that this basic consumption is the same for all workers, whether high or low skilled, employed or unemployed. This means that with a high-to-low skilled wage ratio of more than 1.5 and a replacement rate of less than 50 percent (which is the case for some of the WorldScan regions), we are easily locked in a situation where the income of the unemployed low skilled is not sufficient to cover basic consumption.

There are several possible ways to deal with this problem. As an ad-hoc solution, we set the Frisch parameters for all countries to the level of the EU-15 and impose a lower bound to the replacement rate of 50 percent. In doing this, we assume that either there exists a complementary social assistance system or home production allows individuals to cover their basic consumption, even if official unemployment benefit payments are not sufficient.

"Basic consumption" is a somewhat elusive concept anyway. The main aim of estimating a LES is not to make statements about what is absolutely necessary to survive. Rather, "basic consumption" is a technical means to produce income elasticities of consumption demand that are in line with empirical findings. Other utility functions have been proposed for estimation that produce flexible income elasticities without relying on something like "basic consumption" (Hanoch, 1975; Hertel et al., 1991; Bröcker, 2005).

An alternative route of dealing with the problem of basic consumption would be to explicitly model household production along the lines of Benhabib et al. (1991). This would remove the requirement that basic consumption has to be covered by income generated from sources outside the household itself.

9.2 Functional versus personal income distribution

In the current labour-market set-up, and in contrast to the earlier representative agent formulation, WorldScan captures certain aspects of personal income distribution: the distinction between high and low skilled as well as employed and unemployed individuals. On the other hand, capital and transfer income is treated separately, which highlights functional income distribution. Functional income distribution is also stressed by the assumption that only the residual household saves, whereas the worker households spend there incomes exclusively on consumption. There are several reasons for this pragmatic, eclectic approach. Most importantly, for matching skill-specific labour income with other income sources, it would be necessary to work with country-specific micro-data sets, which is beyond the scope of the “MODELS” project. But even if one is prepared to embark on this enormous amount of data work, several complications must be overcome.

To start with, this would require a more differentiated household structure than in WorldScan. In WorldScan, households are essentially groups of identical *individuals*. This assumes away all complications that arise both in accounting and in behavioural responses if we allow for households that consist of several, heterogeneous individuals. Even the basic combinations of high and low skilled partners, participating and non-participating individuals would leave us with considerably more household types than are now in WorldScan. Examples of models that work still at the level of aggregated households, but account for most of the possible household compositions, are MIMIC (Graafland et al., 2001) and the representative household version of PACE-L (Böhringer et al., 2005). One step further are models that work with data from individual households from a micro data set (e.g. Arntz et al., 2008). We know, however, of no such approach that covers more than a single country.

Even with micro data at hand, savings by worker households may cause considerable modelling problems. If worker households save, capital income of these households depends on savings in the past. As we have a model where the status of the household (participation, employment) can change, past savings are dependent on the complete employment history of the household. A small number of periods is sufficient to produce an intractably high number of households to be distinguished. The problems generating from this savings dynamics can only be managed by either taking resort to trivialising assumptions (all households pool their savings, so that individual capital income does only depend on aggregate savings, see Hansen, 1985) or by a dynamic microsimulation set-up.

Given the huge time and data requirements of a microsimulation-based approach, the current set-up of WorldScan is the best we can do given the resource constraints we are facing. In terms of economic outcomes, the most important implication is that there is no income effect on labour supply of capital or transfer income (because worker households do not receive such income in the model). We do not consider this to be a serious shortcoming, but it must be kept in mind when interpreting the results.

9.3 Empirical foundation of the wage bargaining equation

The current set-up of wage formation through collective bargaining is micro-founded in the sense that it can be traced back to the optimising behaviour of agents with specified objective functions (see Section 6). However, it leaves no scope for calibrating the resulting wage equation (6.2) to empirical estimations of wage curve elasticities. This is because the only remaining free parameter, the relative bargaining power of trade unions, λ, is needed to calibrate the model so that empirical unemployment rates are met.

This is an empirical weakness of the model. Empirical wage curve elasticities have frequently be estimated, which is an empirical resource that should be used for calibrating the model. However, the estimated coefficients are very volatile (see Folmer, 2009). This is in itself a hindrance to calibration. More severely, for most of the estimated coefficients it is not clear which subset of the model equations exactly corresponds to the estimated wage curves, so that the empirical estimations cannot be interpreted directly in the context of the model at hand. Take the elasticity of the wage with respect to the average wage income tax rate as an example. In order to link the present set-up in WorldScan to an empirical estimate of this elasticity, we must answer a number of questions: Does the estimation capture to the reaction in a single small representative sector or in the economy as a whole? If we look at the reaction in an individual sector, which variables are treated exogenous, which are endogenous? In particular: Which of the possible feedback effects are included in the reaction whose "elasticity" we are assessing? If we assume that a higher average tax has a wage-inflating effect, this will feed back on the fallback option of the trade union, leading to further upward wage pressure. Is this included in the estimated elasticity? Higher wages will lead firms to demand higher prices. This produces an adjustment of profits, which, given (6.2) we should expect to affect the bargaining outcome. Finally, higher prices feed back into a higher price level and therefore lower real wages; again, this is likely to produce further adjustment. We must cut off these feedback loops somewhere in order to define the elasticity we are interested in. Establishing this cut-off point is crucial and difficult at the same time, because it must both be possible to implement it in the model *and* to identify it in the data used for the estimation. If the empirical model used to estimate the wage curve elasticity deviates from the model to be calibrated, it is almost impossible to construct a consistent cut-off point ex post. Given the many versions of wage curves that are around in the empirical literature, and given the fact that in for many estimations, the empirical specification is only loosely motivated by theoretical considerations, the resulting difficulties are severe.

For most existing studies, the interpretation of wage curve elasticities is only implicit in the choice of data (Which regressors? Which level of aggregation? Which lag structure in the estimation?), which, together with assumptions about the scope and speed of adjustment, give a vague indication of a correspondence with equations in the general equilibrium model. The only exception are estimations that remain close to a theoretical model and try to identify the parameters of this specific model, such as Graafland and Huizinga (1999). Still, even such estimations can only be used if the estimated model is precisely the same as the labour market module of the general equilibrium model to be calibrated. Graafland and Huizinga (1999) heavily rely on an informal sector with unobservable productivity, which gives the model the necessary flexibility to be adjusted to the data. Such a set-up is relatively ill suited for a multi-sectoral general equilibrium model, except if we are prepared to explicitly model this informal sector: What kind of goods are produced? And how do they substitute with the goods produced in the formal economy?[21]

In principle, if we want a better empirical foundation of the wage equation, we must specify an empirical version of it, which corresponds as closely as possible the formulation in the general equilibrium model,[22] and confront it with the data. Currently, this is not the case for the specification found in WorldScan. The wage reactions in the model must therefore be treated with the necessary caution.

9.4 Dynamic calibration of the labour market

Sections 4 to 6 have focused on the static set-up and calibration of the model. If we extend the model in a recursive dynamic way, as it is the case with WorldScan, we face additional calibration challenges. The most important one is related to one of the main difficulties in dynamic labour supply theory: In cross-sections, we normally observe labour supply elasticities that are small, but significantly positive, both at the intensive and extensive margins. Taken at face value, this should lead to higher labour supply over time, where we have productivity increases and correspondingly higher real wages. But this is not what we actually observe. At least in the intensive dimension, labour supply rather decreases with increasing productivity. How can it be explained that in a cross-section the substitution effect dominated the income effect, and over time it is the inverse?

The most promising line of reasoning seems again to be a model of household production, which allows us to model increasing opportunity costs of working over time. In a model of household production, this is easily accommodated through an increase in household productivity, which matches the productivity change in market labour. As we do not have such a model of household production in WorldScan, we take resort to a shortcut that captures the basic idea of this approach.

We introduce compensatory efficiency increases for leisure and compensatory changes in the distribution of fixed costs of taking up work, to counteract the effects of increasing productivity

[21] Graafland and Huizinga (1999) work in the context of a model with a single universal good, where such questions do not arise.

[22] To match the current set-up of WorldScan, this would be without an informal sector, but perhaps with the value of involuntarily unemployed time as a free parameter to be estimated.

over time. In particular, we introduce a productivity parameter α_i in the utility function of the workers:

$$U_e = \left[\theta_C \left(\frac{C_D}{\bar{C}_D}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_C)\left(\frac{\alpha_i F}{\bar{F}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}$$

α_i is adjusted over time in the baseline calibration of WorldScan, so that the number of supplied hours remains constant (this makes α_i increasing over time). The calibration of the distribution of fixed costs of taking up work (see Section 5) is repeated for each year, taking the changes in the endogenous model parameters in (5.2) into account and holding the labour supply elasticity at the extensive margin, η_{Nw}, constant.[23] An exogenously given time path of participation rates is accommodated by adjusting $\bar{N}$ and $\bar{U}_l$ over time in (5.3). For concreteness, we think of the resulting shifts in the distribution of fixed costs as shifts in commuting costs (although there are also other plausible cost components) due to a changing valuation of time, caused by productivity increases.

Finally, without adjustment, we would have a trend in unemployment over time. Such a mechanism is already present in the static model, because, with basic consumption, an increase in the real wages (and, through the replacement rate, in unemployment benefits) has a different relative utility effect for the employed and the unemployed. The introduction of the "productivity of leisure" parameter produces a further disproportional utility effect between the employed and unemployed, which affects the unemployment rate. Such changes are not entirely without economic rationale, but we consider it as unlikely that they will produce a systematic trend in unemployment rates. Therefore we opt for treating λ, the relative bargaining power of the trade unions, as a time-varying parameter, and we adjust its level so that unemployment remains constant over time in the baseline.

[23] Otherwise, the secular increase in U_e would cause an ever increasing elasticity of labour supply. Thanks to Gerard Verweij who pointed this out to me.

10 Illustrative simulations

We illustrate the working mechanisms of the WorldScan labour market module with a series of scenarios, which are inspired by EU climate policy and the theoretical debate about a possible "Double Dividend" of environmental taxes. We assume that each EU member country implements a policy that brings down energy use by 20 percent in the base year of the model, 2001. This is achieved by a uniform tax on energy use, both in production and consumption. In the base scenario (1), we assume that the revenue of the tax is not recycled, but used for higher public spending. In the three following scenarios (2-4), we analyse different ways of recycling the tax revenue.

Although inspired by the current climate policy debate, it should be clear at the outset that our simulations are purely illustrative and cannot be taken as a quantitative assessment of existing EU plans. This has several reasons. First, we restrict our attention to the base year, 2001, which allows us to study the model reactions without the complications of dynamic calibration (Section 9.4) and the discussion about an appropriate baseline choice. Second, we assume that there is a uniform reduction target for all EU member countries, which disregards burden-sharing agreements, but simplifies the comparison between countries. Third, the model version we use does not differentiate energy carriers by their carbon intensity. We simply assume that emissions are proportional to energy use. All this precludes a quantitative assessment of the results. Nevertheless, we think that the labour market results are qualitatively robust, and we expect the ranking of the scenarios in terms of welfare and various labour market indicators to carry over to a climate policy assessment that takes account of more detail.

10.1 Scenario 1: No tax revenue recycling

In Scenario 1, the energy tax is levied so that the reduction target in each country is met, but no tax revenue recycling takes place. Tax revenue is used for higher public spending. Table 10.1 reports results for a selected set of five large European economies: France, Germany, Great Britain, Italy and Spain. In Appendix D, we add full tables for all WorldScan regions.[24]

Column "Energy tax" of Table 10.1 gives the necessary tax rate in per cent as an ad-valorem tax to the energy price exclusive of other taxes. These tax rates are in the range of 50%, which produces considerable increases in relative energy prices. This has two effects on the real wage. (In column "Real wage" we report the change in the before-tax wage relative to the consumption price index.) Wages go down because of the production inefficiencies created by the tax (and corresponding lower productive use of energy and capital), and consumer prices go up because

[24] As can be seen in those full tables, the results for the five large economies singled out in the tables of the main text, which are relatively uniform, do not always carry over to the smaller countries. Explaining all differences between the countries requires a lot more analysis in detail.

Table 10.1 Scenario 1: Labour market results

	Energy tax %	Hours of work %	Participation %	Unemployment p.p.	Real wage %
France	61.9				
High skilled		– 0.354	– 0.734	0.205	– 3.526
Low skilled		– 0.216	– 1.098	0.434	– 3.294
Germany	46.1				
High skilled		– 0.379	– 0.498	0.149	– 3.033
Low skilled		– 0.263	– 0.868	0.512	– 3.247
Great Britain	45.0				
High skilled		– 0.301	– 0.490	0.062	– 2.682
Low skilled		– 0.231	– 0.640	0.271	– 2.635
Italy	45.2				
High skilled		– 0.259	– 0.736	0.136	– 3.022
Low skilled		– 0.287	– 0.687	0.379	– 3.031
Spain	42.1				
High skilled		– 0.305	– 0.699	0.136	– 3.192
Low skilled		– 0.291	– 0.897	0.449	– 3.448

of the energy tax on consumption. This results in real wage drops that range between 2.6 and 3.6 percent. The remaining three columns of Table 10.1 display the labour market reactions for the two skill types at the three relevant margins, which all go in the direction of lower employment. Hours of work go down by between 0.2 and 0.4 percent. The negative participation reactions are even stronger, ranging between 0.4 and 1.1 percent. This is a direct reflection of the assumed labour supply elasticities, which are higher at the extensive margin. Finally, unemployment goes up by between 0.06 and 0.6 percentage points. The change in unemployment can be traced back to the LES set-up with basic consumption. With lower real incomes, the share of basic consumption increases and the marginal effect of higher wages on utility becomes higher *relative* to the level of utility, which is the crucial relationship in the Nash bargaining set-up. The change in unemployment is generally larger for the low skilled, because here initial unemployment rates are higher, and unemployment changes are roughly proportional to the initial level of unemployment.

Table 10.2 shows the welfare effects in the basic scenario without tax revenue recycling. We express them as equivalent variation, given as a percentage of GDP (which allows us to directly compare the results with changes in real GDP below). We use the same decomposition as in Section 8. For both skill groups, we have individuals that remain employed (“E $\rightarrow$ E”), individuals that become unemployed (“E $\rightarrow$ U”), and individuals that remain unemployed (“U $\rightarrow$ U”). The fourth category (“U $\rightarrow$ E”) is not relevant, because unemployment is increasing in all countries. The welfare change for the employed dominates the unemployment related changes, because the employed are by far the largest group. Only for the low skilled, where unemployment rates are higher, switches to unemployment cause a quantitative relevant welfare

Table 10.2 Scenario 1: Welfare effects (equivalent variation in % of initial income)

	France	Germany	Gr.Brit.	Italy	Spain
High skilled					
E → E	– 0.368	– 0.435	– 0.516	– 0.265	– 0.315
E → U	– 0.010	– 0.009	– 0.005	– 0.007	– 0.008
U → U	– 0.003	– 0.003	– 0.002	– 0.002	– 0.003
U → E	0.000	0.000	0.000	0.000	0.000
Participation	– 0.001	– 0.001	– 0.001	– 0.001	– 0.001
Low skilled					
E → E	– 0.402	– 0.425	– 0.477	– 0.424	– 0.590
E → U	– 0.028	– 0.033	– 0.024	– 0.029	– 0.045
U → U	– 0.004	– 0.004	– 0.003	– 0.006	– 0.007
U → E	0.000	0.000	0.000	0.000	0.000
Participation	– 0.002	– 0.002	– 0.002	– 0.002	– 0.003
Other income	– 0.807	– 0.772	– 0.307	– 0.789	– 0.553
Government	0.148	0.371	0.305	0.235	0.407
Sum	– 1.479	– 1.313	– 1.032	– 1.288	– 1.118
GDP	– 2.680	– 2.416	– 1.877	– 2.538	– 2.551

contribution. The correction for the fixed costs of those switching to non-participation (positive, because these are *saved* fixed costs) is negligible.

What does matter, by contrast, are the changes in government consumption and in other incomes, given in the rows "Government" and "Other income", respectively. Adding up (row "Sum") produces a welfare loss of between one and one and a half percent of GDP. This is considerably less than the GDP loss itself (row "GDP"), because lower labour supply directly translates into lower GDP, whereas it is partly compensated through the positive value of leisure in the welfare calculations.

10.2 Scenario 2: Lump-sum transfer to worker households

In the three following scenarios (Scenarios 2, 3 and 4), we perform a revenue neutral tax reform by using one tax instrument for tax revenue recycling, so that the level of real government consumption remains constant. In Scenario 2, this is a lump-sum transfer to all participating worker households (the same whether high or low skilled, employed or unemployed).

Comparing Table 10.3 with 10.1 shows the consequences of the lump-sum transfer. The labour supply reaction at the intensive margin is again negative, and even more so than in Scenario 1. This is a straightforward income effect of the lump-sum transfer. On the other hand, the negative participation reaction is less pronounced than in Scenario 1. This is due to the design of the lump-sum transfer, which is paid to all participating households, thus increasing the incentives to participate. Finally, unemployment is still going up, but slightly less so than in Scenario 1. This can again be explained by the basic consumption mechanism. Because of the lump-sum transfer, real income is not as much reduced as in Scenario 1, and the effect of a higher share of basic consumption is ameliorated.

Table 10.3 Scenario 2: Labour market results

	Energy tax %	Hours of work %	Participation %	Unemployment p.p.	Real wage %
France	62.9				
High skilled		– 0.441	– 0.579	0.149	– 3.573
Low skilled		– 0.346	– 0.815	0.271	– 3.553
Germany	47.4				
High skilled		– 0.557	– 0.331	0.098	– 3.350
Low skilled		– 0.503	– 0.474	0.225	– 3.706
Great Britain	45.9				
High skilled		– 0.392	– 0.348	0.042	– 2.740
Low skilled		– 0.362	– 0.403	0.155	– 2.810
Italy	46.1				
High skilled		– 0.422	– 0.541	0.094	– 3.431
Low skilled		– 0.472	– 0.495	0.273	– 3.512
Spain	43.5				
High skilled		– 0.488	– 0.420	0.053	– 3.466
Low skilled		– 0.544	– 0.471	0.175	– 3.916

Table 10.4 Scenario 2: Welfare effects (equivalent variation in % of initial income)

	France	Germany	Gr.Brit.	Italy	Spain
High skilled					
E → E	– 0.292	– 0.292	– 0.368	– 0.197	– 0.194
E → U	– 0.007	– 0.006	– 0.004	– 0.004	– 0.003
U → U	– 0.002	– 0.001	– 0.001	– 0.001	0.000
U → E	0.000	0.000	0.000	0.000	0.000
Participation	– 0.001	0.000	– 0.001	– 0.001	0.000
Low skilled					
E → E	– 0.305	– 0.241	– 0.306	– 0.311	– 0.326
E → U	– 0.018	– 0.014	– 0.013	– 0.021	– 0.018
U → U	– 0.002	0.000	– 0.001	– 0.002	0.001
U → E	0.000	0.000	0.000	0.000	0.000
Participation	– 0.001	– 0.001	– 0.001	– 0.001	– 0.001
Other income	– 0.772	– 0.685	– 0.275	– 0.715	– 0.474
Government	0.000	0.000	0.000	0.000	0.000
Sum	– 1.401	– 1.240	– 0.969	– 1.251	– 1.015
GDP	– 2.519	– 2.197	– 1.737	– 2.420	– 2.257

Table 10.4 shows the welfare effects of Scenario 2, in close analogy to Table 10.2 for Scenario 1. As the policy reform is now designed to be revenue-neutral, the equivalent variation entry for the government vanishes. As a complement, welfare losses for the worker households are lower, because of the lump-sum transfer. Adding up the welfare changes, we end up with a slightly lower welfare loss than in Scenario 1, caused by the role of the lump-sum transfer in lowering the distortion at the extensive margin (because it is only paid to workers that are active in the labour market).

10.3 Scenario 3: Lower average wage tax rates

In Scenario 3, we recycle the tax revenue from the energy tax by a cut in the average labour income tax (keeping the marginal tax constant). A lower average tax with a constant marginal tax amounts to introducing a tax allowance, which is similar in its working mechanisms to a lump-sum transfer. It seems that, contrary to the case of a lump-sum transfer, only those who actually have a job can benefit, but this is not actually the case, because unemployment benefits are linked to after-tax income through the replacement rate. The only significant difference of this scenario with Scenario 2 is that the progressivity of the labour tax is changed.

Table 10.5 Scenario 3: Labour market results

	Energy tax %	Hours of work %	Participation %	Unemployment p.p.	Real wage %
France	63.4				
High skilled		– 0.607	– 0.313	0.005	– 3.724
Low skilled		– 0.423	– 0.648	0.134	– 3.701
Germany	48.1				
High skilled		– 0.831	0.028	– 0.118	– 3.564
Low skilled		– 0.649	– 0.235	– 0.053	– 3.976
Great Britain	46.1				
High skilled		– 0.490	– 0.191	0.000	– 2.789
Low skilled		– 0.408	– 0.325	0.071	– 2.880
Italy	47.1				
High skilled		– 0.736	– 0.021	– 0.142	– 3.881
Low skilled		– 0.751	– 0.139	– 0.158	– 4.075
Spain	44.4				
High skilled		– 0.811	0.119	– 0.262	– 3.826
Low skilled		– 0.755	– 0.123	– 0.229	– 4.299

Table 10.5 shows the labour market effects of this policy variant. Most straightforward is the effect on unemployment. A lower average tax rate with the same marginal tax rate increases the tax progressivity of the labour tax. This makes higher wages less attractive for the trade union in the wage bargain (see Koskela and Vilmunen, 1996, for the general argument). We end up with lower wages and lower unemployment. Better employment opportunities, in turn, make participation more attractive, which gives a higher participation rate than in Scenario 2 (in Spain, participation of the high skilled even goes up relative to the initial situation). Through lower unemployment and higher participation, the transfer equivalent of the tax allowance can be higher than in Scenario 2, so that the negative income effect on hours of work is increased, and the negative reaction at the intensive margin is stronger than in Scenario 2.

The welfare effects in Scenario 3 (Table 10.6) are similar to those of the previous scenarios. Again, the entry “Government” vanishes, because the policy reform is revenue-neutral. As unemployment is decreasing for a subset of countries and skill types, we now also have the row

Table 10.6 Scenario 3: Welfare effects (equivalent variation in % of initial income)

	France	Germany	Gr.Brit.	Italy	Spain
High skilled					
E → E	– 0.162	0.019	– 0.204	– 0.014	0.041
E → U	0.000	0.000	0.000	0.000	0.000
U → U	– 0.002	0.000	– 0.001	0.000	0.000
U → E	0.000	0.005	0.000	0.005	0.012
Participation	0.000	0.000	0.000	0.000	0.000
Low skilled					
E → E	– 0.247	– 0.129	– 0.249	– 0.102	– 0.109
E → U	– 0.009	0.000	– 0.006	0.000	0.000
U → U	– 0.002	– 0.001	– 0.002	– 0.002	– 0.002
U → E	0.000	0.002	0.000	0.009	0.017
Participation	– 0.001	0.000	0.000	0.000	0.000
Other income	– 0.910	– 1.024	– 0.465	– 1.011	– 0.820
Government	0.000	0.000	0.000	0.000	0.000
Sum	– 1.332	– 1.128	– 0.926	– 1.117	– 0.861
GDP	– 2.386	– 1.986	– 1.667	– 2.152	– 1.931

"U → E". However, both unemployment changes and changes at the extensive margin are low, so that all entries except for those remaining employed and "Other income" are negligible.

Because of the positive effects on unemployment, the welfare changes are slightly less negative than in Scenario 2. This is in line with the GDP changes, which we again find to be roughly twice as large as the welfare changes.

10.4 Scenario 4: Lower average and marginal wage tax rates

In our last scenario, we not only lower the average labour tax rate, but also the marginal rate. The percentage change in both tax rates is the same, so that the progressivity of the tax system remains almost constant.

The quantitative effects in this scenario can be seen in Table 10.7. Through the tax progressivity mechanism, unemployment is higher than in Scenario 3, and back to levels that we already had in Scenarios 1 and 2. Because of the lower marginal labour tax rate, higher working hours become attractive. Labour supply at the intensive margin is uniformly higher than in all other scenarios, and in a number of cases even higher than in the initial situation. The effects at the extensive margin are mixed. On the one hand, higher unemployment (than in Scenario 3) discourages participation. On the other hand, through the lower labour-leisure tax distortion, the situation of those with a job is more attractive. Countries and skill groups differ in how large these effects are and which of them dominates.

The welfare effects of Scenario 4 are displayed in Table 10.8. Compared to Scenario 3, the negative consequences of higher unemployment are more significant, particularly for the low skilled. In addition, there appears to be a redistributive effect from other income to labour

Table 10.7 Scenario 4: Labour market results

	Energy tax %	Hours of work %	Participation %	Unemployment p.p.	Real wage %
France	63.9				
High skilled		– 0.146	– 0.333	0.135	– 3.927
Low skilled		0.049	– 0.625	0.419	– 3.784
Germany	48.9				
High skilled		– 0.148	– 0.008	0.030	– 3.949
Low skilled		0.097	– 0.203	0.335	– 4.159
Great Britain	46.6				
High skilled		– 0.149	– 0.192	0.035	– 2.954
Low skilled		– 0.054	– 0.303	0.195	– 2.978
Italy	47.8				
High skilled		0.136	– 0.035	0.124	– 4.448
Low skilled		0.018	– 0.131	0.280	– 4.363
Spain	44.8				
High skilled		0.078	0.027	0.073	– 4.170
Low skilled		0.104	– 0.165	0.329	– 4.388

Table 10.8 Scenario 4: Welfare effects (equivalent variation in % of initial income)

	France	Germany	Gr.Brit.	Italy	Spain
High skilled					
E $\rightarrow$ E	– 0.167	– 0.006	– 0.203	– 0.008	0.016
E $\rightarrow$ U	– 0.007	– 0.002	– 0.003	– 0.006	– 0.004
U $\rightarrow$ U	– 0.001	0.001	0.000	0.000	0.001
U $\rightarrow$ E	0.000	0.000	0.000	0.000	0.000
Participation	0.000	0.000	0.000	0.000	0.000
Low skilled					
E $\rightarrow$ E	– 0.220	– 0.089	– 0.222	– 0.068	– 0.088
E $\rightarrow$ U	– 0.027	– 0.021	– 0.017	– 0.021	– 0.033
U $\rightarrow$ U	– 0.002	0.000	– 0.001	0.000	0.000
U $\rightarrow$ E	0.000	0.000	0.000	0.000	0.000
Participation	– 0.001	0.000	0.000	0.000	0.000
Other income	– 0.906	– 1.030	– 0.467	– 1.028	– 0.819
Government	0.000	0.000	0.000	0.000	0.000
Sum	– 1.330	– 1.148	– 0.914	– 1.131	– 0.928
GDP	– 2.257	– 1.725	– 1.484	– 1.947	– 1.775

income. The welfare effects are in the same range as with Scenario 3, but not qualitatively the same in all countries. In terms of equivalent variation, Scenario 4 is preferable in France and Great Britain, but inferior in Germany, Italy, and Spain. Abstracting from the original environmental interest, comparing Scenarios 3 and 4 informs us about the desirability of higher tax progressivity (in Scenario 3). We see that the case is not uniform across countries, which reflects the fact that the trade-off between lower unemployment and less distortions of the hours-of-work decision is resolved at different points (see Sørensen (1999) for the general argument and a simple numerical model).

In addition, comparing Tables 10.8 and 10.6 shows cases in which welfare and GDP do not move in line. GDP is higher in Scenario 4 in all five countries, but, as we have discussed, for three countries welfare is lower. This is possible because GDP reacts uniformly to labour supply increases at either of the margins, while the distortionary effects (which determine welfare changes) at theses three margins are different.

10.5 Summary of the scenarios

Table 10.9 summarises the scenarios. We repeat the welfare effects from the tables before, and show in addition the total employment effect, aggregated over the three margins (participation, hours of work and involuntary unemployment). In all of the five countries and for both skill types there is a clear ranking in employment: lowest in Scenario 1, then 2, 3, and highest in Scenario 4. We have seen in the detailed analysis in the sections before, however, that this clear ranking hides considerable different movements along the three margins.

Table 10.9 Summary of the scenarios

	Scenario 1	Scenario 2	Scenario 3	Scenario 4
France				
Welfare (EV)	– 1.479	– 1.401	– 1.332	– 1.330
Employment high skilled	– 1.299	– 1.173	– 0.923	– 0.620
Employment low skilled	– 1.788	– 1.457	– 1.216	– 1.040
Germany				
Welfare (EV)	– 1.313	– 1.240	– 1.127	– 1.148
Employment high skilled	– 1.030	– 0.987	– 0.681	– 0.186
Employment low skilled	– 1.693	– 1.222	– 0.824	– 0.480
Great Britain				
Welfare (EV)	– 1.032	– 0.969	– 0.926	– 0.914
Employment high skilled	– 0.852	– 0.782	– 0.681	– 0.377
Employment low skilled	– 1.159	– 0.930	– 0.808	– 0.566
Italy				
Welfare (EV)	– 1.288	– 1.251	– 1.116	– 1.131
Employment high skilled	– 1.136	– 1.059	– 0.608	– 0.031
Employment low skilled	– 1.396	– 1.270	– 0.712	– 0.429
Spain				
Welfare (EV)	– 1.118	– 1.015	– 0.861	– 0.927
Employment high skilled	– 1.146	– 0.962	– 0.413	0.027
Employment low skilled	– 1.690	– 1.210	– 0.619	– 0.435

Welfare is linked to employment, but not perfectly so. For Scenarios 1 through 3, the changes are precisely parallel: Higher employment goes along with higher welfare. Between Scenarios 3 and 4 the link is broken (as discussed in Section 10.4). Here we have cases in which welfare goes down in spite of higher employment.

As a general result, welfare changes are much less volatile than employment changes. Employment reductions cover the whole range of no change (or even a slight employment gain for the high skilled in Scenario 4 in Spain) to a loss of 1.8 per cent. The welfare results, by contrast, only vary in a relatively narrow range of about 10 per cent between the Scenarios (and within the same country).

11 Summary and Conclusions

We present a labour market module for WorldScan in which labour supply and unemployment are endogenous variables, not exogenous parameters, which they were in the previous set-up. Labour supply at the intensive margin (hours of work) results from the optimising consumption-leisure choice of a representative household. Labour supply at the extensive margin (participation) is modelled as the comparison of the expected utility of participation with a fixed cost of taking up work, which varies between households. Wages and unemployment are determined through collective bargaining between firms and a trade union in a representative sector of each economy.

These modelling choices produce interaction effects, which are integrated in the model as far as possible. Labour supply at the two margins has different consequences for unemployment: Without labour demand reactions, an additional participating worker increases unemployment, whereas an additional hour of an already participating worker does not. Unemployment, in turn, affects labour supply at the extensive margin, because the households consider the expected value of participation in their decision and high unemployment rates have a discouraging effect. Finally, bargained wages feed back to the individual hours-of-work decision, which then co-determines employment in persons.

Interaction effects turn out to be intricate and are not always resolved in a completely consistent way in WorldScan. Most prominently, the empirical parameters of the Linear Expenditure System are not in all cases compatible with empirical wage differentials and replacement rates. Second, there remains a ambiguity between personal and functional income distribution in the disaggregated household accounting. And finally, the wage bargaining equation is not calibrated to empirical wage curve elasticities. However, we think that these weak points of the current set-up are not dominant as drivers of the model's basic reactions to policy shocks. Nevertheless, they must be kept in mind when interpreting the simulation results.

The working mechanisms of the model have been illustrated in some scenarios that analyse the labour market consequences of a policy that restricts energy use by a uniform tax on consumption and intermediate production inputs. We compare a scenario in which tax revenue is used for higher public spending with three variants of budget-balancing tax revenue recycling. The simulation results confirm that the tax recycling instruments (lump-sum transfer, average and marginal labour income tax rate) have different effects on the three margins of employment. Hours of work are most sensitive to the marginal labour tax rate, participation is more closely linked to the average tax rate, and unemployment is most directly affected by the progressivity of the tax schedule. It turns out that a policy that recycles the revenue from the energy tax through lower average labour taxes is most effective in restricting the welfare losses induced by the reduction in energy use. The role of tax progressivity remains ambiguous. There are countries in which a reform that increases tax progressivity is preferable, as well as countries in which the outcome is the opposite. As a coarse rule, welfare moves in line with both employment and GDP. However, this close interrelatedness is broken once we come to the Scenarios with varying tax progressivity.

We see simulations like the ones in Section 10 as the typical use of the model. We then ask: What are the labour market consequences of non-labour market policies like climate policy (energy taxation), R&D stimulation policy (producing productivity spillovers) or trade liberalisation (trade in services)? In addition to the labour market results that the model generates (labour supply, wages, unemployment), it also allows us a more precise assessment of the economic effects on productivity (which are influenced by employment) and the public budget (in particular if we impose a revenue-neutrality requirement) than a model with exogenous labour supply.

In contrast to the analysis of such non-labour market policies, the usefulness of the model is restricted in the case of labour market policy itself. Here, the model clearly lacks a lot of necessary detail in a number of dimensions: It has no age structure[25] (which we need if we want to analyse human capital formation or retirement), it has no wage heterogeneity within skill groups (which we need if we want to analyse subsidy schemes targeted to the low-income segment of the labour market), and its disaggregation of households is limited to skill type and employment status. (We need the composition of households if we want to analyse the participation of married women.) Anyway, we do not think that such specific labour market questions should be analysed using multi-country CGE models. Instead, this is the domain of comparative microsimulation (Immervoll et al., 2004) or models tailored to the particular conditions of a specific national tax and transfer system and demography, like MIMIC (Graafland et al., 2001) or PACE-L (Arntz et al., 2008) .

[25] As described in Section 2, the age structure is taken account of in the calibration of the model. However, the endogenous equation block only contains aggregate employment, so that no age specific reactions to policy changes can be calculated.

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Appendix A Variable names in WorldScan

Table A.1 Variable names in WorldScan

Variable	Description	WorldScan
C_0	basic consumption (not disposable)	CSSCWN_
C_D	disposable consumption	YD_CVN_
C_i	disposable consumption of good i	CNS_WN_
E	employment	LEINVN_
F	leisure (as a multiple of initial leisure)	LEICVI_
h	density of fixed cost distribution (participation)	CN_DPM_
L	labour supply (hours as a multiple of initial hours)	LSINMI_
N	labour supply (participation)	LSEXMN_
p_i^c	price of consumption good i	CNS_PN_
p_U	expenditure function ("price of utility")	YD_CPI_
r	replacement rate	URR_PM_
T	time endowment (as a multiple of initial hours)	LEIFQN_
t_a	average wage tax rate	TF_QPM_
t_m	marginal wage tax rate	TFM_QN_
u	unemployment rate	LUNPQN_
U_e	utility of employed worker	YD_CVN_
U_l	expected utility from participation	YDECUN_
U_u	utility of unemployed worker	YD_CUI_
w	before-tax wage	LEMFPN_
Y_0	non-labour income	TRF_WN_
Y_D	disposable extended income	YD_CWN_
Y_E	extended income of worker household	YE_CWN_
γ_i	basic consumption of good i	CN_SPM_
η_{Lw}	wage elasticity of labour supply (hours)	CN_WPM_
η_{LY}	income elasticity of labour supply (hours)	CN_YPM_
η_{Pw}	wage elasticity of labour supply (participation)	CN_EPM_
λ	relative bargaining power of trade unions	BRG_PM_
π	profits	PRF_WN_
σ	EoS (consumption, leisure)	CN_LPM_
θ_C	value share of consumption in Y_D	CNDCQN0
θ_i	value share good i consumption in C_D	CN_APM_

Appendix B Details of the labour market calibration

Table B.1 WorldScan regions

Region		Region	
AUT*	Austria	ESP*	Spain
BLU*	Belgium and Luxemburg	SWE*	Sweden
DNK*	Denmark	CZE*	Czech Republic
FIN*	Finland	HUN*	Hungary
FRA*	France	POL*	Poland
DEU*	Germany	SVK	Slovakia
GBR*	United Kingdom	SVN*	Slovenia
GRC*	Greece	REX	Remaining EU25
IRL*	Ireland	ROE	Remaining OECD
ITA*	Italy	USA*	United States
NLD*	Netherlands	AAT	Rest of World
PRT*	Portugal		

* calibrated with OECD institutional data

Table B.2 Column items for Tables B.3 and B.4

TF_QPM	average wage tax
TFMQPM	marginal wage tax
CSSCQN	basic consumption as a share of total consumption
LEIFPM	disposable time endowment as a multiple of working hours
CNSCQN	value share of consumption in extended income
CN_LPM	elasticity of substitution (leisure, material consumption)

Table B.3 Calibration details (low skilled)

	TF_QPM	TFMQPM	CSSCQN	LEIFPM	CNSCQN	CN_LPM
AUT	0.444	0.550	0.382	1.067	0.919	2.928
BLU	0.401	0.595	0.400	1.064	0.932	2.793
DNK	0.427	0.516	0.425	1.063	0.916	3.209
FIN	0.414	0.532	0.376	1.068	0.920	2.879
FRA	0.375	0.621	0.426	1.061	0.939	2.797
DEU	0.355	0.512	0.445	1.060	0.924	3.166
GBR	0.218	0.371	0.434	1.062	0.920	3.186
GRC	0.391	0.391	0.406	1.066	0.900	3.365
IRL	0.144	0.275	0.415	1.064	0.915	3.156
ITA	0.394	0.460	0.370	1.069	0.911	3.003
NLD	0.350	0.522	0.522	1.052	0.926	3.629
PRT	0.240	0.330	0.455	1.060	0.912	3.451
ESP	0.324	0.480	0.396	1.065	0.923	2.926
SWE	0.492	0.549	0.391	1.067	0.911	3.102
CZE	0.457	0.490	0.384	1.068	0.906	3.144
HUN	0.325	0.447	0.257	1.081	0.918	2.448
POL	0.327	0.372	0.373	1.069	0.907	3.085
SVK	0.397	0.438	0.362	1.070	0.907	3.030
SVN	0.326	0.326	0.295	1.078	0.900	2.836
REX	0.314	0.314	0.332	1.074	0.900	2.996
ROE	0.262	0.262	0.469	1.059	0.900	3.764
USA	0.232	0.306	0.408	1.065	0.910	3.214
AAT	0.123	0.123	0.485	1.057	0.900	3.885

Table B.4 Calibration details (high skilled)

	TF_QPM	TFMQPM	CSSCQN	LEIFPM	CNSCQN	CN_LPM
AUT	0.556	0.657	0.240	1.082	0.923	2.332
BLU	0.501	0.618	0.327	1.073	0.923	2.624
DNK	0.537	0.649	0.316	1.074	0.924	2.571
FIN	0.523	0.624	0.257	1.081	0.921	2.406
FRA	0.495	0.525	0.295	1.078	0.906	2.754
DEU	0.435	0.347	0.292	1.080	0.885	3.045
GBR	0.295	0.266	0.308	1.077	0.896	2.950
GRC	0.460	0.584	0.266	1.080	0.923	2.412
IRL	0.297	0.458	0.313	1.074	0.923	2.578
ITA	0.459	0.559	0.346	1.071	0.918	2.773
NLD	0.382	0.504	0.291	1.077	0.920	2.540
PRT	0.309	0.415	0.233	1.084	0.915	2.407
ESP	0.404	0.474	0.292	1.078	0.912	2.659
SWE	0.558	0.650	0.274	1.079	0.921	2.469
CZE	0.496	0.526	0.331	1.074	0.906	2.902
HUN	0.397	0.495	0.178	1.090	0.916	2.237
POL	0.346	0.364	0.294	1.078	0.903	2.792
SVK	0.435	0.488	0.325	1.074	0.909	2.824
SVN	0.326	0.326	0.169	1.092	0.900	2.406
REX	0.313	0.313	0.210	1.088	0.900	2.532
ROE	0.268	0.268	0.260	1.082	0.900	2.704
USA	0.301	0.415	0.257	1.081	0.916	2.474
AAT	0.144	0.144	0.212	1.088	0.900	2.538

Table B.5 Column items for Table B.6

LSUPQN	Initial participation rate (as a share of total population older than 15)
LSEXMP-	Lower bound of U_0 (as a multiple of the initial utility level)
LSEXMP+	Upper bound of U_0 (as a multiple of the initial utility level)

Table B.6 Calibration details (participation)

	low skilled			high skilled		
	LSUPQN	LSEXMP-	LSEXMP+	LSUPQN	LSEXMP-	LSEXMP+
AUT	0.483	– 5.022	7.439	0.483	– 3.688	6.012
BLU	0.427	– 4.255	8.060	0.427	– 4.258	8.063
DNK	0.535	– 5.726	6.849	0.535	– 4.123	5.455
FIN	0.505	– 4.878	6.751	0.505	– 3.882	5.776
FRA	0.448	– 3.961	7.112	0.448	– 5.044	8.447
DEU	0.490	– 5.303	7.549	0.490	– 6.216	8.497
GBR	0.487	– 5.530	7.881	0.487	– 5.739	8.101
GRC	0.432	– 6.571	10.972	0.432	– 3.846	7.383
IRL	0.458	– 5.625	8.844	0.458	– 4.177	7.129
ITA	0.413	– 5.445	10.178	0.413	– 4.720	9.145
NLD	0.510	– 6.123	7.845	0.510	– 4.200	5.997
PRT	0.502	– 6.374	8.310	0.502	– 4.048	6.004
ESP	0.456	– 4.869	8.014	0.456	– 4.681	7.790
SWE	0.506	– 5.649	7.482	0.506	– 4.025	5.899
CZE	0.500	– 5.897	7.886	0.500	– 5.369	7.359
HUN	0.412	– 4.058	8.223	0.412	– 3.671	7.669
POL	0.451	– 5.751	9.215	0.451	– 5.213	8.560
SVK	0.489	– 5.630	7.917	0.489	– 5.107	7.372
SVN	0.481	– 5.381	7.880	0.481	– 4.413	6.836
REX	0.464	– 5.741	8.779	0.464	– 4.697	7.574
ROE	0.471	– 7.468	10.509	0.471	– 5.084	7.832
USA	0.504	– 5.938	7.815	0.504	– 4.163	6.072
AAT	0.467	– 7.740	10.957	0.467	– 4.710	7.505

Appendix C Labour market effects of variations in institutional parameters

Table C.1 Column items for Tables C.2 to C.7

Wage	per cent change in producer wage
Unemployment	percentage point change in unemployment rate
Unemployment(r)	per cent change in unemployment rate
Employment	per cent change in employment (hours)
Hours	per cent change in hours (per employed person)
Participation	per cent change in participation (in persons)

Table C.2 Effects (%) of one p.p. increase in the average wage tax (low skilled)

	Wage	Unemployment	Unemployment(r)	Employment	Hours	Participation
AUT	0.290	0.223	4.811	– 0.152	0.482	– 0.398
BLU	0.395	0.339	3.953	– 0.380	0.389	– 0.397
DNK	0.352	0.230	4.663	– 0.184	0.408	– 0.348
FIN	0.490	0.434	3.472	– 0.520	0.325	– 0.349
FRA	0.444	0.373	3.643	– 0.486	0.339	– 0.409
DEU	0.394	0.364	3.523	– 0.444	0.300	– 0.337
GBR	0.241	0.216	3.023	– 0.248	0.259	– 0.273
GRC	0.439	0.553	4.563	– 0.483	0.451	– 0.302
IRL	0.193	0.159	3.119	– 0.130	0.278	– 0.240
ITA	0.416	0.460	3.997	– 0.423	0.424	– 0.325
NLD	0.259	0.146	4.208	– 0.231	0.271	– 0.350
PRT	0.199	0.205	4.520	– 0.102	0.404	– 0.290
ESP	0.401	0.450	3.715	– 0.446	0.403	– 0.336
SWE	0.451	0.352	4.772	– 0.384	0.378	– 0.381
CZE	0.478	0.566	5.126	– 0.512	0.524	– 0.397
HUN	0.294	0.295	3.799	– 0.264	0.436	– 0.378
POL	0.652	0.675	2.776	– 0.852	0.301	– 0.259
SVK	0.841	0.754	2.752	– 1.002	0.292	– 0.255
SVN	0.273	0.260	3.110	– 0.272	0.294	– 0.282
USA	0.221	0.201	3.195	– 0.184	0.287	– 0.256

Table C.3 Effects (%) of one p.p. increase in the average wage tax (high skilled)

	Wage	Unemployment	Unemployment(r)	Employment	Hours	Participation
AUT	0.189	0.061	5.109	– 0.059	0.530	– 0.524
BLU	0.275	0.135	4.996	– 0.107	0.488	– 0.454
DNK	0.271	0.196	5.762	– 0.116	0.589	– 0.499
FIN	0.299	0.235	5.864	– 0.061	0.658	– 0.471
FRA	0.323	0.266	5.217	– 0.150	0.510	– 0.378
DEU	0.229	0.222	5.411	– 0.045	0.489	– 0.300
GBR	0.146	0.076	3.820	0.027	0.365	– 0.259
GRC	0.388	0.248	3.696	– 0.281	0.391	– 0.405
IRL	0.145	0.051	3.218	– 0.077	0.302	– 0.326
ITA	0.307	0.225	4.092	– 0.257	0.386	– 0.403
NLD	0.102	0.087	5.825	0.188	0.657	– 0.377
PRT	0.164	0.064	2.926	– 0.093	0.282	– 0.308
ESP	0.314	0.227	3.341	– 0.253	0.325	– 0.333
SWE	0.186	0.201	8.754	0.208	0.953	– 0.533
CZE	0.181	0.103	5.141	– 0.067	0.472	– 0.432
HUN	0.114	0.041	3.720	– 0.033	0.404	– 0.394
POL	0.272	0.182	4.036	– 0.083	0.417	– 0.309
SVK	0.298	0.318	7.237	– 0.063	0.761	– 0.487
SVN	0.110	0.080	3.644	0.026	0.409	– 0.300
USA	0.148	0.062	3.087	– 0.050	0.319	– 0.306

Table C.4 Effects (%) of one p.p. increase in the marginal wage tax (low skilled)

	Wage	Unemployment	Unemployment(r)	Employment	Hours	Participation
AUT	0.183	– 0.091	– 1.964	– 0.285	– 0.379	– 0.001
BLU	0.114	– 0.205	– 2.385	– 0.166	– 0.407	0.019
DNK	0.160	– 0.089	– 1.808	– 0.270	– 0.360	– 0.004
FIN	0.040	– 0.272	– 2.179	– 0.044	– 0.395	0.041
FRA	0.080	– 0.262	– 2.564	– 0.108	– 0.426	0.026
DEU	0.078	– 0.206	– 1.998	– 0.106	– 0.361	0.026
GBR	0.096	– 0.110	– 1.539	– 0.145	– 0.280	0.017
GRC	0.045	– 0.207	– 1.707	– 0.071	– 0.337	0.031
IRL	0.102	– 0.071	– 1.398	– 0.153	– 0.247	0.019
ITA	0.054	– 0.225	– 1.954	– 0.067	– 0.357	0.037
NLD	0.198	– 0.066	– 1.908	– 0.266	– 0.345	0.011
PRT	0.108	– 0.062	– 1.371	– 0.196	– 0.268	0.007
ESP	0.033	– 0.236	– 1.951	– 0.044	– 0.348	0.036
SWE	0.145	– 0.153	– 2.080	– 0.229	– 0.406	0.012
CZE	0.079	– 0.222	– 2.012	– 0.102	– 0.385	0.035
HUN	0.111	– 0.138	– 1.785	– 0.144	– 0.320	0.026
POL	– 0.275	– 0.538	– 2.212	0.410	– 0.396	0.098
SVK	– 0.561	– 0.802	– 2.929	0.734	– 0.507	0.141
SVN	0.092	– 0.128	– 1.533	– 0.124	– 0.295	0.032
USA	0.090	– 0.090	– 1.425	– 0.154	– 0.270	0.020

Table C.5 Effects (%) of one p.p. increase in the marginal wage tax (high skilled)

	Wage	Unemployment	Unemployment(r)	Employment	Hours	Participation
AUT	0.332	– 0.031	– 2.573	– 0.467	– 0.464	– 0.034
BLU	0.244	– 0.064	– 2.377	– 0.376	– 0.427	– 0.016
DNK	0.249	– 0.081	– 2.378	– 0.424	– 0.450	– 0.057
FIN	0.223	– 0.094	– 2.347	– 0.371	– 0.434	– 0.034
FRA	0.179	– 0.102	– 1.991	– 0.278	– 0.383	– 0.002
DEU	0.158	– 0.066	– 1.617	– 0.225	– 0.307	0.013
GBR	0.133	– 0.027	– 1.366	– 0.223	– 0.261	0.010
GRC	0.170	– 0.155	– 2.306	– 0.230	– 0.405	0.010
IRL	0.177	– 0.030	– 1.846	– 0.263	– 0.309	0.016
ITA	0.214	– 0.116	– 2.102	– 0.253	– 0.381	0.007
NLD	0.195	– 0.027	– 1.833	– 0.321	– 0.328	– 0.021
PRT	0.181	– 0.038	– 1.733	– 0.239	– 0.292	0.014
ESP	0.143	– 0.129	– 1.899	– 0.184	– 0.345	0.023
SWE	0.304	– 0.050	– 2.179	– 0.468	– 0.420	– 0.099
CZE	0.270	– 0.039	– 1.966	– 0.320	– 0.372	0.012
HUN	0.244	– 0.021	– 1.881	– 0.301	– 0.330	0.008
POL	0.168	– 0.069	– 1.539	– 0.199	– 0.286	0.015
SVK	0.232	– 0.079	– 1.806	– 0.246	– 0.334	0.005
SVN	0.159	– 0.034	– 1.540	– 0.222	– 0.277	0.020
USA	0.163	– 0.034	– 1.710	– 0.246	– 0.296	0.015

Table C.6 Effects (%) of one p.p. increase in the replacement rate (low skilled)

	Wage	Unemployment	Unemployment(r)	Employment	Hours	Participation
AUT	0.027	0.035	0.761	– 0.048	0.001	– 0.012
BLU	0.061	0.072	0.838	– 0.102	0.001	– 0.025
DNK	0.031	0.049	0.990	– 0.064	0.002	– 0.014
FIN	0.086	0.106	0.849	– 0.146	0.004	– 0.029
FRA	0.073	0.077	0.757	– 0.122	– 0.002	– 0.034
DEU	0.075	0.093	0.901	– 0.119	0.003	– 0.018
GBR	0.047	0.068	0.952	– 0.081	0.002	– 0.010
GRC	0.115	0.170	1.404	– 0.232	0.011	– 0.049
IRL	0.032	0.047	0.921	– 0.054	0.002	– 0.007
ITA	0.139	0.140	1.212	– 0.186	0.011	– 0.039
NLD	0.023	0.031	0.894	– 0.035	0.001	– 0.003
PRT	0.024	0.039	0.859	– 0.049	0.001	– 0.010
ESP	0.091	0.112	0.925	– 0.171	– 0.007	– 0.037
SWE	0.045	0.069	0.936	– 0.090	0.003	– 0.019
CZE	0.126	0.138	1.248	– 0.175	0.008	– 0.029
HUN	0.046	0.048	0.615	– 0.064	0.001	– 0.014
POL	0.358	0.361	1.483	– 0.532	0.025	– 0.081
SVK	0.517	0.444	1.621	– 0.671	0.031	– 0.091
SVN	0.042	0.056	0.671	– 0.063	0.004	– 0.006
USA	0.039	0.058	0.918	– 0.066	0.003	– 0.007

Table C.7 Effects (%) of one p.p. increase in the replacement rate (high skilled)

	Wage	Unemployment	Unemployment(r)	Employment	Hours	Participation
AUT	0.009	0.011	0.887	– 0.013	0.000	– 0.003
BLU	0.019	0.026	0.948	– 0.032	0.001	– 0.007
DNK	0.000	0.045	1.332	0.014	0.061	0.000
FIN	0.030	0.038	0.950	– 0.056	0.001	– 0.017
FRA	0.048	0.065	1.276	– 0.084	0.004	– 0.019
DEU	0.046	0.064	1.567	– 0.072	0.006	– 0.011
GBR	0.015	0.026	1.284	– 0.028	0.002	– 0.004
GRC	0.054	0.065	0.967	– 0.083	0.002	– 0.016
IRL	0.010	0.015	0.959	– 0.017	0.001	– 0.002
ITA	0.053	0.055	0.992	– 0.066	0.004	– 0.012
NLD	– 0.001	0.021	1.371	0.020	0.040	0.000
PRT	0.017	0.023	1.053	– 0.025	0.001	– 0.002
ESP	0.009	0.135	1.980	– 0.016	0.157	– 0.028
SWE	0.022	0.023	0.995	– 0.037	0.001	– 0.015
CZE	0.019	0.022	1.082	– 0.023	0.001	– 0.003
HUN	0.007	0.008	0.764	– 0.010	0.000	– 0.002
POL	0.043	0.049	1.095	– 0.056	0.004	– 0.008
SVK	0.051	0.046	1.048	– 0.058	0.003	– 0.013
SVN	0.015	0.021	0.947	– 0.023	0.002	– 0.003
USA	0.013	0.019	0.973	– 0.021	0.001	– 0.002

Appendix D Simulation results for all WorldScan regions

Table D.1 Column items for Tables D.2 to D.5

TAXKQN	uniform "Kyoto" tax rate as a percentage of producer prices
LSINMP.LSL	per cent change in hours (intensive margin) for low skilled
LSINMP.HSL	per cent change in hours (intensive margin) for high skilled
LSEXMP.LSL	per cent change in participation (extensive margin) for low skilled
LSEXMP.HSL	per cent change in participation (extensive margin) for high skilled
UNPDQN.LSL	percentage point change in unemployment for low skilled
UNPDQN.HSL	percentage point change in unemployment for high skilled

Table D.2 Detailed country results for Scenario 1

	TAXKQN	LSINMP		LSEXMP		UNPDQN	
		LSL	HSL	LSL	HSL	LSL	HSL
AUT	0.467	– 0.339	– 0.282	– 0.958	– 0.893	0.254	0.032
BLU	0.369	– 0.238	– 0.271	– 0.998	– 0.870	0.254	0.058
DNK	0.523	– 0.305	– 0.262	– 0.778	– 0.854	0.249	0.097
FIN	0.370	– 0.338	– 0.340	– 1.018	– 1.041	0.612	0.123
FRA	0.619	– 0.216	– 0.354	– 1.098	– 0.734	0.434	0.205
DEU	0.461	– 0.263	– 0.379	– 0.868	– 0.498	0.512	0.149
GBR	0.450	– 0.231	– 0.301	– 0.640	– 0.490	0.271	0.062
GRC	0.350	– 0.369	– 0.277	– 0.529	– 0.753	0.401	0.078
IRL	0.335	– 0.221	– 0.216	– 0.533	– 0.660	0.176	0.044
ITA	0.452	– 0.287	– 0.259	– 0.687	– 0.736	0.379	0.136
NLD	0.267	– 0.238	– 0.239	– 0.859	– 0.725	0.193	0.019
PRT	0.437	– 0.484	– 0.413	– 1.065	– 1.052	0.383	0.055
ESP	0.421	– 0.291	– 0.305	– 0.897	– 0.699	0.449	0.136
SWE	0.538	– 0.381	– 0.286	– 0.899	– 0.859	0.444	0.048
CZE	0.321	– 0.495	– 0.462	– 0.984	– 0.896	0.658	0.071
HUN	0.352	– 0.390	– 0.370	– 1.095	– 0.987	0.291	0.026
POL	0.278	– 0.290	– 0.268	– 0.643	– 0.494	0.977	0.063
SVK	0.247	– 0.469	– 0.449	– 0.993	– 0.925	1.667	0.124
SVN	0.313	– 0.432	– 0.337	– 0.805	– 0.623	0.384	0.030
REX	0.218	– 0.497	– 0.310	– 0.876	– 0.528	0.564	0.005
ROE		0.016	0.014	0.033	0.029	– 0.012	0.001
USA		0.017	0.010	0.042	0.028	– 0.012	0.001
AAT		– 0.001	– 0.003	0.002	– 0.004		

Table D.3 Detailed country results for Scenario 2

	TAXKQN	LSINMP		LSEXMP		UNPDQN	
		LSL	HSL	LSL	HSL	LSL	HSL
AUT	0.486	– 0.727	– 0.511	– 0.213	– 0.400	0.019	0.007
BLU	0.376	– 0.368	– 0.371	– 0.759	– 0.675	0.149	0.032
DNK	0.534	– 0.435	– 0.356	– 0.560	– 0.678	0.160	0.068
FIN	0.383	– 0.637	– 0.527	– 0.543	– 0.693	0.219	0.060
FRA	0.629	– 0.346	– 0.441	– 0.815	– 0.579	0.271	0.149
DEU	0.474	– 0.503	– 0.557	– 0.474	– 0.331	0.225	0.098
GBR	0.459	– 0.362	– 0.392	– 0.403	– 0.348	0.155	0.042
GRC	0.356	– 0.504	– 0.356	– 0.359	– 0.616	0.227	0.047
IRL	0.342	– 0.319	– 0.285	– 0.382	– 0.527	0.116	0.033
ITA	0.461	– 0.472	– 0.422	– 0.495	– 0.541	0.273	0.094
NLD	0.265	– 0.134	– 0.184	– 1.066	– 0.836	0.260	0.027
PRT	0.459	– 0.829	– 0.601	– 0.625	– 0.879	0.190	0.047
ESP	0.435	– 0.544	– 0.488	– 0.471	– 0.420	0.175	0.053
SWE	0.548	– 0.525	– 0.389	– 0.688	– 0.726	0.297	0.034
CZE	0.346	– 1.557	– 1.330	0.358	0.230	– 0.373	– 0.055
HUN	0.361	– 0.743	– 0.610	– 0.513	– 0.609	0.050	0.009
POL	0.299	– 0.872	– 0.709	0.018	– 0.052	– 0.016	– 0.011
SVK	0.272	– 1.798	– 1.480	0.248	0.212	– 0.817	– 0.153
SVN	0.342	– 1.238	– 0.843	0.272	– 0.155	– 0.267	– 0.003
REX	0.240	– 1.656	– 1.096	0.590	0.175	– 0.568	– 0.117
ROE		0.015	0.013	0.032	0.027	– 0.012	0.001
USA		0.016	0.009	0.041	0.027	– 0.012	0.001
AAT		– 0.001	– 0.003	0.002	– 0.005		

Table D.4 Detailed country results for Scenario 3

	TAXKQN	LSINMP		LSEXMP		UNPDQN	
		LSL	HSL	LSL	HSL	LSL	HSL
AUT	0.496	– 1.015	– 1.088	0.323	0.777	– 0.216	– 0.084
BLU	0.380	– 0.460	– 0.522	– 0.573	– 0.364	0.013	– 0.035
DNK	0.539	– 0.507	– 0.503	– 0.429	– 0.381	0.076	– 0.012
FIN	0.395	– 0.999	– 1.071	0.041	0.373	– 0.425	– 0.226
FRA	0.634	– 0.423	– 0.607	– 0.648	– 0.313	0.134	0.005
DEU	0.481	– 0.649	– 0.831	– 0.235	0.028	– 0.053	– 0.118
GBR	0.461	– 0.408	– 0.490	– 0.325	– 0.191	0.071	0.000
GRC	0.363	– 0.705	– 0.606	– 0.102	– 0.116	– 0.187	– 0.171
IRL	0.344	– 0.377	– 0.392	– 0.279	– 0.304	0.050	0.004
ITA	0.471	– 0.751	– 0.736	– 0.139	– 0.021	– 0.158	– 0.142
NLD	0.265	– 0.131	– 0.131	– 1.076	– 0.942	0.277	0.042
PRT	0.464	– 0.926	– 0.874	– 0.484	– 0.405	0.074	– 0.040
ESP	0.444	– 0.755	– 0.811	– 0.123	0.119	– 0.229	– 0.262
SWE	0.554	– 0.640	– 0.570	– 0.513	– 0.389	0.136	– 0.026
CZE	0.358	– 2.442	– 2.350	1.399	1.823	– 1.681	– 0.344
HUN	0.369	– 1.254	– 1.278	0.345	0.636	– 0.430	– 0.079
POL	0.316	– 1.574	– 1.372	0.668	0.997	– 1.844	– 0.431
SVK	0.287	– 2.999	– 2.607	1.077	1.820	– 3.714	– 0.757
SVN	0.346	– 1.281	– 1.193	0.312	0.392	– 0.440	– 0.125
REX	0.245	– 1.912	– 1.720	0.863	1.060	– 1.070	– 0.553
ROE		0.014	0.013	0.030	0.026	– 0.011	0.001
USA		0.015	0.009	0.039	0.025	– 0.012	0.001
AAT		– 0.002	– 0.003	0.001	– 0.005		

Table D.5 Detailed country results for Scenario 4

	TAXKQN	LSINMP		LSEXMP		UNPDQN	
		LSL	HSL	LSL	HSL	LSL	HSL
AUT	0.523	0.428	0.685	0.583	1.052	0.074	0.031
BLU	0.387	0.047	0.033	– 0.492	– 0.304	0.243	0.046
DNK	0.555	– 0.042	0.096	– 0.271	– 0.182	0.143	0.083
FIN	0.407	0.292	0.445	0.197	0.480	0.296	0.102
FRA	0.639	0.049	– 0.146	– 0.625	– 0.333	0.419	0.135
DEU	0.489	0.097	– 0.148	– 0.203	– 0.008	0.335	0.030
GBR	0.466	– 0.054	– 0.149	– 0.303	– 0.192	0.195	0.035
GRC	0.367	– 0.156	0.063	– 0.101	– 0.122	0.095	0.083
IRL	0.348	– 0.081	– 0.021	– 0.268	– 0.297	0.126	0.038
ITA	0.478	0.018	0.136	– 0.131	– 0.035	0.280	0.124
NLD	0.263	– 0.380	– 0.375	– 1.115	– 0.973	0.240	0.022
PRT	0.482	– 0.119	– 0.003	– 0.399	– 0.331	0.223	0.067
ESP	0.448	0.104	0.078	– 0.165	0.027	0.329	0.073
SWE	0.579	0.003	0.184	– 0.166	– 0.010	0.195	0.050
CZE	0.375	0.703	0.833	1.461	1.740	– 0.293	– 0.050
HUN	0.380	0.391	0.469	0.387	0.622	0.223	0.027
POL	0.313	0.252	0.259	0.439	0.544	0.184	0.006
SVK	0.285	0.401	0.532	0.731	0.934	0.138	0.031
SVN	0.358	0.117	0.141	0.281	0.314	0.090	0.032
REX	0.253	0.299	0.380	0.727	0.858	– 0.076	– 0.016
ROE		0.013	0.012	0.028	0.024	– 0.010	0.001
USA		0.015	0.008	0.037	0.023	– 0.011	0.001
AAT		– 0.002	– 0.004	0.001	– 0.005		