CHAPTER 26

The Labor Market in Computable General Equilibrium Models

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Abstract

This chapter reviews options of labor market modeling in a computable general equilibrium framework. On the labor supply side, two principal modeling options are distinguished and discussed: aggregated, representative households and microsimulation based on individual household data. On the labor demand side, we focus on the substitution possibilities between different types of labor in production. With respect to labor market coordination, we discuss several wage-forming mechanisms and involuntary unemployment.

Keywords

Computable general equilibrium model, labor market, labor supply, labor demand, microsimulation, involuntary unemployment

JEL classification codes

C68, D58, J20, J64

26.1 INTRODUCTION

If we look at the body of computable general equilibrium (CGE) literature as a whole, the labor market has certainly not been one of the main points of attention. In fact, many of the classical CGE studies in the areas of trade liberalization, tax analysis and climate policy work with the simplest possible set of assumptions about the labor market: labor supply is fixed and a uniform, flexible, market-clearing wage balances labor supply and demand. The authors of these classical studies apparently did not fear to introduce a serious bias into their analysis when treating the labor market in this simplified manner—and they may have been right. Even if one is convinced that the real labor market is much more complex than our simplifying model, this does not automatically mean that its full complexity must show in every concrete analysis. Engaging in a more detailed modeling of the labor market is only worth the while if it can be made plausible that assumptions about the labor market mechanisms actually change the outcome of a particular study significantly. Given that in a modeling context we are bound to work with simplifications anyway, we see the burden of proof with those claiming that this is the case.

Handbook of CGE Modeling - Vol. 1 SET
ISSN 2211-6885, http://dx.doi.org/10.1016/B978-0-444-59568-3.00026-2

There are two typical—and quite distinct—constellations that motivate researchers to go beyond the basic setup of a labor market clearing, flexible wage. They either want to analyze a specific change in the labor market institutions or they are interested in the labor market consequences of a policy measure that is not directly labor market related. As an example of the first motivation, take the case of in-work benefits, which are supposed to increase labor supply of the low skilled. Addressing this issue in a CGE model requires a mechanism that endogenizes labor supply and a labor market segmentation that separates the low-skilled from other groups. Thus, a certain level of labor market complexity is necessary. The second motivation can be illustrated by the analysis of trade liberalization. This affects the labor market only indirectly, but we can ask about the aggregate consequences ("What are the effects on wages and unemployment?") as well as about distributional effects ("Who gains and who loses?"). We give a more extensive overview of motivating issues in Section 26.2.

Apart from these question-driven approaches to labor market modeling, there is also an approach that one could call "presentation-driven." Say you work in the field of climate policy analysis—an issue that is neither intrinsically labor market related nor likely to have significant effects on the labor market. However, when you present your results, they are called into doubt, because "your model doesn't even allow for involuntary unemployment" (which, as everyone admits, is a worrisome feature of most economies). Trying to convince your audience that including unemployment does not make much of a difference would divert the discussion from the main issue and might be difficult after all. Thus, it can be a sensible strategy to add a more complex labor market module to the model, if only to prevent people from digressing. A similar constellation can be found "history-driven" when modelers start off from an existing model containing labor market features that are irrelevant for the question at hand, but would require some effort to eliminate. In both presentation- and history-driven contexts, we want to make sure that the labor market features present in the model do not complicate the interpretation of the results unnecessarily by producing spurious effects.

We fully recognize that model development in practice works under many restrictions that are not strictly academic. This is what we have often experienced in the work with our own models as well. Nevertheless, as economists, our thinking is dominated by the question-driven approach. Here, we want to advocate and support a "question precedes model" strategy. In our view, the ideal setup of a CGE study is the following. First, we need to formulate a clear question to be answered, preferably more specific than merely "analyzing the consequences of policy X." Often we can get, simply by phrasing the question clearly, a good idea of which model features will be relevant to the outcome and which will not. It is a question of modeling efficiency to focus on the first and to disregard the latter.

Stated broadly, this chapter has two objectives: (i) Giving an overview of what options there are for labor market modeling in a CGE framework and (ii) discussing advantages or disadvantages of these options, depending on the modeling context. The structure of the chapter is derived from the three major parts of any labor market module—labor supply, labor demand and market coordination—and from two directions of model development: refinement of mechanisms and disaggregation of units. With respect to labor supply, we primarily focus on the distinction between the representative household and microsimulation approaches. Concerning labor demand, substitutability and complementarity of different types of labor in production are center stage. Finally, when it comes to labor market coordination, we review different theories of imperfectly competitive labor markets. The second structuring dimension distinguishes between two strands in the development of labor market modeling: more complex mechanisms and a deeper disaggregation. Starting from the default option of almost all first-generation CGE models—market-clearing wages in a single labor market—we can in principle develop in both directions independently: (i) More complex mechanisms, say endogenous unemployment, at the same level of aggregation or (ii) the same, simple mechanism at a deeper level of disaggregation.

In many cases, however, there are interactions between complexity and disaggregation, which we will explore in this chapter as well. Let us illustrate this by three examples. (i) The introduction of involuntary unemployment confronts us with characteristically different unemployment rates for different groups of workers, which leads us to treat these labor market segments separately. (ii) We find that an important mechanism of labor market coordination—collective wage bargaining—is only relevant to particular sectors, which requires us to think about sectoral labor mobility. (iii) The differentiation between male and female labor supply, which is necessary if we want to do justice to empirical labor supply elasticities, raises questions about the substitutability of male and female work in production. We must always be aware of the fact that introducing a new model feature, which may be well motivated in a certain context, can create loose ends at other points in our model.

We try to give a comprehensive overview of modeling options, but in some respects we have been selective. (i) We mainly focus on issues that can be treated in static or recursively dynamic models. Problems that require a dynamic model with forward-looking agents, such as life cycle decisions like educational choice and the timing of retirement, are not covered. (ii) Business cycle issues, such as the role of sticky wages in the propagation of shocks (new Keynesian features typically covered in dynamic stochastic general equilibrium models), are beyond the scope of this chapter. (iii) We concentrate on models at the national or multinational level and disregard special problems of factor mobility that arise in regional modeling.

26.2 A CLASSIFICATION OF LABOR-MARKET RELATED QUESTIONS

In Section 26.1, we advocated the perspective of seeing models as tools to answer questions. The most straightforward type of question is: "What effect will policy intervention X have on economic indicator Y?" Depending on which kind of policy intervention and which kind of economic indicator we have in mind, the criteria for an assessment of CGE labor market modeling may vary significantly. Here, we look more systematically at the types of questions that have been addressed with CGE models. This results in a classification that is used for structuring a list of typical CGE studies with a labor market focus.

26.2.1 Location of the initial shock

It is important to be clear about the location where the initial policy shock enters the model. Does it affect the labor market directly or only indirectly through other elements of the model? Let us return to the examples mentioned in Section 26.1. Take the case that we want to analyze the macroeconomic consequences of a policy encouraging labor supply of low-skilled workers, e.g. some in-work benefit system. Then we need a labor market module that is sufficiently complex for the policy shock to be meaningfully modeled. In this case this means that labor supply must be flexible and the low-skilled must be treated as a separate group.

Many of the big themes of CGE modeling, in contrast, are not directly labor market related. International trade liberalization hits export and import markets, climate policy measures affect energy markets and the impact of both policies on the labor market is only indirect through a shift in labor demand, i.e. in the real wages that can potentially be paid to the workers at a given level of employment. The same applies to tax policy analysis, as far as it is concerned with capital taxation, corporate taxation, intermediate input taxes or consumption taxes. The only exemption is wage taxation, which needs a labor market representation with flexible labor supply and heterogeneous wages for a meaningful analysis.

In all cases in which the labor market is only affected indirectly through labor demand, we are confronted with the following key question: will the real wage follow the movement of the marginal product of labor one-to-one, as it would in a perfect labor market? Or is there some sort of wage rigidity that hinders a parallel movement? Put into even more policy-relevant terms: to what extent will higher demand for labor translate into higher wages and to what extent into more employment (and *vice versa* for lower labor demand)? What is asked for is a "wage curve," i.e. a functional relationship between unemployment and the wage, which then in turn determines the wage–employment split. We return to the issue of the wage curve in Section 26.5.3, where we review different options of modeling imperfect labor markets.

26.2.2 Outcome variables of interest

Just as important as the location of the initial shock is the outcome variable we are interested in. Potential outcome variables of CGE models can be classified according to the level of aggregation they require. At one extreme of the spectrum, we have typical macro variables, which give us an impression of the overall economic effect of the policy measure analyzed: GDP, national income, exports and imports, consumption and investment or a welfare measure such as the Hicksian equivalent variation. At an intermediate level of aggregation, we have sectoral effects: output, employment, productivity, exports and imports by sector, which are prominent in many core issues of CGE modeling (e.g. trade liberalization, climate policy). Here, however, they are only of interest in so far as they affect the labor market. Labor market variables with a comparable, intermediate level of aggregation are group-specific outcomes such as wages, participation, employment and unemployment by skill group or gender. Finally, if the model allows for full disaggregation, we have the additional option of reporting these variables by sociodemographic attributes that have no functional role in the labor market mechanism modeled, e.g. income, class, age, education or number of children. This kind of reporting is normally motivated by distributional concerns.

Unlike the location of the initial shock, the outcome variables used will not directly constitute a classification criterion of studies. The criterion is rather whether a model encompasses both the macro and the micro level. If it does, this will normally also be reflected in the reporting of results.

26.2.3 A classification of typical studies

Let us categorize a number of typical CGE studies with a labor market focus according to the criteria developed in the preceding paragraphs. Where is the policy shock located? Does the model contain a genuine micro level?

We start, in roughly chronological order, with studies that focus on labor market shocks:

- Early attempts at addressing labor market issues in a CGE framework are Gelauff *et al.* (1991) and Dewatripont *et al.* (1991), who analyze labor taxation and social security contributions in the Netherlands and Belgium, respectively.
- Sørensen (1997) studies options of stimulating low-skilled employment (tax cut for low incomes and consumption tax relief on low-skilled intensive services) in a model calibrated to the Danish economy.
- Hutton and Ruocco (1999) and Böhringer *et al.* (2005) analyze changes in labor taxation with an aggregated labor market module. The wage-generating mechanism is efficiency wages in the first paper and collective bargaining in the latter.

- Bovenberg *et al.* (2000) focus on tax reform as well, but in a model that allows for more dimensions of labor market heterogeneity. A full-fledged version of their model for the Dutch economy is presented in Graafland *et al.* (2001).
- Aaberge *et al.* (2004), Aaberge *et al.* (2008) and Boeters (2010) are examples of integrating microsimulation elements with a focus on refinancing the pension system, stimulation of low-skilled employment and tax progressivity, respectively.
- Agénor *et al.* (2007) simulate various labor market policy measures (reduction in payroll taxation, cuts in public sector wages and employment, reduction in trade union bargaining power) in a model with a dual labor market and collective wage bargaining for a stylized Middle-East or North-African economy. Agénor and El Aynaoui (2003) is an application of this model to Morocco.
- Cogneau and Robilliard (2008) set up a linked microsimulation–CGE model of Madagascar for analyzing poverty alleviation policies such as agricultural subsidies, a workfare scheme and untargeted *per capita* transfers.
- Dixon *et al.* (2011) study the labor market effects of restricting employment of illegal immigrants in the US by either stricter border controls or higher fines for employers.

A second set of CGE studies, again in roughly chronological order, analyze policy or macroeconomic shocks that do not directly hit the labor market, but nevertheless have effects on employment and distribution that depend on the labor market specification:

- Ballard *et al.* (1985) is a classical study on tax policy. Their discussion of labor market issues, however, is restricted to choosing an appropriate value of the aggregated elasticity of labor supply.
- The study of de Melo and Tarr (1992) has a seminal status for the analysis of trade liberalization. As a specific labor market feature, they introduce wage bargaining in the automobile sector, which naturally leads them to a kind of dual labor market structure.
- The trade liberalization issue has been linked to poverty analysis in models that use a full microsimulation–CGE linkage, e.g. Hérault (2007) for South Africa, Bourguignon and Savard (2008) for the Philippines, and Bussolo *et al.* (2008) for Latin America.
- Fæhn *et al.* (2009) and Fraser and Waschik (2010) are two studies from the field of energy economics and climate policy analysis that have a special focus on the interactions of energy and labor markets.
- The impact of macroeconomic shocks such as financial or currency crises is analyzed in Ferreira *et al.* (2008) for Brazil and in Robilliard *et al.* (2008) for Indonesia.

26.3 LABOR SUPPLY

According to the outline in Section 26.1, labor supply modeling can develop towards a higher degree of complexity in two ways: (i) More subtle labor supply mechanisms and (ii) a lower level of aggregation. The structure of this section is derived from the aggregation dimension. We start at the most aggregated level of a single representative household (Section 26.3.1) and show how basic calibration tasks can be approached: (i) Implementing empirically plausible labor supply elasticities, (ii) differentiating labor supply along the intensive and extensive margin, and (iii) allocating involuntary unemployment. In Section 26.3.2, we discuss the changes resulting from the existence of several representative households instead of a single one. Finally, in Section 26.3.3, we turn to microsimulation, where labor supply is implemented at the lowest possible aggregation level, i.e. at the level of the individual household.

26.3.1 Labor supply of a single representative household

At the level of a single representative household, unbothered by disaggregation issues, we can concentrate on the task of modeling labor supply in a way that is consistent with given empirical elasticities. In many classical CGE models (e.g. Dervis *et al.*, 1982), in addition to working with a single representative household, it is assumed that the labor supply of this household is fixed. Once we want to model flexible labor supply, we are confronted with a crucial distinction. Labor supply is flexible along two margins: hours of work (intensive margin) and participation (extensive margin). Here, we show how labor supply of a representative household can be calibrated to a set of three aggregate labor supply elasticities: (i) Elasticity of participation with respect to the wage, (ii) elasticity of working hours with respect to the wage and (iii) elasticity of working hours with respect to (non-wage) income. The calibration is performed by determining the parameters of a conventional utility function comprising material consumption and leisure.[1]

26.3.1.1 Hours of work

We consider a worker household that must decide on its hours of work under a budget constraint and a time constraint. The budget constraint is:

$$p_{\mathrm{C}}(C_{\mathrm{D}} + C_0) = wH(1 - t_{\mathrm{a}}) + Y_0,$$

where p_{C} is the consumption price index, C_{D} and C_0 are disposable and necessary consumption, respectively, w is the wage rate, H is hours of work, t_{a} is the average tax rate on labor income, and Y_0 is non-labor income.[2] The time constraint is:

$$F + H = T,$$

[1] The following material is adapted to the present context from Boeters and van Leeuwen (2010).

[2] Compared to the simplest possible textbook example of labor supply, this formulation contains three extensions that are important for empirical calibration: necessary consumption, non-labor income and a variable average tax rate, which causes average and marginal tax rates to diverge. As we focus on static models, we do not extend the model with savings (for the joint calibration of labor supply and savings, see Rutherford, 1998).

with leisure F and time endowment T. The choice of the worker household is modeled as the maximization of a utility function that covers disposable consumption and leisure, $U_e = U_e(C_D, F)$. As our task is to determine concrete functional parameters, we assume a constant elasticity of substitution (CES) utility function[3] with parameters θ_C and σ:

$$U_e = \left[\theta_C\left(\frac{C_D}{\bar{C}_D}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_C)\left(\frac{F}{\bar{F}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}. \tag{26.1}$$

From this utility function, we can derive the following expenditure and demand functions, where variables with an upper bar denote initial (and thus constant) values:

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

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

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

where p_U is the necessary expenditure for one unit of utility and t_m is the marginal labor income tax rate. The utility level can alternatively be calculated as:

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

where Y_D is disposable extended income defined as:

$$Y_D = w[H(1-t_a) + (T-H)(1-t_m)] + Y_0 - C_0,$$

evaluating leisure with the marginal after-tax wage rate.

Y_D is also used to calibrate the share parameter of the utility function (26.1). θ_C is the initial share of disposable consumption in disposable extended income:

$$\theta_C = \frac{\bar{C}_D}{\bar{Y}_D}, \tag{26.2}$$

[3] We use the "calibrated share form" of the CES function (see Rutherford, 1998). By expressing all quantities and prices as multiples of the initial values, this form clearly conveys the ideas that quantities normalizations are arbitrary and that the essential information is about relative changes. In addition, the value shares in the initial situation can be used as share parameters of the function without transformation.

and, correspondingly:

$$1-\theta_{\mathrm{C}} = \frac{\bar{w}\left(1-\bar{t}_{\mathrm{m}}\right)\bar{F}}{\bar{Y}_{\mathrm{D}}}.$$

In the following two subsections, we describe how labor supply at the hours-of-work margin is calibrated to empirical labor supply elasticities.

26.3.1.2 Income elasticity of labor supply

Here, we argue that the disposable time endowment, T, should be calibrated in a way that produces an income elasticity of labor supply in an empirically plausible range. In contrast, an *ad hoc* specification of T is likely to result in an unrealistic value of this elasticity. We follow the approach of de Melo and Tarr (1992). Ballard (2000) has highlighted this approach as a means of improving the empirical fit of the model.

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

$$\varepsilon_{FY_{\mathrm{D}}} = 1.$$

From this we can derive the income elasticity of labor supply. To be precise, we calculate the percent change in labor supply with respect to an exogenous variation of the non-labor income, Y_0, that would increase $Y = wH(1-t_{\mathrm{a}}) + Y_0$ by 1% if labor supply did not react:

$$\eta_{HY} = \varepsilon_{HY_0}\frac{Y}{Y_0} = \varepsilon_{HF}\varepsilon_{FY_{\mathrm{D}}}\frac{\mathrm{d}Y_{\mathrm{D}}}{\mathrm{d}Y_0}\frac{Y}{Y_{\mathrm{D}}}.$$

We have:

$$\varepsilon_{HF} = -\frac{T-H}{H}$$

$$\varepsilon_{FY_{\mathrm{D}}} = \frac{\mathrm{d}Y_{\mathrm{D}}}{\mathrm{d}Y_0} = 1,$$

and therefore:

$$\eta_{HY} = -\frac{T-H}{H}\frac{Y}{Y_{\mathrm{D}}}$$

$$= -\frac{T-H}{H}\frac{wH(1-t_{\mathrm{a}})+Y_0}{w[H(1-t_{\mathrm{a}})+(T-H)(1-t_{\mathrm{m}})]+Y_0-C_0}.$$

[4] We denote the elasticity $\frac{\partial \log x}{\partial \log y}$ by ε_{xy} or (if it is an empirical value to be reproduced in the model), η_{xy}.

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

$$\begin{aligned}\frac{T}{H} &= \frac{[wH(1-t_{\mathrm{a}})+Y_0]-\eta_{LY}(w[H(1-t_{\mathrm{a}})-H(1-t_{\mathrm{m}})]+Y_0-C_0)}{[\eta_{HY}wH(1-t_{\mathrm{m}})]+wH(1-t_{\mathrm{a}})+Y_0} \\ &= 1-\frac{\eta_{HY}[wH(1-t_{\mathrm{a}})+Y_0-C_0]}{\eta_{HY}wH(1-t_{\mathrm{m}})+wH(1-t_{\mathrm{a}})+Y_0}.\end{aligned} \tag{26.3}$$

For small, negative values of $\eta_{HY}, T > H$ is warranted. At the same time, small absolute values of η_{HY} will result in a small amount of disposable leisure. In a simplified benchmark case with $Y_0 = C_0 = 0$ and proportional taxes $(t_{\mathrm{m}} = t_{\mathrm{a}} = t)$, Equation (26.3) reduces to:

$$\frac{T}{H} = 1-\frac{\eta_{HY}}{1+\eta_{HY}} = \frac{1}{1+\eta_{HY}}. \tag{26.4}$$

If we follow Ballard (2000) and set η_{HY} to the empirically plausible value of -0.1, we arrive at $T/H \approx 1.1$. This may seem overly little: only 4 h of disposable leisure in relation to a standard work week of 40 h. In *ad hoc* specifications, one often finds a value of 1.75 (e.g. Rutherford, 1998). However, this would lead to income elasticities of labor supply that are far beyond what we empirically observe.[5]

26.3.1.3 Wage elasticity of labor supply

With the relative time endowment, T/H, determined by the income elasticity of labor supply, we proceed with calibrating the value of the elasticity of substitution between material consumption and leisure, σ, using the wage elasticity of labor supply,[6] η_{Hw}, which is calculated as:

$$\eta_{Hw} = \varepsilon_{H\tilde{w}} = -\frac{T-H}{H}\varepsilon_{F\tilde{w}},$$

where $\tilde{w} = w(1-t_{\mathrm{m}})$. The elasticity of leisure demand with respect to the marginal after-tax wage can be routinely decomposed into a substitution effect and an income

[5] Equivalently to calibrating the time endowment T, we can also set some arbitrary time endowment (say, 24 h a day) and calibrate a minimum level of leisure in the fashion of a Stone–Geary utility function. This approach has been taken in Annabi (2003), although without discussion of the consequences for the income elasticity of labor supply.

[6] To be precise, we deal with the elasticity of the hours of work with respect to the *marginal after-tax* wage. Differently specified elasticities require modifying the calculations accordingly.

effect. The income effect deserves attention, because we need the effect of the wage on the disposable extended income, Y_D:

$$\eta_{Hw} = -\frac{T-H}{H}\left[-\sigma\theta_\mathrm{C} - (1-\theta_\mathrm{C}) + \frac{w(1-t_\mathrm{m})T}{Y_\mathrm{D}}\right].$$

Solving for σ gives the calibration equation:

$$\sigma = \frac{\eta_{Hw} - \frac{T-H}{H}\left((1-\theta_\mathrm{C}) - \frac{w(1-t_\mathrm{m})T}{Y_\mathrm{D}}\right)}{\frac{T-H}{H}\theta_\mathrm{C}}. \tag{26.5}$$

To get a feeling for magnitudes, we again consider the special case with $Y_0 = C_0 = 0$ and $t_\mathrm{m} = t_\mathrm{a}$. Then, we have:

$$\frac{w(1-t_\mathrm{m})T}{Y_\mathrm{D}} = 1,$$

and Equation (26.5) simplifies to:

$$\sigma = \frac{\eta_{Hw} + \frac{T-H}{H}\theta_\mathrm{C}}{\frac{T-H}{H}\theta_\mathrm{C}} = 1 + \frac{\eta_{Hw}}{\frac{T-H}{H}\theta_\mathrm{C}}. \tag{26.6}$$

Further simplification of Equation (26.6) is achieved by observing that in this case:

$$\theta_\mathrm{C} = \frac{H}{T},$$

which yields:[7]

$$\sigma = 1 + \frac{T}{T-H}\eta_{Hw}.$$

Finally, we insert Equation (26.4), which leaves us with:

$$\sigma = 1 - \frac{\eta_{Hw}}{\eta_{HY}}.$$

This shows that the inclusion of η_{HY} in the calibration makes the outcome for σ more volatile. With an exogenous, relatively large T/H ratio, a small value of η_{Hw} would have warranted a small deviation of σ from one. With η_{HY} additionally appearing in the equation, σ can easily assume much higher values. To get a feeling for numerical values,

[7] This is also what you get in Rutherford (1998), if you leave out the upper nest with the consumption—savings decision (assuming that the savings rate is zero).

we follow Sørensen (1999) and set η_{Hw} to 0.1.[8] Together with $\eta_{HY} = -0.1$ (as in Section 26.3.1.2), this produces $\sigma = 2$.

Alternatively, it would be possible to calibrate the model to the compensated and uncompensated elasticities of labor supply. Ballard and Fullerton (1992) use values of 0.2 and 0 in their benchmark case.

26.3.1.4 Labor supply: Participation

When we proceed to the calibration of labor supply along the extensive margin (participation), we can no longer base our work on the fiction that the representative household represents a large number of identical individuals. The simplest way of implementing the difference between participating and non-participating households is to assume heterogeneity in their fixed cost of taking up work. Those with low fixed costs enter the labor market, whereas those with high fixed costs stay at home.[9] It is not necessary 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 labor market attachment—an inherent utility from interacting with others in a productive environment.

The two-step labor 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 if there is involuntary unemployment. A possible assumption is that individuals draw a comparison between the (unemployment-weighted) expected utility of supplying labor and their respective fixed costs. In the case of unemployment (index u), utility is:

$$U_{\mathrm{u}} = \left[\theta_{\mathrm{C}}\left(\frac{C_{\mathrm{D}}^{\mathrm{u}}}{\bar{C}_{\mathrm{D}}}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_{\mathrm{C}})\left(\frac{T}{\bar{F}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}, \tag{26.7}$$

where disposable consumption in the case of unemployment, $C_{\mathrm{D}}^{\mathrm{u}}$, is income less necessary consumption:

$$C_{\mathrm{D}}^{\mathrm{u}} = Y_{\mathrm{D}}^{\mathrm{u}} = cwH(1-t_{\mathrm{a}}) + Y_0^{\mathrm{u}} - C_0,$$

and unemployment benefits are assumed to be a fixed replacement rate, c, multiplied with the after-tax income of the employed workers, $wH(1-t_{\mathrm{a}})$. The formulation (26.7) creates a problem, however. All relevant variables in this equation are fixed, either institutionally (c, t_{a}) or through the calibration of the labor supply decision of the

[8] The meta analysis of Evers *et al.* (2008) suggests a somewhat higher elasticity, but it is difficult to distil a core value from this study.

[9] For a general discussion of this approach, see Bourguignon and Magnac (1990), Magnac (1991), and Kleven and Kreiner (2006a).

employed workers $(\theta_{\mathrm{C}}, \sigma, T)$. For a reasonable unemployment model, we must have $U_{\mathrm{u}} < U_{\mathrm{e}}$, which is not automatically warranted. If several factors interact, U_{u} may turn out to be larger than U_{e}. As an outcome of the calibration (see Sections 26.3.1.2 and 26.3.1.3), $\bar{F}$ is typically only a small share of T and the elasticity of substitution, σ, is considerably larger than one. Both these facts contribute to a high utility level of the unemployed. On the other hand, we have basic consumption, C_0, which makes the relative difference between $C_{\mathrm{D}}^{\mathrm{u}}$ and $\bar{C}_{\mathrm{D}}$ larger than simply given by the replacement rate. If the first factor dominates, we end up with a utility reversal.

Finding a solution to this problem would require further exploring the value of involuntarily unemployed time, which seems to be an unresolved question in labor economics. The model can in principle easily be adjusted in order 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 labor. However, there is no strong reason to assume that the outcome of the calibration is also informative with respect to the utility *difference* between two distant points, $U_{\mathrm{e}} - U_{\mathrm{u}}$. We can approach the utility reversal problem by introducing an additional parameter. This parameter allows for the possibility that unemployed workers 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 labor 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.[10] In general terms, we may assume that a given fraction, δ, of the additional non-working time of the unemployed does not count as "leisure:"

$$U_{\mathrm{u}} = \left[\theta_{\mathrm{C}}\left(\frac{C_{\mathrm{D}}^{\mathrm{u}}}{\bar{C}_{\mathrm{D}}}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_{\mathrm{C}})\left(\frac{T-\delta\bar{H}}{\bar{F}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}.$$

Given U_{u}, with the implied difficulties, we can calculate the expected utility of supplying labor, U_{l}:

$$U_{\mathrm{l}} = (1-u)U_{\mathrm{e}} + uU_{\mathrm{u}},$$

which is the same for all individuals. They compare it with their idiosyncratic fixed cost of supplying labor, U_0, and supply labor if $U_{\mathrm{l}} > U_0$.

The distribution of the U_0s over the population must be calibrated. As our empirical basis, we have the actual participation rate and the elasticity of labor supply at the extensive margin. 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. A relatively simple assumption is that costs are

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

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 caused by an exogenous variation in the wage. We consider the case of an isolated change in the wage of the respective individuals when they are employed. In this case, the unemployment rate and the utility from unemployment can be considered constant.[11] In terms of elasticities, we then have:

$$\begin{aligned}\varepsilon_{U_\mathrm{l},w} &= \frac{(1-u)U_\mathrm{e}}{U_\mathrm{l}}\varepsilon_{U_\mathrm{e},w} = \frac{(1-u)U_\mathrm{e}}{U_\mathrm{l}}\left(\varepsilon_{Y_\mathrm{D},w} - \varepsilon_{p_\mathrm{U},w}\right)\\ &= \frac{(1-u)U_\mathrm{e}}{U_\mathrm{l}}\left(\frac{wT(1-t_\mathrm{m})}{Y_\mathrm{D}} - \frac{wF(1-t_\mathrm{m})}{Y_\mathrm{D}}\right)\\ &= \frac{(1-u)U_\mathrm{e}}{U_\mathrm{l}}\frac{wH(1-t_\mathrm{m})}{Y_\mathrm{D}}.\end{aligned}$$

The elasticity of labor supply at the extensive margin can be calculated as:

$$\eta_{Nw} = \varepsilon_{N,U_\mathrm{l}}\varepsilon_{U_\mathrm{l},w} = h\frac{(1-u)U_\mathrm{e}}{N}\frac{wH(1-t_\mathrm{m})}{Y_\mathrm{D}},$$

where h is the density of the fixed cost distribution and N is the number of participating individuals. Solving for h we obtain:

$$h = \eta_{Nw}\frac{NY_\mathrm{D}}{(1-u)U_\mathrm{e}wH(1-t_\mathrm{m})}. \tag{26.8}$$

Given a particular value for η_{Nw},[12] h can be evaluated at the initial point and 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; after the initial situation, it is endogenous.

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

$$\begin{aligned}U_0^- &= \bar{U}_\mathrm{l} - \frac{\bar{N}}{h}\\ U_0^+ &= \bar{U}_\mathrm{l} + \frac{N_0 - \bar{N}}{h},\end{aligned}$$

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

[12] Kleven and Kreiner (2006b, pp. 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. One might choose a value of 0.2, which is roughly the aggregate average in Kleven and Kreiner's core scenario.

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

$$N = \bar{N} + h(U_1 - \bar{U}_1). \tag{26.9}$$

26.3.1.5 Supply of different labor varieties

So far, we have assumed that the labor supplied by the representative household is homogeneous. If we want to distinguish between different types of labor, but remain in the setting with a single representative household, we can allow for transformation among the different labor supply options.[13] For concreteness, let us abstract from any further complication associated with the valuation of leisure and focus on the distribution of a fixed endowment of time between two labor supply options. This can straightforwardly be modeled by a constant elasticity of transformation (CET) function with the two options as arguments. Examples for this approach are Hutton and Ruocco (1999), who discuss full-time versus part-time work, Gaasland (2008) for the case of farm versus non-farm work and Cloutier *et al.* (2008) for skilled versus unskilled labor. In formal terms, we have a given amount of labor supplied, $\bar{L}$, as a CET aggregate of two varieties, L_1 and L_2:

$$\bar{L} = CET(L_1, L_2) = \left[\beta_1 L_1^{\frac{\tau-1}{\tau}} + \beta_2 L_2^{\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}}, \tag{26.10}$$

where the β_i are share parameters and $\tau < 0$ is the elasticity of transformation. The standard CET approach (e.g. analogously to the transformation of domestic production into domestically sold and exported varieties) is to maximize earnings:

$$\max_{L_1, L_2} \; Y = w_1 L_1 + w_2 L_2,$$

for exogenous wages w_i, subject to the resource constraint (26.10). This gives first-order conditions:

$$w_i = \frac{\partial CET(L_1, L_2)}{\partial L_i},$$

which determine the allocation of the endowment between the options.

The problem with the ordinary CET setup is that the L_i will in general *not* add up to $\bar{L}$. This makes the interpretation of the result difficult, because it was precisely the aim of

[13] Modeling setups with differentiated households are discussed in Sections 26.3.2 and 26.3.3.

the exercise to *distribute* a given amount of labor supply between two options.[14] As a reaction to this problem, other modelers (e.g. Dixon and Rimmer, 2003, and Giesecke *et al.*, 2011, who deal with occupation-specific labor supply) have approached the distribution of labor across varieties as an issue of substitutability. They use the ordinary time constraint:

$$L_1 + L_2 = \bar{L}, \tag{26.11}$$

and assume that *incomes* from the two varieties of labor are imperfect substitutes in the utility function[15] U:

$$U = CES(w_1 L_1, w_2 L_2) = \left[\gamma_1 (w_1 L_1)^{\frac{\sigma-1}{\sigma}} + \gamma_2 (w_2 L_2)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}},$$

with distribution parameters γ_i and elasticity of substitution $\sigma > 0$. The distribution of labor between the two varieties is modeled as utility maximization subject to the resource constraint (26.11). This solves the additivity problem, but generates new difficulties in the interpretation. Why should incomes from different sources be imperfectly substitutable in generating utility? A possible interpretation is that individual households have varying innate affinity for the different labor supply options. They receive utility not only from income, but also from the closeness to their most preferred option. Households can be ranked according to their innate affinity, with those at the top of the list switching to the respective option first. The higher participation in a certain option, the lower therefore the marginal non-income valuation of this option, creating a smooth transformation from other options. An explicit model of closeness to the intrinsically preferred option has been included in MIMIC (Graafland *et al.*, 2001, pp. 84–86) for the choice between discrete hours-of-work options. Implicitly, similar assumptions are also at work in the standard discrete choice modeling of labor supply (see Section 26.3.3). In any case, it remains a challenge to make an approach of this sort a consistent integral part of a full model. One question to be answered in this context is: how can we account for income effects of the non-income utility from labor supply options on the demand of other goods and leisure?

26.3.2 Labor supply of several representative households

The approach of Section 26.3.1 can be extended to more than a single representative household. In general, there is no restriction to the number of representative households

[14] Magnani and Mercenier (2009), in a model of occupational choice, try to solve this problem by only deriving the *ratios* between the different types of labor supply from the CET setup and then combining these ratios with the time constraint. This cannot completely eliminate the consistency concerns. However, Magnani and Mercenier (2009) show that the resulting expression can be interpreted as the outcome of the aggregation of a mass of agents that are heterogeneous in one dimension, which is an attractive feature of this approach.

[15] Giesecke *et al.* (2011) use a CRESH utility function. Here, we simplify with a CES function.

with which we can work. A common split in only two households is the distinction between low-skilled and high-skilled workers (e.g. Lejour *et al.*, 2006). At the other end of the spectrum, there are models with as much as 100 representative households (e.g. Piggott and Whalley, 1985, who differentiate between households by household composition, profession and wage level, or Dixon and Rimmer, 1995, who have the marginal propensity to consume as an additional criterion for differentiation). At a certain level of disaggregation, however, the question arises naturally whether one should then not rather switch to microsimulation, where the unit is the individual household (see Section 26.3.3).

When working with several representative households, we must decide on the criteria of differentiation. This is not always clear-cut, because several types of arguments tend to interfere. (i) Foremost, we want the household structure to respond to the research question pursued. For example, when we try to answer distributional questions, a household differentiation by income class is natural. When the research motivation is female labor market participation, we need to differentiate by household composition. (ii) However, any disaggregation at the household level requires complementary assumptions with respect to labor demand and labor market coordination. When we distinguish between two households, do we also want to specify diverging labor demand conditions or coordination mechanisms for the two types of labor supply? Or can labor of the two households simply be added up to a homogeneous aggregate? (For details, see Sections 26.4 and 26.5, respectively.) Our choice of household disaggregation criteria can be influenced by these follow-up problems. (iii) We need data for the calibration of the differentiated households. Depending on the disaggregation criteria, these can be more or less easily available (see Section 26.3.2.2).

26.3.2.1 Possible household types

This section contains a list of criteria that have been used for separating representative households. For each criterion we discuss the motivation for the split and possible problems in implementation.

26.3.2.1.1 Skill type

The split into skill types, usually understood as level of education, responds to the huge amount of literature on skill-specific wage disparities and their possible reasons (skill-biased technological change and shifts in international trade patterns in the course of globalization). It acknowledges that wages do not always move in parallel, which becomes relevant in situations where differential effects on labor markets of different skill types are plausible. A typical example of a situation of this sort is trade liberalization, which changes the exposure of a country with imports from regions with different comparative advantages (e.g. Thierfelder and Robinson, 2002; Carneiro and Arbache, 2003). Similar effects can be the consequence of sectoral reallocations due to tax policy or climate policy measures.

Most of the literature on skill-specific labor market effects uses a split into two classes, high- and low-skilled (with a conventional cutoff point analogously to completed college education in the US). This follows a long tradition of attempts to estimate the substitution pattern between these two skill classes and capital (see Thierfelder and Robinson, 2002). Conceptually, it is easy to extend the skill split to more than two classes. However, the more skill classes, the more challenging labor demand estimation, which becomes more likely to produce implausible substitution patterns (see Section 26.4). In addition, the more skill classes, the less plausible the implicit claim that skill is an unchangeable attribute of the households (i.e. that individuals cannot switch from one skill class to another). Jung and Thorbecke (2003) and Cloutier *et al.* (2008) are two examples in which the choice of the skill type is endogenous, involving investment in education. Jung and Thorbecke (2003) work in a recursively dynamic context and let the education decision be governed by myopic expectations. The model of Cloutier *et al.* (2008) is static, representing a long-term equilibrium. Transformability of skills is imperfect (CET function) and the choice between skills is driven by contemporary wages.

A data-related issue with skill classes in multicountry models is the problem of comparability of skills data across borders. The larger the differences between educational systems, the higher the obstacles to finding comparable data. Dimaranan and Narayanan (2008) explain how the skills split is implemented in the GTAP (Global Trade Analysis Project) context. As detailed data are only available for a subset of the countries covered by GTAP, they estimate a functional relationship between the share of skilled labor payments, growth of GDP *per capita* and the average number of years of tertiary education. This is used to generate values for the countries with missing data.

26.3.2.1.2 Household composition

The two most important dimensions of household composition are couples versus singles and the number of children. The differentiation between the resulting household types is mainly inspired by labor supply estimates. Labor supply flexibility of singles and couples shows huge differences, and the presence of children is a major factor determining female labor market participation. Most estimations of labor supply are performed at least at this level of disaggregation and many labor market economists are very reluctant to use more aggregated values. A second motivation for disaggregation by household composition is a fiscal system that varies by household characteristics (e.g. Bahan *et al.*, 2005).

Once we explicitly account for couples as a distinct household type, we are faced with a new problem: cross-effects of the income of one partner on the labor supply of the other. In this case, a full set of elasticities would be more extensive than the one discussed for the representative household in Section 26.3.1. This is one reason why the intricacies of couple households are normally not approached in the representative household setting, but rather by means of microsimulation (see Section 26.3.3).

A certain simplification is achieved, however, if we assume that not all labor supply is flexible. A common specification is to assume one of the partners in the household to be the breadwinner, who supplies labor inflexibly. Only the labor supply of the other household members is considered flexible and calibrated to empirical elasticities. This approach is followed, for example, in the MIMIC model (Graafland *et al.*, 2001). Two options of modeling representative couple households with flexibility of both partners' labor supply are explored and compared in Boeters *et al.* (2005). In models of low-income economies, Fontana and Wood (2000) and Cockburn *et al.* (2007) distinguish between labor supply of partners depending on the home production responsibilities of women.

26.3.2.1.3 Occupation

Classification by occupation is a close substitute to classification by skill type. There are three potential reasons for differentiating along the occupation instead of the skill (education) dimension. (i) For many countries, labor classification by occupation is more readily available (or even the only available information), e.g. in the official International Labor Organization data.[16] (ii) Switching from one occupation to another may be more difficult than switching from low-skilled to high-skilled tasks within the same occupation. So labor supply might be better formulated in occupational than in educational terms. (iii) There are professional organizations for occupations that limit the access to specific labor markets and thereby create wage differentials. A model that combines occupational and skill classifications (Giesecke *et al.*, 2011) is discussed in Section 26.4.2.

26.3.2.1.4 Sectoral employment

Classification by sectoral employment is another close substitute for skill and occupation. If labor is immobile between sectors and if there are sectoral wage differentials, a sectoral classification of labor supply may be an appropriate way to capture the consequences of sectoral shifts caused by, for example, trade liberalization or climate policy. Decaluwé *et al.* (2010) use this approach in a model of the Quebec economy.

In studies on low-income countries the distinction between workers attached to the rural versus the urban sector is important. This combines sectoral and regional aspects. In the short run, workers are attached to their respective sector. In the long run, however, mobility between the rural and the urban sectors must be taken into account (see Section 26.5.5). Whalley and Zhang (2004) use this household decomposition in a model of

[16] In the LABORSTA database at http://laborsta.ilo.org, sectoral data are given in an occupational breakdown (Tables 1E). Educational data are only available at the country level.

China to capture the Hukou system (constraints on movement of workers from rural to urban sectors).

26.3.2.1.5 Income class

Household differentiation by income class is usually motivated by distributional analysis, with income deciles as common classification criteria (e.g. Kim and Kim, 2003).[17] There are two aspects to observe here. (i) The classification of households with different composition into income classes requires some kind of equivalence scale, the choice of which will always be somewhat arbitrary. (ii) Income is not an ideal classification criterion because it is not exogenous. It may be the case that through the policy shock analyzed, a household switches from, say, the 10th to the 9th decile. Only in the unlikely case that all factor prices move in parallel does the relative income position of all households remain unchanged. With relative factor prices changing, it is important to keep in mind the exact interpretation of results with respect to income deciles. We report the change for the decile of households that were in a certain decile *before* the reform. This does not necessarily mean that precisely these households are in the same decile *after* the reform.

26.3.2.1.6 Income types

A classification by skill type or occupation is at the same time a classification by income type. In addition, a classification by type of non-labor income might be useful in certain contexts. The distinction between labor, capital and other income (most prominently welfare benefits and old-age pensions) is particularly important for income tax reforms that treat different sorts of income differently (e.g. dual income taxes). In the case of transfers, the recipients of these income type are often a clearly separated group (pensioners or the unemployed). The recipients of labor and capital income, however, are not that clearly separate. Nevertheless there may be practical modeling reasons for forming a distinct household that collects capital income. Often micro data used for household decomposition contain unreliable or no information about capital income. Allocating all capital income to a hypothetical capitalist household may then be preferable to constructing some *ad hoc* method of allocating it to the individual worker households (this is the route chosen by Arntz *et al.*, 2008).

In developing countries with a large agricultural sector, by contrast, special attention is paid to the income from agricultural land ownership. A household decomposition by status of land ownership is used in Boccanfuso and Savard (2008) for analyzing the impact of the liberalization of the groundnut sector in Senegal.

[17] In Bassanini *et al.* (1999) households are formed according to income classes as well, but then interpreted as skill groups.

26.3.2.1.7 Wage level

Household classification by wage level is an option when we analyze policy measures such as a minimum wage or wage subsidies in the low-income segment. Certainly, the wage level will be correlated with classification criteria discussed above: skill level, occupation or sectoral employment. However, for policy measures that directly target a particular range of wages, these classification criteria may not be sufficient because they leave a large share of wage dispersion unexplained (Lee, 1999).

The problem of wage-targeted policy measures is that they can affect workers with slightly different wages in a qualitatively different way (e.g. those just above or just below the minimum wage). Addressing this problem in the setting of representative households requires us to use precisely the critical wage level as a demarcation criterion for households. This is somehow artificial, however, because a classification dictated by the policy measure in question will only accidentally be useful for labor supply or labor demand. Working with a set of completely disaggregated households (see Section 26.3.3) becomes preferable, because this does not force us to sacrifice other important dimensions of disaggregation (e.g. household composition). Examples of the representative household approach to analyzing minimum wages are Dixon and Rimmer (2003) and Dixon *et al.* (2010).

26.3.2.1.8 Age

Differentiating households by age is mostly a feature of overlapping generations (OLG) models and therefore not discussed in this chapter.

26.3.2.2 Sources of elasticity estimates

When we work with a larger number of representative households, the requirements for having elasticities available to calibrate those households increases in proportion. In Section 26.3.1, we had three elasticities (of hours of work with respect to the wage and with respect to other income, of participation with respect to the wage) to calibrate a single representative household. With n households, we require at least three n elasticities.[18]

These elasticities will not normally be available from existing studies.[19] Given the large number of possible classifications of households, it would be a coincidence if there existed a labor supply estimation with exactly the classification needed. In addition, the results of any empirical study will normally be presented in a condensed form, as average elasticities for large subgroups of the population (e.g. singles and partners in couples) so that the reader does not have access to the original level of disaggregation.

[18] Or even more when we take account of the cross-elasticities in couple households.

[19] Evers *et al.* (2008) is a comprehensive meta analysis of labor supply elasticities. A comparative estimation of elasticities in a number of Organization for Economic Cooperation and Development (OECD) countries can be found in Bargain *et al.* (2011b).

This means that working with a large number of representative households leaves us with two options: either assuming that elasticities are identical for large subsets of these households or estimating the elasticities ourselves. Given that only in a minority of cases do CGE projects encompass resources for estimation, the availability of suitable elasticity estimates easily becomes a binding restraint. Arntz *et al.* (2008), Cogneau and Robilliard (2008), and Bourguignon and Savard (2008) are examples of studies that contain labor supply estimates to be used in a combined micro—macro simulation framework.

26.3.2.3 Heterogeneity within aggregate households

Distinguishing between a number of representative households is likely to be insufficiently fine for a meaningful distributional analysis. As long as there is homogeneity *within* a representative household, the distributional impacts for large subsets of the population are exactly the same. In poverty analysis, a common indicator is a headcount index, which is defined as the share of the population that is below a poverty line defined in absolute or relative terms. With an indicator of this sort, poverty is bound to remain exactly as before if none of the representative households crosses the critical line. In contrast, as soon as at least one of the households crosses the line, this immediately leads to a large, discrete change in poverty. Normally we want to have continuous model reactions to continuous variation of the model parameters and therefore such model behavior is considered to be undesirable. Boccanfuso *et al.* (2008) provide an extensive discussion of this issue.[20]

As a possible extension, there are examples of models where a given number of representative households is combined with *within*-household inequality. The most important case is wage inequality according to a specific functional distribution (e.g. log-normal) within an aggregate household defined by skill type and household composition (e.g. Dervis *et al.*, 1982, p. 526). The implicit assumptions of this approach are that relative wages do not change in the course of policy shocks and that the individuals within a representative household do not differ in any other respect than the wage. This restrictiveness of the heterogeneity-within-a-representative-household approach naturally leads to the follow-up step of dispensing with the concept of representative households altogether and switching to individual households instead. This is covered in Section 26.3.3.

26.3.3 Microsimulation of labor supply

One important motivation for microsimulation, i.e. working with microdata of individual households and *not* aggregating them into representative households, is

20 There are other definitions of "poverty" that can produce useful results even with representative households (see, e.g. Johnson and Dixon, 1999).

distributional analysis. When performing a distributional analysis, we are often interested in different dimensions: not only income classes, but also household composition, age, regional or sectoral employment. It is not possible to capture all these characteristics adequately in a representative household approach. Any predefined classification of representative households works as a restriction on the available redistributional results. By contrast, in a microsimulation setup, households can be classified and reclassified at the reporting stage so that classification can flexibly be adjusted to the research question.

A second motivation for microsimulation becomes relevant when we model policies that do not affect all individual households in the same way. In this case, the representative households approach requires households to be classified according to the degree to which they are affected by a policy. A switch in attention to another policy measure can then mean a revision of the households classification. Again, working with a microsimulation setup is much more flexible, because simulation is not affected by aggregation issues and aggregation takes place only after simulation results for individual households have been generated.

A third motivation for microsimulation originates in labor supply estimation. Empirical labor supply analysis is done at the micro level (see Section 26.3.3.1). Thus, the natural outcome is labor supply elasticities that vary by household. The most straightforward approach is using the estimated parameters directly, as it is done in microsimulation, rather than aggregating them by simulating the joint reactions of the individual household represented in the aggregate. At best, the reaction of the calibrated representative household precisely mirrors the reactions of the micro units. However, without an explicit comparison, we can never be sure not to produce some unwanted aggregation error.[21]

26.3.3.1 Functional approach to micro labor supply

Since van Soest (1995), labor supply modeling has almost exclusively been performed in a discrete-choice setting. Labor supply econometricians predefine a number of labor supply options, encompassing full-time and part-time work as well as non-participation. Then they estimate the parameters of some discrete-choice function (e.g. multinomial logit), which gives the probabilities for each of the options to be chosen. The attractiveness of the options depends on both leisure and after-tax income associated with a particular number of working hours. While leisure is fixed per option, the after-tax income varies across individuals because of differences in the hourly wage, and in the local properties of the tax and transfer system. It is this variation that the approach exploits for estimating parameters of the utility function that in turn determine the

21 For a general discussion of the relationship between micro and macro labor supply elasticities, see Keane and Rogerson (2011).

discrete-choice probabilities.[22] Usually, these parameters are estimated separately for different subsets of households (couples and singles), with a number of shift parameters for household characteristics (for an introductory survey, see Creedy and Kalb, 2005a).

Before the advent of the discrete-choice approach, labor supply estimations relied on a set of continuous choices, but ran into problems when confronted with non-linear budget constraints (for an overview, see Hausman, 1995). With a nonlinear budget constraint, labor supply can react discontinuously to policy changes, even if the choice set is continuous. This causes problems both for estimation and for simulation. Therefore, it has become standard to directly address the discontinuity issue by a discrete-choice setup.

In the tradition of labor supply estimations, discrete choice has mainly been implemented for modeling different hours-of-work options (including non-participation). In the modeling of the labor market in low-income countries, discrete choice has additionally been used to capture the formal—informal and the employment—unemployment switch (Magnac, 1991; Bourguignon *et al.*, 2005). However, compared to the hours-of-work choice, formal versus informal work and employment versus unemployment lend themselves less naturally to the interpretation of a *choice*. A more common interpretation is that these are reactions to changing demand conditions, where the role for choosing is limited. Maintaining the discrete choice framework in these contexts requires conceptualizing the allocation of employment and formal work as governed by some kind of intrinsic propensity. If demand conditions change so that there is more opportunity for employment or formal work, the workers with the highest propensity will switch status. Bourguignon *et al.* (2005), Bourguignon and Savard (2008), and Cogneau and Robilliard (2008) have advocated this approach in different contexts. It remains important to keep in mind that this excludes the interpretation that status switches of workers are the consequences of involuntary reactions to changes in demand conditions.

26.3.3.2 Counterfactual microsimulation

In a microsimulation setting, a counterfactual policy simulation means that the after-tax income for one or several of the discrete labor supply options changes (whereas the amount of leisure remains fixed per option). This affects the relative attractiveness of the different options and thus the respective probabilities with which they will be chosen. There are two different methods of implementing the simulation, which we will discuss in turn.

22 In the van Soest (1995) approach, differences in the choice behavior of observationally identical households are rationalized by household-specific, stochastic preference shocks. A different route is chosen by Aaberge *et al.* (1995) and Dagsvik and Strøm (2003), who base their estimation on a model of varying demand conditions in the labor market.

First, if the discrete-choice function lends itself to generating explicit expressions for the choice probabilities, we can use these expressions directly in the model. The most important case is the multinomial logit model, in which the unobserved, idiosyncratic error terms, ε_i, that generate heterogeneity between observationally identical individuals are assumed to be extreme-value distributed. The logit approach produces expressions of the following form for the probabilities (p) to prefer a particular option i over all other options j from the choice set:

$$\begin{aligned} p_i &= p\left(\varepsilon_i > \varepsilon_j + U_j - U_i\right) \quad \forall j \neq i \\ &= \frac{\exp(U_i)}{\sum_j \exp\left(U_j\right)}, \end{aligned}$$

where U_i is the estimated deterministic utility per option (McFadden, 1974). The probabilities p_i are in general strictly positive for all options. If we work with these probabilities, we interpret each individual household from the sample as representing a larger number of identical households. These households are distributed among the different labor supply options according to the probabilities. It is sometimes seen as a drawback of this approach that it does not exactly reproduce the aggregate labor supply behavior of the sample population in the initial situation. In the sample each household chooses exactly one single option, with a probability of zero for all other options. This need not be a problem if one is inclined to adopt the sample perspective. Even if all choices are clear-cut within the sample, this need not be the case for the underlying population. However, if reproduction of the observed choices in the sample is a high priority, other simulation methods are called for.

The second approach, due to Duncan and Weeks (1998), which addresses the problem of the reproduction of the initial sample choices, relies on the drawing of random numbers. We draw a large number of sets of random numbers for the error terms ε_j of the discrete choice options.[23] Of these sets of random numbers, only those are kept that result in the choice observed in the sample. Drawing is repeated until a certain number (10 or 100) of fitting sets per household have been obtained. That is, sets where the random number of the option actually chosen is sufficiently large so that:

$$\varepsilon_i > \varepsilon_j + U_j - U_i \quad \forall j \neq i. \tag{26.12}$$

In the counterfactual simulations the values of the U_j change. This means that the inequality (26.12) potentially does not hold any more for some sets of random numbers. We then obtain positive probabilities for other options than the one initially chosen.

23 These error terms must be consistent with the estimation, e.g. sets of extreme value distributed random numbers in the case of the logit model.

This evaluation of sets of random numbers cannot be done in a simultaneous system of equations, because of its non-continuity. Using a separate microsimulation module and iterating it with the main CGE model becomes necessary. In addition, the probability steps generated can only be as fine as implied by the number of random number sets (e.g. with 10 random numbers, we have 10% steps), which means that the reaction of the micro-households become discrete. This can may create problems in the convergence of the model modules when iterated.[24]

As a variant to the Duncan and Weeks (1998) procedure, Bonin and Schneider (2006) have derived explicit switching probabilities for the multinomial logit model, conditional on the initial choice. This makes it possible to set up a simulation mechanism that, as in Duncan and Weeks (1998), reproduces the initial situation exactly, but without drawing random numbers and using them to evaluate the utility function under counterfactual conditions. Analytical switching probabilities have been applied in some microsimulation studies (e.g. Peichl *et al.*, 2010), but not in a combined micro–macro model yet.

26.3.3.3 Linkage of the micro and macro modules

Once the working mechanisms of the micro module have been determined, the linkage between the micro and the macro part of the model enters center stage. In principle, there are three options. (i) One-way linkage: first running one module, then the other. (ii) Iteration in a soft link: run both modules alternatingly, until they converge. (iii) Integrated model: combine both modules in a single model code and solve in one step. We will discuss these options in turn.[25]

Depending on the shock analyzed and the question asked, a *one-way linkage* can be either a bottom-up linkage (first micro, then macro; e.g. when simulating a change in the taxation of labor) or a top-down linkage (first macro, then micro; e.g. when simulating a trade shock and analyzing its distributional consequences). Except for very special conditions, a one-way linkage will produce inconsistent results, because the reactions of the second module are not fed back into the first one. Let us consider a special case of a top-down linkage, where a one-way linkage is consistent indeed. When labor supply of the individual households is completely inelastic, and all households have the same consumption and savings structure, the microsimulation part of the linkage consists solely in distributing the aggregate changes in factor income among households so that distribution analysis can be performed. There is no feedback to be transmitted into the macro model. Obviously, these are very restrictive assumptions, which are not strictly valid in any realistic setting. In a somewhat looser sense, it has been argued that feedback

24 The model in Arntz *et al.* (2008) contains an algorithm that identifies individual households that jump back and forth in the iterations, and then smoothes the reaction of these households.

25 Assessments of the different linkage options can also be found in Davies (2004) and Peichl (2009).

effects can be expected to be small so that a one-way linkage provides a sufficient approximation. The problem with such an argument is, as always, that we do not know whether an irrelevance-of-feedback assumption is justified until we actually have performed the iteration, and compared the results with and without feedback.

This is the reason why we believe the step to an iteration procedure between the two model parts is advisable. Iteration not only takes account of the feedback, but also forces the modeler to conduct an additional consistency check. If both modules are consistent, then the model has the potential of *convergence through iterations*. Convergence is, however, not assured. There is not much systematic knowledge about convergence-enforcing algorithms. In their "sequential recalibration" approach, Rausch and Rutherford (2010) propose using level information from the micro model to recalibrate a conventional utility function of a representative household in the macro module. The first-order characteristics of this function (marginal reaction to changes of the exogenous parameters) are determined by arbitrarily chosen elasticities. With respect to the final result, the value of these elasticities does not matter, because the share parameters of the function are recalibrated in each iteration step. The elasticities can then be used to achieve a smooth convergence behavior of the model.

Another idea is to not only use level information from the micro module for transfer to the macro module, but also first-order information, i.e. the (simulated) derivatives of the endogenous variables with respect to the exogenous variables. However, with a complex microsimulation module, generating this first-order information is not necessarily faster than doing more (because more slowly converging) iterations. This remains a question of trial and error. In Boeters (2010), working with first-order information turned out not to be successful. Instead, introducing damping factors (i.e. transferring not the complete reaction of the micro module to the CGE model, but only a fraction) was the key to achieving convergence.

Finally, under certain conditions it is also possible to form an *integrated whole of the two modules*. This requires: (i) That there be explicit expressions for the microreactions (e.g. use of the analytical switching probabilities for the logit model by Bonin and Schneider, 2006), (ii) that they be sufficiently simple and (iii) that there be not too many micro units. This constitutes a tradeoff between ease of handling and detail in heterogeneity. Magnani and Mercenier (2009) strongly advocate an integrated approach, but to us a more liberal attitude seems advisable. As with other model characteristics, the choice of the iteration setup should be guided by the questions asked and the type of results aspired to. If an extensive sensitivity analysis with many model runs is the goal, an integrated model design may be an enormous asset. If, on the other hand, integration means that the most plausible functional forms for microsimulation are no longer available, or that essential dimensions of heterogeneity are lost, a soft link with iterations is preferable.

26.3.3.4 Data consistency between micro and macro modules

If we opt for an integrated model setup, data consistency is an obvious issue. The general equilibrium approach requires that all markets clearance conditions (demand equals supply) and all income balances (expenditure equals income) hold. If this is not the case either within the datasets or between them, adjustment is required to get the model afloat.[26]

Adjustment, however, is no less an important issue if we work with an iterated soft link or a one-way linkage. Even if the consistency requirement does not impose itself as strictly as with an integrated model, lack of consistency can cause serious problems in these cases as well.[27] In the soft-link case, failing convergence of the two model parts can result at the technical level. At the level of the interpretation of results, both in the soft-link and the one-way-linkage cases, spurious effects can be the consequence. Data discrepancies that are somehow transferred from one module to the other (and thus implicitly eliminated) then seem to be scenario results (for further discussion, see Bourguignon and Savard, 2008).

The two most common data inconsistency issues are: (i) Inconsistency at the level of the individual income balances (income does not equal expenditure plus savings), and (ii) inconsistency between micro and macro information about consumption shares, savings rates, income shares (labor income, capital income, transfers) and/or skill (or other labor) types.

In the first case, data must be adjusted at the level of the individual households so that the individual income balances hold. In the second case, in addition to adjustment at the individual level, there is a second option. We can leave the individual household data as they are, but introduce some aggregate entity ("residual household"), which makes up for the discrepancy. For concreteness, consider the case in which the share of capital income in the household dataset is smaller than in the national accounts. Then we can either shift some income from labor to capital at the level of the individual households. Or we can inflate the micro module to the point where macro labor income is met and introduce a residual capital income recipient for the rest. This approach has been chosen, for example, in Arntz *et al.* (2008).

Data adjustment is always highly context dependent so that it is not possible to derive general rules to be followed. This remains a task where expert judgement is required, including profound knowledge both of the background of the data, the model

26 See Robilliard and Robinson (2003) for a general discussion of this point and for a specific proposal how to deal with inconsistencies.

27 This kind of problem is usually not well documented. If a consistency problem arises in a concrete study, the data is corrected, but this is normally not an issue focused on. If there is a problem that happens to escape the modelers, inconsistent results are reported, but it is almost impossible for a reader or reviewer to discover this. Thus, all the evidence we have is discussions among active modelers who alerted us to possible inconsistencies at this point.

mechanisms and the aim of the modeling project. Some—maybe obvious but still rather vague—guidelines for data adjustments are:

- Keep the data you consider most reliable and adjust the rest. Normally, it is reasonable to assume that national account data have been prepared in a way that warrants consistency according to internationally agreed principles. Thus, we will over-ride national account information by information from micro datasets only if there is a strong reason.
- Adjust the data so that the implied changes interfere as little as possible with the aim of the study. Try to avoid adjustment of variables that are key to the policy shock analyzed or to the interpretation of the results.
- Use simple methods of adjustment (straight multipliers) as long as there are no strong reasons for complex mechanisms (cross entropy estimation as in Robilliard and Robinson, 2003).[28]
- Adjust large quantities rather than small ones, in order to avoid large relative changes.

Needless to say that these guidelines can easily interfere with and contradict one another so that, ultimately, they cannot replace expert judgement.

26.3.4 Household-specific expenditure structures

Our main interest is in aspects of household disaggregation that are directly related to labor market outcomes. However, households may also differ in other respects, and this must be kept in mind when working with a labor supply module, either at the level of several representative households or at the level of individual households in microsimulation.

26.3.4.1 Household-specific savings

If micro datasets contain information about income spending, we can work with household-specific savings rates in the CGE setup, either with representative or individual households. In a static setting, this does not cause any additional complications. The individual savings must only be aggregated to macroeconomic savings. If the model is set up as a (recursively) dynamic one, however, household-specific capital stocks must be traced through time (see Dixon and Rimmer, 1995, for an example with household-specific savings rates).

The issue becomes considerably more involved once we consider involuntary unemployment in a dynamic setting. As savings (and therefore the dynamically updated capital stock) are dependent on the labor market status (employed or unemployed), current wealth becomes a function of the whole labor market history of the respective household. If unemployment is a stochastic phenomenon with non-zero probabilities for

[28] In our initial example of the share of capital income being too low in the household survey, the Robilliard and Robinson (2003) procedure would imply to give the household with high capital income a higher aggregation weight. Just shifting a constant share of labor income to capital income is a reasonable alternative.

both employment and unemployment, this means that we must keep track of all possible labor market histories. With t periods, this means 2^t possible states per individual and even 4^t for couples, when unemployment can vary independently for both partners. For a larger number of periods, this quickly becomes intractable.

There are two possible approaches to this problem. The first has been intensively explored in forward-looking dynamic modeling, i.e. the conditions under which it is possible to pool savings of the individual households and derive an aggregated savings function. Usually these conditions are rather restrictive and therefore not particularly appealing (Benhabib and Bull, 1983; Krebs and Scheffel, 2010). The second option is stochastic dynamic microsimulation. Here, we give up the ambition to track all possible labor market histories and merely assign each individual a labor market state, depending on the drawing of random numbers. Examples of dynamic microsimulation, even if not in a CGE context, are Merz (1993) and Heckman *et al.* (1998).

26.3.4.2 Household-specific consumption structures

Another dimension where household-specific information on income spending can be used is the consumption structure. This information is often available in micro datasets. A complication implied is that household-specific consumption structures lead to household-specific real wages, which in principle matters when deriving labor supply. However, as long as household consumption structures do not differ dramatically, this effect is unlikely to be large. The error we make by working with a household-independent consumer price index seems tolerable, at least for high-income countries (for income-related consumption structures in the context of a reform of the value added tax, see Boeters *et al.* 2010).

For low-income countries, however, household-specific consumption structures may be relevant, in particular in the context of distributional analysis. Expenditure structures vary strongly between rural and urban households, and between urban poor and urban non-poor (see, e.g. Boccanfuso and Savard, 2011).

26.3.5 Dynamic labor supply

Most of the labor market aspects discussed in this chapter are independent of whether we work in a static or dynamic model. In dynamic models, both recursive and intertemporal, we are faced with additional complications due to the secular trend in labor productivity. Dynamic models are usually calibrated to a steady increase in productivity and real wages over time. Given the labor supply mechanisms implemented in the model, this will in general have long-term effects on hours of work, participation and unemployment. These must be carefully checked for plausibility.

One of the main difficulties in dynamic labor supply theory is the consistency of short-term and long-term reactions. In cross-sections, we normally observe labor supply elasticities that are small, but significantly positive, both at the intensive and extensive margins. Taken at face value, this would mean a secular increase in labor supply, following productivity and real wage developments. However, this is not what we actually observe. Long-term labor supply is almost perfectly stable and at the intensive dimension, labor supply rather falls than rises with the secoral increase in productivity (see Prescott, 1986; Ngai and Pissarides, 2008; Ramey and Francis, 2009, where modern treatments tend to distinguish work, leisure and home production, rather than only work and leisure). One radical answer to this dilemma stems from dynamic modeling, where the use of functional forms is restricted by the requirement to derive explicit expressions. In this context authors often choose a Cobb–Douglas specification of utility, because this produces exactly offsetting income and substitution effects of wage changes (see King *et al.*, 1988; Kimball and Shapiro, 2008). This effectively means giving up the ambition to calibrate utility functions to empirical short-run labor supply elasticities, as described in Section 26.3.1. When working with recursively dynamic models, however, we are less restricted in the choice of functional forms and can search for a specification that allows for labor supply effects in a policy counterfactual without implying a long-term labor supply trend.

A suitable framework for counteracting higher labor supply in the long run is a model of household production (e.g. Benhabib *et al.*, 1991). By introducing productivity of work at home, which follows the productivity change in market work, we can let opportunity costs of working increase over time. When we do not have an explicit representation of household production in our model (as in the specification exposed in Section 26.3.1), we can resort to a short-cut that captures the essence of the home production approach.

For hours-of-work, this short-cut consists in introducing compensatory efficiency increases for leisure, α, in the utility function of the workers, Equation (26.1), when calibrating labor supply (Section 26.3.1.1):

$$U_{\mathrm{e}} = \left[\theta_{\mathrm{C}}\left(\frac{C_{\mathrm{D}}}{\bar{C}_{\mathrm{D}}}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_{\mathrm{C}})\left(\frac{\alpha F}{\bar{F}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}},$$

α may then be adjusted over time in the baseline calibration of the model so that the number of supplied hours remains constant (this makes α increasing over time). Similarly, in the calibration of participation (see Section 26.3.1.4), the distribution of fixed costs of taking up work may be adjusted so as to prevent an endogenous trend in participation. The calibration is repeated for each year, taking the changes in the endogenous model parameters in Equation (26.8) into account and holding the labor supply elasticity at the extensive margin, η_{Nw}, constant.[29] An exogenously given time path of participation rates may be accommodated by adjusting $\bar{N}$ and $\bar{U}_{\mathrm{l}}$ over time in Equation (26.9). A possible

[29] Otherwise, the secular increase in U_{e} would cause an ever-increasing elasticity of labor supply.

interpretation of the resulting shifts in the distribution of fixed costs is a shift in commuting costs due to a changing valuation of time caused by productivity increases.

26.4 LABOR DEMAND

In comparison to the other main themes covered in this chapter—labor supply and labor market coordination—labor demand offers the least conceptual choices. In CGE models, labor demand is derived from sectoral production functions, which are almost exclusively set up as nested CES functions. The challenge in CGE models with a more detailed labor market module is to adjust the production functions in a way that responds to the requirements of the other model components (in particular labor differentiation initiated on the supply side) and does justice to our empirical knowledge about labor demand elasticities.

We have seen in Section 26.3 that there are a large number of motives for distinguishing different types of labor, often originating from distributional analysis. The basic question is whether these types of labor also need to be distinguished on the labor demand side. It is important to realize that we do not have to do so. Any labor differentiation on the supply side can be made undone on the labor demand side by simply adding up all labor (e.g. male and female labor, labor of different age categories) to a uniform aggregate.[30] Even if wages diverge empirically, this need not prevent homogeneous aggregation. We can assume that workers differ by constant labor efficiency factors, which allows us to add up the individually supplied, *efficiency-weighted* hours of work, even if not the raw hours of work. Constant labor efficiency factors mean that wages within an additive labor demand category will change exactly in proportion. The critical question is thus: do we think that proportional wage movements describe a particular labor market segment sufficiently well or are there reasons to believe that relative wages of different subcategories of labor will systematically respond to changes in relative supply or demand? Only in the latter case must we think about how to represent different types of labor in the production function.

26.4.1 Functional implementation of labor demand[31]

Modeling labor demand for a specific set of labor types, we start from a given estimation of labor demand elasticities. The first decision to be taken is what kind of elasticities we want to work with. Labor demand estimations can be reported either in terms of labor demand elasticities or of substitution elasticities. Both are interconnected, but the relation between them can only be made explicit if we know the input value shares

30 For example, Borjas *et al.* (2011) find that similarly skilled immigrants and natives are perfect substitutes in production.

31 This section uses material from Boeters and Feil (2009).

(see, e.g. Hamermesh, 1993, Chapter 2). This creates two follow-up problems: (i) Many labor demand estimations do not report value shares so that we cannot compute substitution elasticities from demand elasticities or *vice versa* and (ii) in general, the value shares in the estimation will deviate from the value shares in the datasets used to set up the CGE model. So we either have to use the type of elasticity we can extract from the empirical study or—if the empirical study leaves the choice open—we must decide which type of elasticity we treat as more fundamental. These fundamental elasticities are then taken from the study and the other type of elasticity is derived, using the value shares from the model. At the end of Section 26.4.3, we motivate the choice of labor demand elasticities as the empirical basis for calibrating CGE models.

Take as a concrete example Falk and Koebel (1997), who estimate labor demand elasticities for five production sectors in Germany, using a Translog production function with five inputs: three skill classes of labor (low-, medium- and high-skilled), capital and materials. The result is a full matrix of estimated cross-price elasticities. Assume that we try to approach these empirical results with a conventional, separable, nested CES function as in Figure 26.1. Value added is split into the contributions of low-skilled labor and an aggregate of non-low-skilled labor and capital in the upper-level nest. At a second level, capital is split off, and finally, medium and high-skilled labor are separated. Such a setup can account for stylized patterns of substitution elasticities, in particular the well-known capital–skill complementarity (Fallon and Layard, 1975), but it is not flexible enough to represent full matrices of estimated cross price demand elasticities.

In the production structure of Figure 26.1, we end up with four free parameters (elasticities of substitution at various levels of the production tree) to be calibrated. However, a fully flexible structure, such as the one estimated by Falk and Koebel (1997), features at least 10 independent elasticities of substitution: a 5×5 matrix where 10

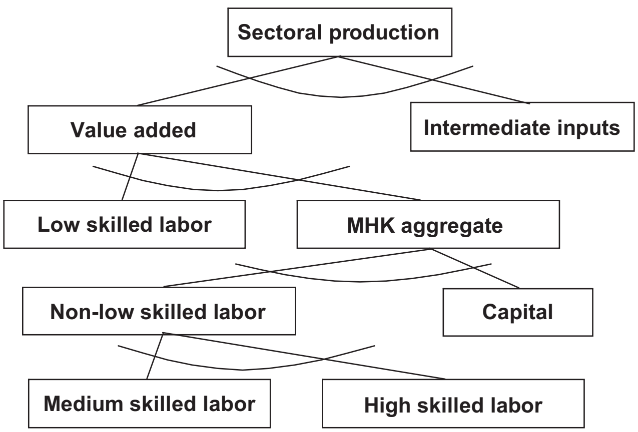

Figure 26.1 Separable, nested CES function.

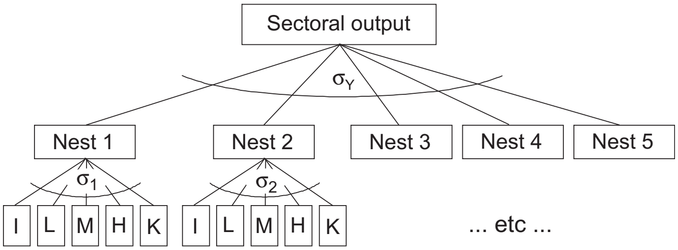

Figure 26.2 NNCES setup of production function.

elements are mirror images of the opposite side and five elements are linearly dependent on the other entries in the same row or column.

The NNCES (non-separable, nested CES) approach to production function calibration (Pollak and Wales, 1987; Perroni and Rutherford, 1995, 1998) increases the flexibility of the nested CES framework through an extension to more generic forms. Other flexible forms known from econometric tradition (Translog or Diewert) can locally represent arbitrary production or cost functions as well, but they typically do not exhibit global regularity (the corresponding cost function must be non-decreasing and concave in prices). This can cause computational problems in CGE models (Perroni and Rutherford, 1995).[32]

The basic idea behind the NNCES function is that each factor of production may enter the production function at more than one single place (therefore "non-separable"). A typical setup is depicted in Figure 26.2: sectoral output is decomposed into five subnests, each of which then in turn contains input from all factors: intermediate inputs ("I"), the three skill types ("L," "M," "H") and capital ("K"). Flexibility is increased not only by a larger number of elasticity parameters (six), but also because the split of each production factor into the individual subnests can be chosen freely.

This is now the exact opposition of the problem we had before: instead of too few parameters, we have too many. We have 26 free parameters at hand (six elasticities and four free share parameters for each factor) for producing a match between the model and the 10 exogenous elasticities. To resolve the resulting indeterminacy, it has been proposed to restrict certain elasticities to zero or one (Pollak and Wales, 1987) or to add a penalty function. A plausible goal for the calibration is to limit the dispersion of input factors across several nests and to restrict the absolute value of the elasticities of substitution. With a penalty function of this sort, the approach can be expressed as:

$$\min \mathrm{P} = (\sigma_Y)^2 + \sum_n (\sigma_n)^2 - \sum_{n,i} \left(\theta_n^i\right)^2$$

32 Nevertheless, other functional forms can be found in the literature. For example, Dixon *et al.* (1992, pp. 133–137) work with an explicit Translog function for labor demand. Apparently, practical problems with calculation are less severe than the theoretical arguments in Perroni and Rutherford (1995) suggest.

$$\text{s.t.} \quad \eta_{ij}/\theta_j^Y = \sigma_Y + \sum_n (\sigma_n - \sigma_Y)\ \frac{\theta_n^i \theta_n^j}{\theta_n^Y}$$

$$\theta_n^Y = \sum_i \theta_i^Y \theta_n^i$$

$$1 = \sum_n \theta_n^i,$$

where i and j are indexes for the factors of production and n is an index for the nests at the intermediate level ("Nest 1," etc., in Figure 26.2). The θ_n^i are the shares of the individual nests in the total amount of factor i, θ_n^Y is the share of the respective nest in total sectoral output. The own- and cross-price elasticities, η_{ij}, as well as the aggregate value shares, θ_i^Y, are exogenous to the calibration. σ_Y, the σ_ns and the θ_n^is must be determined by minimizing the penalty function. An implementation of this approach for Germany can be found in Boeters and Feil (2009).

26.4.2 Dimensions of labor demand heterogeneity

Here, we review the multiple dimensions of labor heterogeneity that have led to specific labor demand categories in applied modeling. Partly, these dimensions overlap with those of labor supply, discussed in Section 26.3.2.1. However, on the labor demand side, different aspects are relevant. In particular, it is more challenging to justify a particular labor split. In the following, we report the dimensions of labor demand heterogeneity encountered in the literature and we check to what extent they can be backed up with empirical estimates of labor demand elasticities. After discussing the dimensions one-by-one, we turn to additional issues that arise once we combine several dimensions in a single production function (Section 26.4.3).

26.4.2.1 Skill type

The most prominent decomposition of labor is along the skill (or qualification) dimension. The distinction of two skill types (skilled and unskilled or qualified and non-qualified) has a long tradition in the discussion about raising wage differentials and skill-biased technological change (see, e.g. Berman *et al.*, 1998). This split can be found in many CGE models, even if they do not focus on labor market issues, simply because it is implemented in the GTAP dataset (Dimaranan and Narayanan 2008). With two types of labor, the simplest way of value-added modeling is a one-level structure, where capital services and the two types of labor are included with a single elasticity of substitution. An example is the GTAP model (Hertel *et al.*, 2008), where sector-specific elasticity estimates from Jomini *et al.* (1994) are used. Other papers with a two-skills split and a similar specification are Böhringer *et al.* (2005) for Germany, Boccanfuso and Savard (2008) for Senegal, and the global WorldScan model (Lejour *et al.*, 2006).

A potential advantage of labor split into the two standard skill types (i.e. low- and high-skilled, with college degree, or a national analogue, as the demarcation line) is the availability of advanced labor demand estimations. We can draw upon an established literature on the substitution possibilities between low-skilled labor, high-skilled labor and capital (e.g. Griliches, 1969; Fallon and Layard, 1975; Krusell *et al.*, 2000). However, these results are not often used for the specification of existing CGE models. Exceptions are Agénor *et al.* (2003), if only qualitatively, and Rojas-Romagosa (2010), who revises the value-added modeling in WorldScan.

Labor splits into more than two skill categories can be regularly found in existing models, but they are more difficult to back up with elasticity estimates from the literature. Löfgren (2001) uses four skill categories, without any substitution possibilities (Leontief specification). Maisonnave *et al.* (2009) have three categories, with a Cobb–Douglas specification. Models that use an empirical specification are Boeters and Feil (2009) (with the NNCES approach described in Section 26.4.1) and MIMIC (Graafland *et al.*, 2001, p. 11). Interestingly, in the estimations used for the specification of MIMIC, capital–skill complementarity is rejected for the Netherlands.

26.4.2.2 Occupation

The classification by occupation is a close substitute for skill. The choice between these two options may be driven by data availability, in particular when internationally comparable data are needed (Boeters and van Leeuwen, 2010). In some models, occupation and skill characteristics are combined in the labor segmentation (e.g. Carneiro and Arbache, 2003; Colombo, 2008). Giesecke *et al.* (2011) present an ambitious setup for the Vietnamese economy, which cross-classifies skill (qualification) and occupation. Labor demand of firms is formulated primarily in terms of occupations, which, in turn, are decomposed by skill. Households, on the other hand, are primarily defined by skill and supply occupation-specific labor according to the transformation mechanism presented in Section 26.3.1.5.

26.4.2.3 Full-time and part-time labor

Hutton and Ruocco (1999) are concerned with the prevalence of part-time work among women. This motivates them to distinguish between part-time and full-time work as imperfect substitutes in production. They report no estimation results for the elasticity of substitution between these labor types and use a Cobb–Douglas structure in their model. There is some empirical work trying to determine the substitutability between workers and hours (for an overview of the earlier literature, see Hamermesh, 1993, pp. 127–134), but it has not been used in a CGE context yet.

26.4.2.4 Formal and informal labor

The distinction between formal and informal work can be found in many CGE models. There are different motivations for making this explicit in a model: productivity differentials between the formal and informal sector, wage differentials between workers in the two sectors, and a differential treatment in taxation (see Section 26.5.5 for a detailed discussion). Problems of labor demand modeling do, however, not arise in most cases, because formal and informal labor is used in separate sectors. The question of substitutability between formal and informal work then shifts to the substitutability between formally and informally produced goods and services in consumption. Only models with highly aggregated production sectors have both formal and informal labor in the same production function. An example is MIMIC (Graafland *et al.*, 2001, p. 110), using estimations of Baartmans *et al.* (1986) for calibration.

26.4.2.5 Rural and urban labor

Similar to the formal/informal distinction, the rural/urban divide is mostly a sectoral one, with different sectors demanding labor in the rural and urban area. An exception is Hendy and Zaki (2010), who allow for both rural and urban labor as input in each sector. The elasticity of substitution is chosen without reference to an empirical study.

26.4.2.6 Gender

The gender decomposition of labor in CGE models has become more widespread, driven by the rising interest in the gender dimension of inequality and the recognition of the special role women play for economic development. The gender decomposition has been introduced to the literature by Fontana and Wood (2000), followed by Fofana *et al.* (2003), Fontana (2004), Colombo (2008), and Hendy and Zaki (2010).[33] As with other dimensions of decomposition, the empirical foundation is a problem. Fontana and Wood (2000) do not base their specification on empirical estimations, but argue qualitatively for relatively low elasticities "to reflect the rigidity of gender roles" (p. 1179). As those roles are highly varying across countries and in many cases also over time, it is not likely that deep substitution parameters can be identified through econometric techniques.

26.4.2.7 Ethnicity

A more recent and less common decomposition is by ethnic group, where the specific delineation of groups is country-specific. Maisonnave *et al.* (2009) use an ethnic decomposition into African, Colored, Indian and White in a model of the South African economy. In the case of Israel, Flaig *et al.* (2011) use the ethnic/nationality categories Jewish and non-Jewish, Israeli and non-Israeli, Palestinians and foreigners. In both cases,

[33] An early predecessor is Dixon *et al.* (1978), who analyze the economic consequences of an exogenous increase of relative female wages.

the substitution elasticities are chosen *ad hoc*. Maisonnave *et al*. (2009) assume that there is no substitution possible (Leontief specification). The elasticities in Flaig *et al*. (2011) have been set relative to the GTAP skilled/unskilled substitution elasticity, based on expert judgement.

26.4.3 Labor heterogeneity in several dimensions

In Section 26.4.2, we have presented possible dimensions of labor demand separately. Many of the papers discussed do not only deal with one dimension, but with labor heterogeneity in two or more dimensions. Once we have more than a single dimension, we must think about the structure of the production function. The following options have been used in the literature:

- Cross-classifying all dimensions, deleting irrelevant combinations (if necessary) and organizing all categories of labor in a single CES nest. This approach has been chosen by Colombo (2008), who has a $2 \times 2 \times 2$ classification of skill, occupation (self-employed, waged workers) and gender. Carneiro and Arbache (2003) use a non-exhaustive cross-classification of formal/informal, three skill types, rural/urban and civil servants in a one-level nesting.
- There are is a considerable number of examples where multilevel CES structures are used for different dimensions of heterogeneity. Flaig *et al*. (2011) combine two skill types at the upper level with ethnicity/nationality at the lower level. Hendy and Zaki (2010) use a CES production function with three levels: urban and rural workers at the upper level, male and female work at the intermediate level, and skilled and unskilled labor at the lowest level. Maisonnave *et al*. (2009) decompose three skill types at the upper level (Cobb–Douglas specification) and four ethnicities at the lower level (Leontief specification). The dimensions in Dixon and Rimmer (2003) are occupation and two aspects of entitlement in a low-wage policy proposal, and in Dixon *et al*. (2011) occupation, legal status and place of birth.

Apart from the problem of finding labor demand parameters at all (in most of the studies reviewed, elasticities of substitution are merely guessed), with several dimensions of heterogeneity, we are faced with the problem of the nesting hierarchy. Which types of labor should be grouped into a nest at a higher level and which at a lower level? Traditionally, a loose convention has established that factors of production that are close complements are grouped together at a low level of the nesting, whereas factors that are good substitutes are combined at a higher level (i.e. higher levels of the nesting have higher values of the elasticity of substitution than lower levels). There is no empirical reason for such a convention. Ultimately, the only criterion that counts is which nesting fits the data best. In the case of KLEM estimations, there have been studies that compare different CES nestings with regard to their empirical performance (e.g. van der Werf, 2008). We do not know, however, of any comparable study in the field of

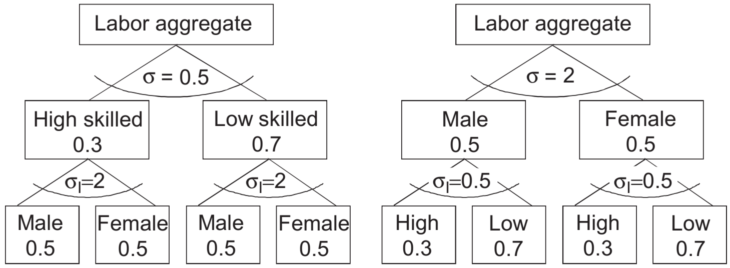

Figure 26.3 Two-level nesting options.

labor demand estimations. Here, the estimation techniques are rather dominated by flexible functions, which are a candidate for direct implementation in CGE models (see Section 26.4.1).[34]

When deciding for a multilayer CES structure, modelers are left with the question of how to set up the nesting. Let us take an optimistic case and assume that some estimates (or guesstimates) of elasticities of substitution between different varieties in each dimension are available. It is important to realize that the same elasticities of substitution, if implemented in a different nesting structure, can lead to different demand elasticities. In a two-level nesting structure as in Figure 26.3, the own-price elasticity of factor of production i is:

$$\eta_{x_i p_i} = -\sigma_{\mathrm{I}}(1-\theta_{i\mathrm{I}}) - \sigma(\theta_{i\mathrm{I}} - \theta_i), \tag{26.13}$$

where σ and σ_{I} are the elasticities of substitution at the upper and lower level, respectively, θ_i is the value share of factor i, and $\theta_{i\mathrm{I}}$ is the value share of factor i in its relevant subnest. For concreteness, let us distinguish between high/low-skilled and male/female workers. The value share of high-skilled work is 0.3, and within each skill class, male and female workers have the same share of 0.5. Elasticities of substitution are 0.5 between skill groups and 2 between genders. The two nesting options are given in Figure 26.3. For the own-price demand elasticity for low-skilled male work, we obtain:

$$\eta_{\mathrm{LM}} = -2 \times (1-0.5) - 0.5 \times (0.5 - 0.35) = -1.075$$

$$\eta_{\mathrm{LM}} = -0.5 \times (1-0.7) - 2 \times (0.7 - 0.35) = -0.85,$$

for the left and right panel of Figure 26.3, respectively. This is a significant difference.

This is another example of the general phenomenon discussed in Section 26.4.1: There is no one-to-one relationship between elasticities of substitution and

[34] A recent example for a flexible-form labor demand estimation with several dimensions of labor heterogeneity (skill, age and type of employment contract) is Bargain *et al.* (2011a).

elasticities of demand. We need to answer the question of which of these parameters —elasticities of substitution or elasticities of demand—we want to consider as more fundamental. General equilibrium economists tend to focus on the elasticities of substitution. Researchers working on the substitution possibilities between capital, high- and low-skilled labor (e.g. Krusell *et al.*, 2000) have tried to identify the relevant elasticities of substitution, not elasticities of factor demand. On the other hand, labor market economists are often interested in labor demand elasticities as an ingredient to a partial labor market model (see Peichl and Siegloch, 2010). In principle, this question of which elasticity is more fundamental could be approached empirically. What is needed are comparative labor demand estimations with different datasets (implying varying value shares). This would allow us to address the question: which estimated parameters are more stable across datasets—elasticities of substitution or demand elasticities? However, we do not know of any empirical study approaching the issue from this angle.

In the absence of an empirical guideline, we tend to favor elasticities of demand as the more fundamental ones. After all, demand elasticities are the elasticities that are most directly linked to empirically relevant results (e.g. "By how much must the wage fall to induce absorption of a certain change in labor supply?"). This is a point in favor of treating labor demand elasticities as fundamental and calibrating elasticities of substitution (conditional on the given value shares) so that the demand elasticities are met (as in Section 26.4.1 in the case of the NNCES function).

26.5 LABOR MARKET COORDINATION

26.5.1 Scope of the market

Determining the scope of a labor market in a CGE model, i.e. delineating the individuals under a uniform labor market regime, touches upon a number of issues that are hardly ever explicitly discussed in economics texts. This is because they tend to fall in-between the major fields of theoretical and empirical work. In theory papers, it is customary to merely *postulate* how many and which markets are to be distinguished. Empirical labor market economists, in contrast, take multidimensional heterogeneity at face value. This becomes apparent in multiple regression analysis, the very point of which is to filter out the effects of as many dimensions of heterogeneity as possible. The question of how to delineate labor markets does not arise naturally in either the purely theoretical or the purely empirical context. In applied modeling, however, this question imposes itself on the model builder. It is often answered in an implicit way, which remains silent about other options and about the consequences of a particular choice. Here, we want to make the relevant issues more explicit.

By the criteria reviewed in Sections 26.3 and 26.4, both labor supply and labor demand are potentially differentiated in several dimensions. The follow-up question is about whether, and to what extent, this differentiation is to be transferred to labor market coordination. There are two extreme options to decide this question: (i) A large number of very narrowly defined labor markets with an independent wage rate in each of them or (ii) a single labor market, in which the sum of all supply and demand is coordinated. In practical modeling, labor market differentiation is most often driven by the supply rather than the demand side. Model builders are motivated, either by distributional concerns or by the design of the policy instrument, to distinguish between different types of workers (e.g. by gender, age or skill level), and impose this distinction on labor demand and labor market coordination as well.

It is a basic point to be kept in mind, however, that we do not have to differentiate between labor markets simply because we have decided to distinguish between different types of labor. Treating different types of labor as homogeneous inputs and aggregating them in a single market with a uniform wage is a perfectly viable option. Naturally, wage differentials between individuals are an empirical fact, which is, *prima facie*, not compatible with a homogeneous market. However, there are at least two simple mechanisms—both discussed in a CGE context by Boadway and Treddenick (1978) already—that allow us to work with a uniform market model in spite of existing wage differentials. The first of these mechanisms is efficiency weighting. Individuals with higher hourly wages are assumed to supply more effective units of labor per hour than low-wage individuals. Weighting with individual-specific efficiency factors derived from the wages, we can simply add up labor supply of heterogeneous individuals. Assuming efficiency factors to be constant implies that wages of different individuals in one market move precisely in proportion, leaving relative wages unchanged.

The second mechanism for accommodating wage differences without separating markets are compensating wage differentials, typically applied to sectoral wages. Jobs in different sectors are associated with varying non-pecuniary conditions such as riskiness of the job or agreeableness of the work sphere. Under intersectoral mobility of workers, differences in observed wages can be rationalized by assuming that lower wages are compensated by non-pecuniary benefits so that, taken as a package, job opportunities are equally attractive for workers across sectors.[35] Simple and well-established as this idea is, it may create follow-up problems in modeling: (i) Non-pecuniary benefits contribute to household utility and must be accounted for when performing a welfare analysis. (ii) As a contribution to household utility,

[35] It is a considerable empirical challenge in itself to determine what share of observed sectoral wage differentials is attributable to a different composition of the work force and what share remains as a pure sectoral wage differential. It has repeatedly been shown that neither of these shares is negligible (see, e.g. Slichter,1950; Krueger and Summers, 1988; Genre *et al.,* 2011).

non-pecuniary benefits might have an income effect on labor supply.[36] (iii) If there is involuntary unemployment, this is an additional factor contributing to the relative attractiveness of sectors (see Section 26.5.5).[37]

The crucial empirical question for labor market differentiation is whether wages of different groups of workers move in parallel (with appropriate constant adjustment factors) or not. This question arises almost exclusively in the modeling context, once we want to determine whether market segmentation is appropriate or not. Thus, it is no surprise that it has not been addressed in existing empirical labor market studies, with the exception of the wage differential between skilled and unskilled workers. For other potential labor market segmentations original empirical research is required. A case in point is gender-specific labor markets. There is a growing literature interested in gender-specific labor market consequences of various policy shocks (e.g. Fontana and Wood, 2000, Fofana *et al*., 2003, Hendy and Zaki, 2010). These studies assume that there are separated labor markets for men an women, but they do not provide empirical evidence supporting an independent movement of gender-specific wages. If such evidence exists, it could considerably strengthen the modeling setup.

Another basic point to be kept in mind is that homogenizing forces on *one* side of the market, either supply or demand, are sufficient for the constitution of a homogeneous labor market. If labor is perfectly *transformable* between different categories (see Section 26.3.1.5), this will create a uniform labor market, because any potential wage differential would provoke labor supply adjustments that cause wages to equalize. The most relevant case is sectoral labor mobility. In almost all other dimensions of labor supply heterogeneity (gender, age, skill), transformation options are limited, if existent at all. The mirror image of a labor market homogenizing effect can arise at the labor demand side. Once two types of labor are perfectly substitutable in production, any difference in the wages will disappear. While it is standard in labor demand modeling to assume imperfect substitutability of skill types, the case with other dimensions of labor heterogeneity (gender, age, hours of work) is much more complex. Clearly, the burden of proof is with those that claim imperfect transformability in these cases (see Section 26.4.2).

A special constellation to be mentioned is one-way transformation or substitution, which causes asymmetry between labor market segments. An example is the dual labor market model of Harris and Todaro (1970), discussed in Section 26.5.5, where workers who do not find a job in the formal sector can always retreat to the informal sector, but

36 In Böhringer *et al*. (2005) this effect is included in the following way: labor supply responds, not to the wage *per se*, but to the value of a job. The value of a job, in turn, is equal across sectors and composed of three components: wage, non-pecuniary benefits and unemployment risks.

37 The approach of Devarajan and Rodrik (1991) remains somewhere half-way in this compensating differential story. They assume sector-specific efficiency factors that are calibrated to match intersectoral wage differentials. However, they do not address the question of what prevents all workers from switching to the highest paying sector.

not in the opposite direction. Another asymmetry pattern is plausible in the demand for skills. There are many low-skilled tasks that can without a problem be taken over by high-skilled workers, if necessary—but not inversely.

26.5.2 Wage-forming mechanism

The vast majority of CGE models have worked with one or both of the two extreme assumptions about wage formation: flexible, market-clearing wages and institutionally fixed wages. In the market-clearing setup, competition on both sides of the labor market is assumed so that wages equilibrate demand and supply, and there is no involuntary unemployment. In contrast, in the fixed-wages setup, wages do not respond to changes in supply or demand conditions. Labor supply and demand are determined given a fixed level of wages, and the resulting difference is interpreted as involuntary unemployment.

Simple as it seems, the fixed-wages setup is not without difficulties in a CGE context. Actual wage contracts are usually fixed in nominal terms. In general, however, nominal prices are undetermined in CGE models, since only relative prices have significance. If we nevertheless fix a nominal wage in our CGE model, what we essentially do is fix a real wage in terms of the numéraire of the model.[38] We consider it to be good modeling practice to make the fixation of real wages explicit and not implicit through the choice of a numéraire.[39] If the domestic consumer price index (CPI) is chosen to be the numéraire, the fixation of nominal wages may well be plausible, because explicit or implicit indexation of wages to consumer prices is a common phenomenon.[40] However, it is not in all cases that the CPI acts as numéraire. In many applied one-country models of small open economies this role is taken by the export and import prices. Then fixing a nominal wage means that the wage is indexed to foreign prices, which is implausible, except if it is an explicit institutional feature of the economy modeled.

Fixing real wages is the simplest possible way of accounting for labor market rigidities and involuntary unemployment. However, being simple means being restrictive as well. Even if we take it for granted that there are institutions fixing the real wage, this fixation will hardly be absolute. At least in the medium and long run, wages do adjust to labor market conditions, even if subject to longer lasting contracts. Thus, the next plausible step is to think about *which* labor market conditions will drive the wage adjustment and *how* the adjustment takes place.

In general, any in-between modeling of labor market rigidities will have the form of a "wage curve." Understood in a broad sense, this is any locus off the labor supply curve

[38] We have come across CGE papers where the authors apparently confused fixing the wage as an institutional feature of the labor market and using it as the numéraire of the model.

[39] The numéraire choice is often not reported in the model description, just because it is assumed to be arbitrary. In this case the fixation of nominal wages becomes a black-box phenomenon.

[40] This is explicit, for example, in Dixon *et al.* (1978), Corden and Dixon (1980), and Dixon *et al.* (1982).

whose intersection with labor demand determines the wage, thus replacing labor supply in this function. There are two principal approaches to the construction of a wage curve. The first one is empirical. We start from the observed situation and try to determine the factors driving changes in the wage econometrically. The result of the estimation is then implemented as an empirical wage curve in the model (for an overview, see Folmer, 2009). The "wage curve" (in a narrow sense) of Blanchflower and Oswald (1995) is the best known example of this approach. Blanchflower and Oswald find an empirically astonishingly stable relationship between the level of unemployment and the wage (see our extensive discussion in Section 26.5.6). Two examples of models that include the unemployment-wage relationship (and *only* this) explicitly as one of the equations are Hutton and Ruocco (1999) and Maisonnave *et al.* (2009). In the MIMIC model (Graafland *et al.*, 2001, p. 125), the wage depends, in addition, on the average and marginal labor tax rates.

For setting up a wage curve to be empirically estimated, we need to determine the variables that are candidates for inclusion in the equation. Usually, this is done based on a structural model of wage determination in imperfectly competitive labor markets, which brings us to the second approach to the wage curve. There are three theories that have been used in this way: search and matching (Pissarides, 1990), efficiency wages (Shapiro and Stiglitz, 1984) and collective wage bargaining (McDonald and Solow, 1981). By establishing a wage that is above the market-clearing level, these theories cover at the same time the phenomenon of involuntary unemployment. As theories of unemployment they are discussed in Section 26.5.3.

The attempts to determine the empirical content of these structural theories of wage formation may be classified into two strands. In the first dominant type of literature, the theories are used to derive empirical wage curve specifications, which are then used to generate elasticity estimates (as reviewed in Folmer, 2009). In the second type of literature (Pissarides, 1998; Sørensen, 1999), the focus is on the structural parameters in each of the theories. These are identified and given empirically plausible values. Our review in Section 26.5.3 follows the second approach and pays particular attention to the question of how this fits in with the stylized fact of Blanchflower and Oswald's wage curve.

26.5.3 Involuntary unemployment

Pissarides (1998) and Sørensen (1999) show how the most prominent options of modeling unemployment—search and matching, efficiency wages, and collective bargaining—are calibrated and implemented in a simple CGE context. We start by briefly reviewing the core ideas of the three options, before going into more detail in Sections 26.5.3.1—26.5.3.3.

The *search-and-matching model* starts from the core assumption that finding a job is a time- and effort-consuming process, the more so the less vacancies there are. Similarly, posting a vacancy is costly and not worth the effort if there are no unemployed workers to be found. Therefore, a certain level of unemployment is necessary to keep the process of continuous reallocation of jobs running. The level of unemployment is determined by structural parameters of the labor market, such as the efficiency of the matching process.

Search-and-matching models exist in a vast number of varieties, which is partly due to the fact that they lend themselves conveniently to empirical estimation with micro data. The model varieties differ in several aspects: whether there is on-the-job search or not, how wages are determined once a match materializes, and whether jobs and/or workers are homogeneous or heterogeneous in productivity. However, only the most simple of these varieties have been used in a CGE context.

The core idea of the *efficiency wage model* is that employers can increase the productivity of workers by paying wages that are above the market-clearing level. There are several versions of the precise productivity-increasing mechanism. In the original version the market-clearing wage is below the subsistence level of workers so that only higher wages allow workers to reproduce their working skills (Leibenstein, 1963). In other versions of the story higher wages increase the motivation of workers ("gift exchange," Akerlof, 1982) or they create unemployment so that firing workers becomes a serious threat that deters workers from shirking ("unemployment as a worker disciplining device," Shapiro and Stiglitz, 1984). In any case, the formal theory starts from an efficiency curve, which gives work efficiency as a function of the (relative) wage. For the empirical implementation, the story behind this efficiency curve is not strictly necessary.

The *collective wage-bargaining model* formalizes the idea that wages result from negotiations between firms' associations and trade unions. The crucial idea is that part of the social costs of higher wages and resulting unemployment are externalities not borne by the bargaining parties in a particular sector, but by society as a whole (through unemployment benefits financed by general tax revenue or social security contributions). This externality induces the bargaining parties to go for wages that are above the market-clearing level.

In the case of bargaining theories, as well, we have quite a few subvarieties: right-to-manage versus efficient bargaining, insider model versus utilitarian union, bargaining over wages only versus bargaining over wage/hours-of-work packages, monopoly union versus two bargaining parties. However, the differences between these varieties become small, or even irrelevant, once the model is calibrated to the actual unemployment rate. For the case of the insider model versus utilitarian union model this is shown in Boeters (2011).

Even if we tend to use a structural model for the implementation of involuntary unemployment, we are left with the difficult question of which one to use. All mechanisms sketched above have their plausibility, albeit to a different degree in different segments of the labor market. The search-and-matching mechanism is certainly an important element in any convincing explanation of unemployment. However, one can doubt whether this is the whole story. It characterizes unemployment mainly as a transitory phenomenon and downplays long-term, structural effects. The efficiency–wage approach is right in stressing the disciplining effect of unemployment, but one can doubt whether work effort would actually drop to zero without unemployment, as the shirking theory implies. Finally, the relevance of collective bargaining for wage formation is mainly determined by the concrete institutions of the country in question. It is considerably higher for continental Europe and Scandinavia than for the Anglo-Saxon countries.

In the following sections, we present simple formalizations of the three basic approaches. We also discuss how, and to what extent, they can be given an empirically meaningful interpretation in a CGE context.

26.5.3.1 Search and matching

The core element of any search-and-matching model is the matching function, which gives matches, M, as a function of the number of unemployed workers, U, and vacancies, V. A Cobb–Douglas specification with efficiency parameter μ and share parameter ε $(0 < \varepsilon < 1)$ reads:[41]

$$M = \mu U^{\varepsilon} V^{1-\varepsilon}.$$

It is convenient to define "labor market tightness," θ, as an additional variable:

$$\theta \equiv V/U,$$

and express the probabilities of finding a job, a, and filling a vacancy, q, as:

$$a \equiv M/U = \mu\theta^{1-\varepsilon}$$

$$q \equiv M/V = \mu\theta^{-\varepsilon}.$$

There are two different labor market states for workers: employed (index E) and unemployed (index U). With instantaneous utilities U, discount rate ρ and exogenous separation rate s for existing jobs, the following recursive value equations can be formulated, where J^i is the value of being in state i:

$$\rho J^{\mathrm{E}} = U^{\mathrm{E}} - s\left(J^{\mathrm{E}} - J^{\mathrm{U}}\right)$$

$$\rho J^{\mathrm{U}} = U^{\mathrm{U}} + a\left(J^{\mathrm{E}} - J^{\mathrm{U}}\right).$$

Analogously, on the part of the firm, jobs can be either occupied (index O) or vacant (index V). With job productivity[42] p, labor cost w and vacancy cost γ, we have:

[41] The material of this section follows closely the expositions in Pissarides (1998) and Sørensen (1999).
[42] Productivity is endogenous in a general equilibrium context, but it remains exogenous for the individual firm.

$$\rho J^{\mathrm{O}} = p - w - s\left(J^{\mathrm{O}} - J^{\mathrm{V}}\right)$$

$$\rho J^{\mathrm{V}} = -\gamma + q\left(J^{\mathrm{O}} - J^{\mathrm{V}}\right).$$

Finding a match for a vacant job creates a rent, which needs to be shared between firm and worker. A simple sharing rule is Nash bargaining, which is formalized as the maximization of a Nash function containing the weighted product of the individual shares, $J^{\mathrm{E}} - J^{\mathrm{U}}$ for the worker and $J^{\mathrm{O}} - J^{\mathrm{V}}$ for the firm. In logs and with λ as the relative bargaining power of the worker, Nash bargaining can be formulated as:

$$\max_{w}\left[\lambda \log\left(J^{\mathrm{E}} - J^{\mathrm{U}}\right) + \log\left(J^{\mathrm{O}} - J^{\mathrm{V}}\right)\right],$$

where the bargaining parties treat and J^{U} and J^{V} as exogenous. This gives the following first-order condition:

$$\lambda \frac{\mathrm{d}U^{\mathrm{E}}}{\mathrm{d}w}\left(J^{\mathrm{O}} - J^{\mathrm{V}}\right) - \left(J^{\mathrm{E}} - J^{\mathrm{U}}\right) = 0.$$

Substitution of the state value variables, observing the free-entry condition, $J^{\mathrm{V}} = 0$, brings us to:

$$\frac{\mathrm{d}U^{\mathrm{E}}}{\mathrm{d}w}\lambda\gamma(\rho + s + a) - q\left(U^{\mathrm{E}} - U^{\mathrm{U}}\right) = 0.$$

If utility is linear in consumption, we have:

$$\frac{\mathrm{d}U^{\mathrm{E}}}{\mathrm{d}w} = 1 - t^{\mathrm{m}}$$

$$U^{\mathrm{E}} = (1 - t^{\mathrm{a}})w$$

$$U^{\mathrm{U}} = c(1 - t^{\mathrm{a}})w,$$

where t^{m} and t^{a} are the marginal and average tax rates on labor income, and c is the replacement rate (unemployment benefit as a share of after-tax labor income). Then we have:

$$(1 - t^{\mathrm{m}})\lambda\gamma(\rho + s + a) - q(1 - c)(1 - t^{\mathrm{a}})w = 0,$$

and w can be expressed as a markup on the cost of a vacancy, γ:

$$w = \frac{(1 - t^{\mathrm{m}})\lambda(\rho + s + a)}{q(1 - c)(1 - t^{\mathrm{a}})}\gamma. \tag{26.14}$$

As long as the institutional parameters—λ, c and the tax rates—are constant, the markup factor depends positively on the probability of finding a job, a, and negatively on the probability of filling a vacancy, q. In the dynamic equilibrium,[43] inflow to and outflow from unemployment must be the same, which means:

$$au = s(1-u),$$

and can be used for replacing a in Equation (26.14):

$$w = \frac{(1-t^{\mathrm{m}})\lambda\left(\rho + \dfrac{s}{u}\right)}{q(1-c)(1-t^{\mathrm{a}})}\gamma. \tag{26.15}$$

This is a wage curve in the narrow sense, because it gives us the wage, w, as a decreasing function of the unemployment rate, u.

26.5.3.1.1 Calibration

The calibration of the search-and-matching model to empirical wage curve elasticities turns out to be a problem. Taking logs on Equation (26.15) and calculating the partial derivative with respect to u gives the wage curve elasticity:

$$\eta_{wu} = \frac{\mathrm{d}\log w}{\mathrm{d}\log u} = -\frac{s}{u\rho + s}. \tag{26.16}$$

The expression on the right-hand side contains only three parameters—the separation, unemployment and discount rates. These are parameters on which in principle empirical information is available. In contrast, parameters that are difficult to fix empirically, i.e. the bargaining power λ and the vacancy cost γ, have disappeared. Rather than helping us to determine additional parameters, Equation (26.16) produces an empirical implausibility. At a yearly basis,[44] s is of the same order of magnitude as u, and ρ is small. This gives a value of close to -1 for Equation (26.16), considerably diverging from the prominent wage curve elasticity value of -0.1. (See Section 26.5.6 for the interpretation of empirical wage curve estimates.)

This empirical implausibility is not necessarily the end of the calibration story. It is reasonable to argue that in Equation (26.15), the probability of filling a vacancy, q, is not to be treated as a parameter, but as an endogenous variable that moves inversely with unemployment. However, deriving the precise functional relationship is not straightforward and involves other equations, which again requires decisions about what is endogenous and what is exogenous.

43 We focus on the equilibrium version of the search-and-matching theory. An interesting disequilibrium setup, whose ambition is to cover short-term adjustment as well, is presented in Dixon and Rimmer (2003) and applied to illegal immigration in Dixon *et al.* (2011).

44 The choice of the time unit for flow accounting is relevant to the individual flow rates. However, changing the time unit would affect s and ρ proportionally so that the effect cancels out.

26.5.3.2 Efficiency wages

The cornerstone of the efficiency wage theory is some kind of monitoring technology, which is necessary in order to enforce discipline among the workers.[45] In the simplest case we have discrete effort, i.e. workers decide whether to exert either no effort or a given effort package, which avoids being detected shirking. The detection technology is monitoring in regular time intervals, which uncovers shirking, if present, with probability q. As in the search-and-matching setup, we work with recursive value functions. This time we have three, for employed workers that shirk (index ES) or do not shirk (EN) and for the unemployed (U):

$$\rho J^{\mathrm{EN}} = U^{\mathrm{EN}} - s\left(J^{\mathrm{EN}} - J^{\mathrm{U}}\right)$$

$$\rho J^{\mathrm{ES}} = U^{\mathrm{ES}} - (s+q)\left(J^{\mathrm{ES}} - J^{\mathrm{U}}\right)$$

$$\rho J^{\mathrm{U}} = U^{\mathrm{U}} + a\left(J^{\mathrm{E}} - J^{\mathrm{U}}\right),$$

where the J are state values, U are instantaneous utilities, s is the exogenous separation rate, ρ is the discount rate and a is the probability of finding a job. In the steady state, where the flow equilibrium must hold, a can be expressed in terms of the unemployment rate, u:

$$a = \frac{s(1-u)}{u}.$$

If they want to prevent shirking, firms must offer a wage that makes workers indifferent between shirking and not shirking, i.e.:

$$J^{\mathrm{EN}} = J^{\mathrm{ES}} = J^{\mathrm{E}}. \tag{26.17}$$

For tracing out the algebraic consequences of this, we must specify the instantaneous utility function. A common specification (e.g. Pissarides, 1998) is to assume linearity in the wage and commensurability of effort, e, with the wage so that we have:

$$U^{\mathrm{EN}} = w - e, \quad U^{\mathrm{ES}} = w, \quad U^{\mathrm{U}} = b,$$

with unemployment benefits b. Then the non-shirking requirement (26.17) results in the wage equation:

$$w = \rho J^{\mathrm{U}} + \frac{\rho + s + q}{q} e,$$

[45] The following formulation of the theory is based on Pissarides (1998), who in turn draws upon Shapiro and Stiglitz (1984).

i.e. the wage is determined as a markup on the annualized value of unemployment, which increases with the required effort, e, and decreases with the detection probability, q. Further substitution of J^U leads to:

$$w = b + \left[\frac{s}{u} + \rho + q\right] \frac{e}{q}. \tag{26.18}$$

If unemployment benefits are defined as a fixed share of the wage (i.e. we have a constant replacement rate, c), we can use $b = cw$, and Equation (26.18) turns into:

$$w = \frac{1}{1-c}\left[\frac{s}{u} + \rho + q\right] \frac{e}{q}. \tag{26.19}$$

26.5.3.2.1 Calibration

Equations (26.18) and (26.19) are wage curves in the strict sense that they contain a negative effect of the unemployment rate, u, on the wage, w. In the calibration context, we have good prospects to obtain information on (or estimation of) the separation rate, s, the discount rate, ρ, the unemployment rate, u, and the replacement rate. Two unknowns remain, e and q, for which there are no prospects of empirical foundation.[46] As Equation (26.19) must hold in equilibrium,[47] we can formulate an expression for e as a function of q:

$$\tilde{e} = (1-c)q\left(\frac{s}{u} + \rho + q\right)^{-1}, \tag{26.20}$$

where $\tilde{e}$ is the effort normalized by the wage, $\tilde{e} = e/w$.

From Equations (26.18) and (26.19), we can calculate the respective wage curve elasticities, η_{wu} and η^c_{wu}:

$$\eta_{wu} = \frac{\mathrm{d}\log w}{\mathrm{d}\log u} = -\frac{s\tilde{e}}{qu} \tag{26.21}$$

$$\eta^c_{wu} = -\frac{1}{1-c}\frac{s\tilde{e}}{qu}. \tag{26.22}$$

Using Equations (26.20) and (26.21) to eliminate $\tilde{e}$, we arrive at:

$$q = -\frac{s}{u}\left(\frac{1-c}{\eta_{wu}} + 1\right) - \rho \tag{26.23}$$

$$q = -\frac{s}{u}\left(\frac{1}{\eta^c_{wu}} + 1\right) - \rho. \tag{26.24}$$

46 The calibration of the efficiency wage model, again, closely follows Pissarides (1998).

47 Equation (26.19) must hold in both cases, even if unemployment benefits are not defined as a fixed share of the wage.

This allows us to calculate q. If we choose plausible values for the other parameters in equation (23), $s=0.2$, $u=0.1$, $c=0.6$, $\rho = 0.05$ and the target wage curve elasticity of $\eta_{wu}=-0.1$, then we end up with q being close to 6. In the case of a fixed replacement rate, this increases to close to 18. Interpreting these values, it is important *not* to interpret q as a probability (where values above one do not make sense), but as an instantaneous probability rate. A rate of above one means that the relevant event (caught while shirking) is expected more than once in the time interval (one year). Values of 6 and 18 for q then mean that a shirker is caught roughly after two months and in less than one month respectively.[48]

26.5.3.3 Collective wage bargaining

In the model discussed in this section, wage formation is conceptualized as the outcome of collective bargaining between a trade union and a representative firm. There are many varieties of this model, but for a concrete start and to establish terms, we make more specific assumptions: (i) Bargaining is only about the wage, not about employment ("right-to-manage" approach),[49] (ii) the trade union is only concerned with the utility of its employed members ("insider model")[50] and (iii) hours of work are exogenous. Formally, wage determination is implemented as the maximization of a Nash bargaining function, Ω, where trade unions are represented by the utility markup over their fallback option, $U_e - U_a$, and firms by profits, π. The relative bargaining power of the trade union, λ, is an unobservable parameter to be determined in the calibration:

$$\max_{w} \Omega = (U_e - U_a)^{\lambda}\pi. \tag{26.25}$$

Maximization is with respect to the *before-tax* wage, w.[51] The fallback option of the union, U_a, is composed of possible employment in another sector, $\tilde{U}_e$, and unemployment (receiving unemployment benefits), U_u, with weights determined by the unemployment rate, u:

$$U_a = (1-u)\tilde{U}_e + uU_u.$$

48 Pissarides (1998) observes the problem of the indeterminacy of q and e as well. He does not resort to the wage curve for calibration, however. Instead, he uses arguments based on the value of leisure time in the utility function. This produces a consistency problem, because in his model specification, utility is linear in income, as in the model of this section.

49 Sørensen (1999) shows that for the type of numerical analysis intended, the choice between right-to-manage and efficient bargaining (where bargaining extends also to the number of employed workers) hardly matters.

50 Further below in this section, we show that the results are identical to those obtained with a utilitarian union as long as the value shares and the elasticities of labor demand and hours supply are constant.

51 Maximization with respect to the after-tax wage yields the same results. Nevertheless, the distinction must be kept in mind when comparing the formulas obtained with the literature.

The fallback option is exogenous to the individual wage bargain so that the first-order condition of the maximization of the Nash function is:

$$\lambda \frac{\mathrm{d}U_\mathrm{e}/\mathrm{d}w}{U_\mathrm{e} - U_\mathrm{a}} + \frac{\mathrm{d}\pi/\mathrm{d}w}{\pi} = 0.$$

Both firms and employed workers make optimal choices, given the wage. This allows us to apply the envelope theorem and express the first-order condition in terms of partial effects:

$$\lambda \frac{\partial U_\mathrm{e}/\partial w}{U_\mathrm{e} - U_\mathrm{a}} + \frac{\partial \pi/\partial w}{\pi} = 0,$$

where the partial effect for the firm under profit maximization is:

$$\frac{\partial \pi}{\partial w} = -L.$$

Finally, using elasticities, we have:

$$\frac{\partial \log \Omega}{\partial \log w} = \lambda \frac{\partial \log U_\mathrm{e}}{\partial \log w} \frac{U_\mathrm{e}}{U_\mathrm{e} - U_\mathrm{a}} - \frac{wL}{\pi} = 0. \tag{26.26}$$

26.5.3.3.1 General equilibrium

With symmetrical sectors in equilibrium, we set:

$$U_\mathrm{e} = \tilde{U}_\mathrm{e},$$

and Equation (26.26) can be reformulated as:

$$\frac{\partial \log \Omega}{\partial \log w} = \lambda \frac{\partial \log U_\mathrm{e}}{\partial \log w} \frac{U_\mathrm{e}}{u(U_\mathrm{e} - U_\mathrm{u})} - \frac{wL}{\pi} = 0.$$

This reveals the basic wage curve relation: the higher unemployment, u, the lower the union benefit from a marginal increase of w and, consequently, the lower the wage in equilibrium.[52]

26.5.3.3.2 Calibrating the bargaining power parameter

The relative bargaining power of the trade union is a parameter notoriously impossible to observe. Its value can be recovered, however, from the observed unemployment rate. Assuming that the initial state is an equilibrium, Equation (26.26) must hold and the value of λ can be determined as:[53]

52 See our general discussion of the wage curve as basis for calibration in Section 26.5.6.

53 Variables with an upper bar denote the values of the initial equilibrium used for calibration and are therefore treated as constant.

$$\lambda = \frac{\bar{w}\bar{L}}{\bar{\pi}} \left(\overline{\frac{\partial \log U_{\mathrm{e}}}{\partial \log w}} \right)^{-1} \frac{\bar{u}(\bar{U}_{\mathrm{e}} - \bar{U}_{\mathrm{u}})}{\bar{U}_{\mathrm{e}}}. \tag{26.27}$$

The value of λ depends on the specification of the utility function. In particular, it depends on the modeling of the utility of the unemployed, i.e. how a difference in income compared to the employed translates into a difference in utility (see Section 26.3.1.4). However, *given* a particular specification of the utility function, the calculation of λ is straightforward.

The numerical essence of the Nash bargaining first-order condition can then be expressed as:

$$\frac{\partial \log U_{\mathrm{e}}}{\partial \log w} \frac{U_{\mathrm{e}}}{U_{\mathrm{e}} - U_{\mathrm{a}}} = \frac{wL}{\lambda \pi} := \zeta. \tag{26.28}$$

If we are prepared to assume that we are in a Cobb–Douglas world (or close to it),[54] then ζ is a constant and the Nash first-order condition boils down to keeping the left-hand side of Equation (26.28) at its initial level. This does not change when we work with other specifications of the trade union's objective function.

In the case of a utilitarian union, which also takes the level of employment into account when bargaining over the wage, the Nash function is:

$$\Omega' = [(U_{\mathrm{e}} - U_{\mathrm{a}})L]^{\lambda} \pi,$$

and the corresponding first-order condition:

$$\frac{\partial \log \Omega'}{\partial \log w} = \lambda \left(\frac{\partial \log U_{\mathrm{e}}}{\partial \log w} \frac{U_{\mathrm{e}}}{U_{\mathrm{e}} - U_{\mathrm{a}}} - \varepsilon_{Lw} \right) - \frac{wL}{\pi} = 0, \tag{26.29}$$

where the additional term, ε_{Lw} is the (absolute value of the) elasticity of employment, L, with respect to the wage:

$$\varepsilon_{Lw} = -\frac{\partial \log L}{\partial \log w}.$$

As long as this is constant or almost constant, we are essentially back at Equation (26.28), although λ has a different value now:

$$\lambda' = \frac{\bar{w}\bar{L}}{\bar{\pi}} \left(\left(\overline{\frac{\partial \log U_{\mathrm{e}}}{\partial \log w}} \right) \frac{\bar{U}_{\mathrm{e}}}{\bar{u}(\bar{U}_{\mathrm{e}} - \bar{U}_{\mathrm{u}})} - \bar{\varepsilon}_{Lw} \right)^{-1}.$$

54 The assumption can be formulated still somewhat weaker: even if the factor shares change, this will not have a systematic effect on wage negotiations. This comes close to denying the assumption, implicit in the Nash bargaining function, that parties bargain over *relative* markups over their respective outcome. Thus, if some shock increases (reduces) the basis they bargain upon, their markup will increase (fall) accordingly. This mechanism does not have much intuitive appeal.

Compared to Equation (26.27), the denominator shrinks and thus $\lambda' > \lambda$. A utilitarian union is roughly equivalent to an insider union that has a (correspondingly) lower relative bargaining power.

The same applies to a more general Nash function with variable weights for individual utility and employment, such as:

$$\max_{w} \ \Omega'' = (U_e - U_a)^{\lambda} L^{\mu} \pi,$$

which includes both the utilitarian union ($\lambda = \mu = 1$) and the insider model of Equation (26.25) with $\lambda = 1$ and $\mu = 0$ (see Graafland *et al.*, 2001, Chapter 7):

$$\frac{\partial \log \Omega''}{\partial \log w} = \left(\lambda \frac{\partial \log U_e}{\partial \log w} \frac{U_e}{U_e - U_a} - \mu \varepsilon_{Lw} \right) - \frac{wL}{\pi} = 0. \tag{26.30}$$

This leaves us with two parameters, μ and λ, which cannot be identified through a single first-order condition without further information. However, we can choose an arbitrary value of μ, solve for λ and—as long as the value shares and the labor demand elasticities are constant—we still remain with the essential equation:

$$\frac{\partial \log U_e}{\partial \log w} \frac{U_e}{U_e - U_a} = \left(\overline{\frac{\partial \log U_e}{\partial \log w}} \right) \frac{\bar{U}_e}{\bar{u}(\bar{U}_e - \bar{U}_u)}.$$

26.5.3.3.3 Linear utility function

The majority of the existing literature works with the simplifying assumption of a utility function that is linear in net income. If individual hours of work are exogenous and normalized to unity, we have:

$$U_e = (1 - t_a) w$$

$$U_u = b,$$

where b are unemployment benefits. We then can solve the first-order conditions of Nash bargaining explicitly for the wage, which gives us a wage curve:

$$w = \frac{\zeta u}{\zeta u (1 - t_a) - (1 - t_m)} b, \tag{26.31}$$

where w is increasing in t_a and b, and decreasing in u and t_m.

The picture is different if we assume that b is not given in absolute terms, but as a constant share ("replacement rate") of after-tax income:

$$b = c(1 - t_a) w.$$

Then w drops out of the wage-bargaining first-order condition and we are left with:

$$1 = \frac{\zeta uc(1-t_{\mathrm{a}})}{\zeta u(1-t_{\mathrm{a}})-(1-t_{\mathrm{m}})}.$$

This can be solved for u:

$$u = \frac{(1-t_{\mathrm{m}})}{\zeta(1-t_{\mathrm{a}})(1-c)}, \tag{26.32}$$

u is increasing in c and t_{a}, and decreasing in t_{m}. We now have an explicit expression for u, but the downside is that w cannot be determined from the first-order condition any more, but only in general equilibrium. With exogenous labor supply[55] $\bar{N}$, employment is determined as $(1-u)\bar{N}$ and w results implicitly determined as the wage that—given macroeconomic labor demand—creates the desired employment level. There is a monotonous relationship between u and w, but without knowing general equilibrium elasticities, we cannot say anything about the wage curve elasticity.

26.5.3.3.4 Empirical implications

Again, we look at two extreme cases: unemployment benefit fixed in real terms and a constant replacement rate. In the case of fixed unemployment benefits, we have an explicit wage curve, Equation (26.31), which allows us to calculate the implied wage curve elasticity. With proportional taxes ($t_{\mathrm{a}} = t_{\mathrm{m}}$) this is:

$$\eta_{wu} = -\frac{1}{\zeta u - 1}.$$

Taking into consideration the calibration of ζ, Equation (26.28), and assuming a Cobb—Douglas world, where factor shares are constant, we arrive at:

$$\eta_{wu} = -\frac{1-c}{c}.$$

For a replacement rate of $c = 0.6$, this means a wage curve elasticity of $\eta_{wu} = -0.67$, which is considerably higher than the empirically plausible value of -0.1.

In the case of a fixed replacement rate, we have the unemployment rate as a function of policy parameters:

$$u = \frac{(1-t_{\mathrm{m}})}{\zeta(1-t_{\mathrm{a}})(1-c)},$$

i.e. the wage moves independently of u, which makes the derivation of a wage curve elasticity impossible.

[55] When labor supply is endogenous, even more equations become relevant to the determination of the wage.

The challenge in calibrating the wage curve of the collective bargaining model is finding a specification that leaves enough flexibility for adjustment to empirical parameters. A possible approach is to define a "mixed replacement rate regime," in which unemployment benefits are a linear combination of a fixed part and an indexed part. With α as the share of the fixed part, we have:

$$b = \alpha\bar{b} + (1-\alpha)cw,$$

resulting in a wage curve:

$$w = \frac{\alpha\zeta u}{\zeta u(1-t_{\mathrm{a}}) - (1-t_{\mathrm{m}}) - (1-\alpha)c\zeta u}\bar{b}.$$

The same substitutions as above, combined with the assumption of a proportional tax schedule, yield the wage curve elasticity:

$$\eta_{wu} = -\frac{(1-t)(1-c)}{(\alpha-t)c}.$$

For $\alpha = 1$, this reproduces the elasticity value $\eta_{wu} = -(1-c)/c$ derived earlier. Other values for α lead to a shift in η_{wu}. However, as α has an upper bound of 1, changing α can only increase the (absolute value of the) wage curve elasticity and does therefore not solve the calibration puzzle.

26.5.4 Long-term trends in unemployment

In the dynamic calibration of unemployment, we are faced with a problem similar to those discussed in the context of labor supply (see Section 26.3.5). A secular upwards trend in labor productivity, and thus in wages, can produce a trend in unemployment, which might well be spurious. This is because the comparison of state values for employment and unemployment, and essentially the instant utility values for these two states, are crucial for all structural models of unemployment. If an upward trend in wages changes the relative values of employment and unemployment, this will have a systematic effect on unemployment.

With unemployment benefits determined as a fixed share of the after-tax income of the employed (constant replacement rate) and utility linear in income, we arrive at a benchmark situation in which the unemployment rate remains constant even if wages change. Comparison with this reference case reveals how a trend in wages can systematically influence unemployment When unemployment benefits are fixed in absolute terms and do not evolve proportionally with wages, wage increases make employment more attractive compared to unemployment, and thereby reduce the unemployment rate. The inverse effect occurs when we combine a constant replacement rate with basic, non-utility-generating, consumption, e.g. in a linear expenditure scheme. A proportional development in income for the employed and unemployed then does not translate into a proportional development of utility any more. With basic consumption uniform for both groups, relative utility of the unemployed will increase with rising wages, generating an upward trend in unemployment.

Similar non-proportionality effects may be produced by leisure as a utility-generating item (see Sections 26.3.1.1 and 26.3.1.4) or by adjustment factors for leisure productivity (see Section 26.3.5). In the collective bargaining model (see Section 26.5.3.3), we have a simple option for neutralizing all these systematic effects on unemployment in the long run. The relative bargaining power of trade unions, λ may be treated as a time-varying parameter, adjusted so that unemployment remains constant over time in the baseline. In the search-and-matching and efficiency wage models, the matching efficiency and the parameters of the monitoring function can take on similar roles for calibration.

26.5.5 Informal sector and dual labor market

In this chapter, we have repeatedly touched upon the issue of an informal sector and the "dual labor market" structure it can give rise to. For distributional and poverty analysis in particular, the distinction between the formal and informal sector is indispensable, given that a large fraction of the poorest workers are located in the latter (Fortin *et al.*, 1997). Here, we collect different aspects of this issue and investigate whether the dual labor market structure can be seen as simply one special case of differentiated labor markets (as discussed in Section 26.5.1).

On the labor demand side, it is usually a sectoral distinction that motivates the formal/informal divide. There are a number of different reasons for distinguishing between these two sectors: differences in technology, in wage formation or in the administrative treatment of firms, in particular taxation (for an overview, see Fortin *et al.* 1997). A typical assumption about wage formation is that in the informal sector, wages are competitive at a full employment level, whereas in the formal sector, wages are above the market-clearing level by one of the mechanisms discussed in Section 26.5.3 or some form of rent sharing. The basic idea of the "dual labor market" setup of Harris and Todaro (1970) comes in on the labor supply side. Formal and informal labor markets are not seen as completely separated (which would amount to a simple labor market segmentation as discussed in Section 26.5.1), but as connected through imperfect labor mobility. With the wage higher in the formal than in the informal sector, we need a rationing mechanism that prevents a complete shift of the workforce to the formal sector. According to Harris and Todaro (1970), the crucial element is unemployment. Searching for a job is a time-consuming process (as highlighted in the search-and-matching literature, Section 26.5.3.1), therefore a critical level of unemployment will stop the migration from the informal to the formal labor market. The marginal worker is indifferent between a secure job in the informal sector and an uncertain job search process in the formal sector ("waiting queues" for jobs).

In the original Harris and Todaro (1970) setup, migration between the informal and formal sectors is seen as a dynamic phenomenon, with the *change* in the number of workers in the formal sector as a function of the difference between the expected wage in the formal sector and the certain wage in the informal sector. This dynamic specification has been implemented, for example, in Agénor *et al.* (2003, section 3.2.1). In most comparative static applications, however, a steady-state assumption is used, to the effect that expected wages must be equal for all migration incentives to disappear:

$$w_{\mathrm{i}} = (1-u)w_{\mathrm{f}}, \tag{26.33}$$

where w_{i} and w_{f} are informal and formal wage, respectively, and u is the unemployment rate in the formal sector.[56] Equation (26.33), however, has an apparent shortcoming when it comes to calibration. The formal–informal wage differential as well as the unemployment rate are in principle (although not perfectly) observable and Equation (26.33) will hold by mere coincidence. Only by introducing some degree of freedom can Equation (26.33) be changed into a form that can be calibrated. The most straightforward way of creating this degree of freedom is to introduce fixed cost of migration (c_{m}), which is most plausible when the informal and formal sector are thought to be separated spatially (e.g. rural versus urban sector).[57] Even if there is no distance to be bridged, "fixed cost of migration" can be thought of as the cost of becoming accustomed to the rules and conventions of the formal labor market, and of establishing the contacts necessary to find a job. With fixed costs of migration in place, the Harris–Todaro locus becomes:

$$w_{\mathrm{i}} + c_{\mathrm{m}} = (1-u)w_{\mathrm{f}}, \tag{26.34}$$

and c_{m} can be calibrated so that equation (26.34) holds for empirical values of unemployment and the wage differential. In more general terms, c_{m} can be understood as any utility-generating difference between the sectors (apart from the wage and unemployment), e.g. less flexibility or a higher status in the formal sector.[58]

The next hurdle for the Harris–Todaro locus to be taken is the empirical elasticity of migration. Equations (26.33) and (26.34) both assume that, in a partial analysis of the formal sector and as a reaction to a change in the formal wage, unemployment must

56 Harris–Todaro loci of this simplest possible form can be found, for example, in the models of Gilbert and Wahl (2002) for China, and Alzua and Ruffo (2011) for Argentina.

57 In many applications, the formal/informal and urban/rural distinctions have been used interchangeably. Stifel and Thorbecke (2003), however, make the point that they need to be distinguished, which leads to a "dual-dual" model.

58 Stifel and Thorbecke (2003, p. 220) encounter the same problem and solve it with some *ad hoc* "adjustment parameter," used as a multiplier for unemployment in Equation (26.33).

adjust so that the product of the employment rate and the wage remains constant, i.e. the elasticity of unemployment with respect to the formal wage is:

$$\varepsilon_{uw_{\mathrm{f}}} = \frac{1-u}{u}.$$

This can be compared to wage curve estimations and checked against expert judgement. If the outcome of this check is that more adjustment is needed, we have the following two possible extensions. (i) We can assume that the migration costs are not uniform across workers, but heterogeneous. The workers who have the lowest migration costs switch to the formal market first, so that marginal migration costs are increasing with the size of the formal sector and the migration elasticity is reduced compared to the case with homogeneous migration costs.[59] (ii) We can go beyond the simple comparison of expected *wages* and proceed to expected *utilities*. This requires specifying the utility of the unemployed in the formal sector. Is there any unemployment compensation? If not, how do the unemployed organize themselves to make their living? In any case, the Harris–Torado locus becomes:

$$U(w_{\mathrm{i}}) = uU(w_{\mathrm{u}} - c_{\mathrm{m}}) + (1-u)U\big(w_{\mathrm{f}} - c_{\mathrm{m}}\big). \tag{26.35}$$

By specifying the elasticity of the utility function with respect to income (which in turn determines the degree of risk aversion), we can change the migration elasticity. With no risk aversion, Equation (26.35) essentially collapses back into the form of Equation (26.34). With risk aversion, in contrast, an increase in unemployment is more detrimental to utility than to the expected wage. Therefore, we need a smaller increase in unemployment to compensate for a given wage rise. This means that the migration elasticity is lower than in the case of Equation (26.34).[60]

The Harris–Todaro approach is not restricted to assuming full employment in the informal sector. In a more flexible setting, with both formal and informal unemployment, we have:

$$(1-u_{\mathrm{i}})w_{\mathrm{i}} + c_{\mathrm{m}} = \big(1-u_{\mathrm{f}}\big)w_{\mathrm{f}}. \tag{26.36}$$

A formulation similar to Equation (26.36) has been used in Böhringer *et al.* (2005) to model wage differentials between several formal sectors in Germany. As with the calibration issue discussed above, it turned out that it is impossible to match empirical sectoral wage differentials with a plausible spread in unemployment rates. The additional assumption of compensating non-pecuniary job characteristics is necessary to get the model afloat.

59 This idea is similar to the model of the extensive margin of labor supply in Section 26.3.1.4. In an empirical microsimulation setting, Bourguignon *et al.* (2005) use the same idea: they estimate the "closeness" of households to the formal labor market and, once additional jobs become available, assign them to those households with the lowest values of the distance measure.

60 This idea is used in the "generalized Harris–Todaro migration function" in a model for Ethiopia by Gelan (2002).

The Harris—Todaro approach can be implemented in a straightforward manner with sectors that are a part of the official input-output tables. However, the attempt to model the informal sector can run, by its very nature, into data availability problems because informal activities are notoriously difficult to observe. Since the seminal study on Kenya (ILO, 1972), estimates of the size and structure of the informal sector are available for most countries. Given the importance of the informal economy for many developing countries, many statistical offices use methods to make the estimates of the informal sector consistent with the formal economy and publish it as an integral part of the national accounts. When there is reason to doubt the magnitudes officially published, data adjustment may be performed with secondary data sources (see, e.g. Fortin *et al.*, 1997).

Even in countries with a high rate of formal employment, and therefore a low quantitative significance of the informal sector, capturing informal structures can be important as a benchmark for formal wages. In most varieties of unemployment models (Section 26.5.3) it is assumed that the non-market-clearing wage is formed as a markup on the income of the unemployed. When there is a fully fledged social security system, it is reasonable to assume that this benchmark is provided by unemployment insurance or social assistance. If replacement rates from the social security system in the case of unemployment are low, however, we need to specify informal income sources in order to explain how people can survive nevertheless. This is particularly important if the model works with a linear expenditure system that includes some minimum consumption, which must be covered in any case.

The reference point of an informal income that forms the basis of a markup in wage formation in imperfectly competitive labor markets has also been used in the empirical determination of a wage curve. Graafland and Huizinga (1999) use an informal sector (whose productivity is unknown *a priori,* but can be estimated or calibrated) to give the model enough flexibility to reproduce the empirical long-run pattern of wages.

26.5.6 Wage curve as a calibration target

Our discussion of the Harris—Todaro approach to informal sector modeling and migration in Section 26.5.5 enables us to take a fresh look at the wage curve elasticity as a calibration target for structural models of involuntary unemployment. In Sections 26.5.3.1—26.5.3.3, we have assumed that structural wage equations derived from one of the models of involuntary unemployment need to be calibrated to match the results of empirically estimated wage equations. The prime example of a relationship of this sort is the wage curve of Blanchflower and Oswald (1995), which gives a stable relationship between the wage level and unemployment: a wage curve elasticity of -0.1.

However, the usefulness of wage curve estimations for the calibration of structural models of unemployment needs a second look. After all, empirical wage curve estimations are usually based on regional differences, whereas a regional disaggregation can hardly be found in CGE models (except for explicit regional modeling, which we do not cover in this chapter). Are wage curve estimations nevertheless a useful input for calibration?

For concreteness, assume we have two regions (indexed by i) with efficiency wage formation according to the model in Section 26.5.3.2 and in both regions the efficiency wage curve, Equation (26.18):

$$w_i = b_i + \frac{s_i(1-u_i)}{u_i}\frac{e_i}{q_i} + \frac{\rho + s_i + q_i}{q_i}e_i, \tag{26.37}$$

holds (with the respective sectoral variables). In addition, we have a migration equation that links both sectors. Here, we take the simplest possible Harris–Todaro formulation (see Section 26.5.5), even if it is not fully consistent with the dynamic value-function approach that we have used in Section 26.5.3.2:

$$w_1(1-u_1) = w_2(1-u_2).$$

Taken at face value, the migration equation produces a positive wage curve elasticity:

$$\varepsilon_{wu} = \frac{\mathrm{d}w_i}{\mathrm{d}u_i}\frac{u_i}{w_i} = \frac{w_i}{(1-u_i)}\frac{u_i}{w_i} = \frac{u_i}{1-u_i}.$$

This is the Harris–Todaro idea in a nutshell. Higher wages in one sector must be *compensated* by higher unemployment in order to make potential migrants indifferent between the regions. However, this is not what we observe empirically, namely a *decreasing* locus between unemployment and the wage, i.e. the wage being depressed by higher unemployment.[61] The most straightforward way to make this empirical observation consistent with the migration locus is to introduce sector-specific non-labor market amenities, a, e.g. more attractive landscape in a particular region. With normalization for Sector 1, we then have:[62]

$$w_1(1-u_1) = w_2(1-u_2) + a_2. \tag{26.38}$$

When this is the *only* difference between regions, the relation between unemployment and the wages is solely determined by the sectoral wage curves. Unemployment and the wage share the role of compensating for non-economic regional amenities, with their

61 Kingdon and Knight (2006) discuss the choice between a Harris–Todaro locus and the wage curve in the case of a model for South Africa.

62 Note the similarity to fixed migration costs discussed in connection with Equation (26.34).

respective shares derived from the regional wage curves. The resulting elasticity is the one calculated in Section 26.5.3.2:

$$\eta_{wu} = \frac{\mathrm{d}\ln w}{\mathrm{d}\ln u} = \frac{\mathrm{d}w}{\mathrm{d}u}\frac{u}{w} = -\frac{s\tilde{e}}{qu}.$$

Put otherwise, the system consisting of Equations (26.37) and (26.38) produces *different* elasticities depending on which parameter is shocked. For a marginal change in a, we get the elasticity η_{wu}, for a marginal change in a parameter appearing in Equation (26.37), e.g. the autonomous separation rate s, we get the elasticity ε_{wu}. This makes the interpretation of empirical estimation results a difficult task. While we can derive clean elasticities from the equation system, in reality we will measure a mix of all possible differences between regions, affecting or not affecting the regional wage equation. To obtain the clean elasticity η_{wu} needed for calibration, we would ideally correct for factors that enter through the regional wage equation. However, as estimations of the wage curve are usually performed without assuming a concrete model (which would be the prerequisite for identifying factors that directly affect the wage curve) and without the aim of estimating an elasticity that can be used for calibration, this correction is not in the focus of empirical economists. When we use their wage curve estimates for calibration as in Sections 26.5.3.1–26.5.3.3, we implicitly assume that regional differences exist only in the non-economic amenities a.

26.6 WELFARE ANALYSIS

By far the largest part of all CGE studies reviewed in this chapter restrict themselves to a positive economic analysis, i.e. tracing out the consequences of policy shocks for observable economic variables, thus circumventing any potential problems connected to the calculation of welfare measures. Welfare analysis is one of the key assets of CGE analysis however. Therefore, here we review some complications that may arise once we try to compute welfare measures for several representative households (Section 26.6.1) or in a microsimulation setup (Section 26.6.2).

26.6.1 Welfare measures for representative households

Welfare computations in the basic CGE model with several representative households are simple. We record the change in the utility functions of the households, evaluate them at the initial prices, add up and report the result as equivalent variation (EV).[63] Interpreting EV as a welfare measure is subject to the usual caveat: a positive EV of a policy reform means that *if lump-sum redistribution between households is possible*, then a Pareto

[63] The following applies, *vice versa*, to compensating variation (CV), which is obtained if we value utility differences at the after-shock prices.

improvement compared to the initial situation *can* be generated. Such redistribution is not necessarily feasible and, if feasible, cannot be assumed to actually take place. In these circumstances, EV is only valid as a welfare measure if the utility of different households is commensurable and the marginal utility of income is the same for all households.

In a model such as the one discussed in Section 26.3.1, the computation of EV requires special attention when status changes occur. Status changes to be considered are: (i) Participation to non-participation (or back) and (ii) employment to unemployment (or back). Especially in the latter case, calculation of EV is not trivial, because unemployed individuals are not at their utility maximum. As a particular complication, EV for the switch from employment to unemployment is not the negative of EV for a switch from unemployment to employment, because of the quantity restriction. This is discussed in a formal way below.

When status changes take place, the number of individuals per representative household is not constant. Therefore, EV is first calculated for all possible transitions and then summed up with appropriate weights.

The first group to be considered are households that are employed and remain employed:[64]

$$EV_{\mathrm{EE}} = \bar{p}_{\mathrm{U}}\left(U_{\mathrm{e}} - \bar{U}_{\mathrm{e}}\right).$$

Second, we have households that switch from employment to unemployment:

$$EV_{\mathrm{EU}} = \bar{p}_{\mathrm{U}}\left(U_{\mathrm{u}} - \bar{U}_{\mathrm{e}}\right).$$

Third, there are households that are unemployed and remain so. These households are subject to a demand constraint $F = T - \delta\bar{H}$, see Section 26.3.1.4). Therefore, we can restrict the welfare calculation to the consumption part of the utility function:

$$EV_{\mathrm{UU}} = \bar{p}_{\mathrm{C}}\left(C_{\mathrm{D}}^{\mathrm{u}} - \bar{C}_{\mathrm{D}}^{\mathrm{u}}\right).$$

Fourth, there are households that switch from unemployment to employment. Here we have no dual formulation of the utility function and must calculate equivalent income directly by solving the following equation for $\tilde{C}_{\mathrm{D}}^{\mathrm{u}}$:

$$U_{\mathrm{e}} = \left[\theta_{\mathrm{C}}\left(\frac{\tilde{C}_{\mathrm{D}}^{\mathrm{u}}}{\bar{C}_{\mathrm{D}}}\right)^{\frac{\sigma-1}{\sigma}} + (1-\theta_{\mathrm{C}})\left(\frac{T-\delta\bar{H}}{\bar{F}}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}}.$$

EV results as:

$$EV_{\mathrm{UE}} = \bar{p}_{\mathrm{C}}\left(\tilde{C}_{\mathrm{D}}^{\mathrm{u}} - \bar{C}_{\mathrm{D}}^{\mathrm{u}}\right).$$

Here it becomes clear that treatment of switches into and out of employment is asymmetrical by the very nature of EV calculations. In the case of unemployed individuals, we

64 For an explanation of the symbols see Section 26.3.1.

ask “What amount of money would compensate them for being unemployed, given their labor supply constraint?” In the case of employed individuals: “Which income loss would make them indifferent to being unemployed, given the possibility of optimal adjustment of labor supply?”

Apart from the switches between employment and unemployment, we must keep track of the switches between participation and non-participation. We start with households that switch from non-participation to participation. They are faced with idiosyncratic fixed costs of taking up work (see Section 26.3.1.4) and these cost must be accounted for in the welfare calculation. We discuss the two cases of increasing and decreasing participation separately.

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

$$EV_{\bar{\mathrm{N}}} = U_{\mathrm{l}} - \bar{U}_{\mathrm{l}} = \frac{N - \bar{N}}{h}.$$

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

$$EV_{\mathrm{P}} = \int_{\bar{N}}^{N} \frac{N - n}{h} \mathrm{d}n = \frac{\left(N - \bar{N}\right)^2}{2h}. \tag{26.39}$$

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

$$EV_{\mathrm{N}} = U_{\mathrm{l}} - \bar{U}_{\mathrm{l}} = \frac{N - \bar{N}}{h}.$$

Integrating gives:

$$EV_{\mathrm{P}} = \int_{N}^{\bar{N}} \frac{n - \bar{N}}{h} \mathrm{d}n = -\frac{\left(N - \bar{N}\right)^2}{2h},$$

which can be consolidated with Equation (26.39) to become:

$$EV_{\mathrm{P}} = \mathrm{sign}\left(N - \bar{N}\right) \frac{\left(N - \bar{N}\right)^2}{2h}.$$

Finally, all these effects are added up:

$$EV = \min\left(\bar{N}, N\right) \cdot \left[\min\left(1-u, 1-\bar{u}\right) \cdot EV_{\mathrm{EE}} + \min\left(u, \bar{u}\right) \cdot EV_{\mathrm{UU}} \right. \\ \left. + \max\left(0, \bar{u}-u\right) \cdot EV_{\mathrm{UE}} + \max\left(0, u-\bar{u}\right) \cdot EV_{\mathrm{EU}}\right]. \tag{26.40}$$

Depending on the setup, there may be a further complication due to the existence of residual households that originate from the adjustment of data inconsistencies between the macro and micro level (see Section 26.3.3.4). We can either evaluate their utility change (which requires the assumption of a specific utility function) and add the result to the macroeconomic EV in Equation (26.40) or we can define a compensating tax instrument that keeps utility of the residual households fixed and shifts all welfare changes to the worker households.

26.6.2 Welfare measures for microsimulated households

In principle, the concept of EV is applicable to individual households in the same way as it is to aggregated households. There are, however, two potential complications. The first one arises from the fact that the most common form of microsimulation involves discrete-choice modeling of labor supply (see Section 26.3.3.1). Once labor supply cannot be chosen continuously, the determination of EV also involves discrete elements. The second complication joins in if individual households are faced with a stochastic decision, as in the case of involuntary unemployment. We discuss these two problems in turn.

In the deterministic case, we have a utility function U that depends on income from work, Y_i, leisure, F_i, and individual- and option-specific fixed terms, R_i, with option-specific utility, U_i:

$$U_i = U(Y_i, F_i, R_i).$$

When the initial choice of the household is option i and the final, optimal choice in the counterfactual situation is j with utility:

$$U^+ = U\left(Y_j, F_j, R_j\right),$$

the basic idea is to calculate EV so that the following equation holds:

$$U(Y_i + EV, F_i, R_i) = U^+.$$

However, we do not know *a priori* whether the household compensated by a lump-sum transfer will remain with the same labor supply choice. It might switch to another option associated with a different value of the EV. Given the discrete choice, this can only be determined by calculating option-specific EVs for all options k, i.e.:

$$U(Y_k + EV_k, F_k, R_k) = U^+,$$

and then selecting the minimum of the resulting range of values (for an extended discussion of this approach see Creedy and Kalb, 2005b):

$$EV = \min_k \; EV_k.$$

Matters become even more complex when the discrete choice of the households is stochastic. In Boeters (2010), for example, households decide on labor supply *before* they know whether they will end up employed or unemployed. In this case we have a choice between different values of expected utility, probability-weighted averages over n labor market states (where $n = 2$ for singles and $n = 4$ for couples in the employed/unemployed case):

$$EU_i = \sum_n p_{i,n} U\left(Y_{i,n}, F_{i,n}, R_i\right).$$

Again, the basic idea is to calculate EV for all options and then find the minimum. In contrast to the deterministic case, however, utility values are now state-specific as well, whereas EVs are not. We thus obtain:

$$\sum_n p_{k,n} U\left(Y_{k,n} + EV_k, F_{k,n}, R_k\right) = U^+.$$

In Boeters (2010) this has produced the follow-up problem that in a small number of cases, EV takes on a considerably negative value, which is compatible with income from work, but produces negative income when subtracted from unemployment benefits. In the usual case of utility functions that require positive income, this leads to an infeasibility. Boeters (2010) deals with this problem by introducing a state-specific lower bound on EV so that negative values of income are prevented.

26.6.3 Utility weighting

So far, we have assumed that EV is simply summed up over individuals or representative households. This amounts to evaluating a utilitarian welfare function, where each welfare gain or loss counts the same, disregarding the characteristics of the individual or household where it occurs. Normally, economists engaged in distributional analysis are eager to go beyond this approach and proceed to policy evaluation under genuine inequality aversion, i.e. giving higher weights to the utility of the poor than to the utility of the rich.

With heterogeneous households this is an ambitious project and we know of no convincing solution to the resulting problems in the literature. Complications arise due to the combination of two features of heterogeneous labor markets. (i) We look at households that endogenously choose their labor supply. Therefore, income is not well suited as an indicator of the distributional position of a household. A better candidate is earnings potential, i.e. income at some standardized value of labor supply. (ii) Many approaches of inequality aversion assume that utility values of different households are in principle commensurable and that weighting can be derived from the decreasing marginal utility of income. However, with disaggregated, heterogeneous households, we normally encounter incommensurable utility functions. They result from the calibration to labor supply elasticity values, which means that they have different parameters and the absolute utility levels are not comparable. Similarly, if individual utility functions are econometrically estimated, we end up with different utility functions for different households. The marginal utility of income is no longer available as a natural way of deriving welfare weights.

An interesting approach of dealing with these problems is presented in Aaberge and Colombino (2008). The authors propose a weighting method that involves two diverging utility functions per household — one that determines labor supply and a different one for meaningful welfare weighting. This obviously produces consistency problems, but Aaberge and Colombino (2008) argue that they can be tolerated.[65]

26.7 CONCLUSIONS

More than other core elements of a CGE model, the labor market lacks a consensus or majority setup. Which modeling strategy is appropriate strongly depends on the policy shock to be analyzed and on the output variables of interest. Therefore, our main aim in this chapter has been to present a portfolio of modeling options, together with their advantages and disadvantages in different modeling contexts. We hope that this kind of overview can be a useful guide to help practical modelers in their choice of an appropriate specification.

Although there is a broad menu of choices in labor market modeling, some core decisions must be taken. In our view, the most important choices are:

- *In labor supply*: whether to work with a small number of aggregated households or with a large set of microunits.
- *In labor demand*: whether to follow the disaggregation motivated by the labor supply side or rather to aggregate to broad labor demand categories.
- *In labor market coordination*: whether to work with an empirically founded wage curve or rather with a structural model of involuntary unemployment.
- *In model organization*: whether to iterate a micro module (if existing) with the macro module or engage in one-way linkage.

Even if we advocate the view that the model structure can only be chosen when the shock to be analyzed and the type of result to be generated have been specified, we are not completely neutral with respect to the four points above. We want to close this chapter with some broad recommendations that can serve as guidelines.

65 Decoster and Haan (2010) choose another route by implementing the ideas of Fleurbaey (2006) about welfare weighting in a discrete-choice labor supply framework.

- Working with a microsimulation setup is a forceful instrument, which has a number of clear advantages (direct link to modern labor supply estimation, explicitness in distributional questions) and avoids a number of typical problems that arise in determining the characteristics of representative households. Therefore, in our view, any CGE study with labor market focus should carefully check whether the microsimulation setup can be made use of.
- Labor supply analysis suggests a large number of potentially interesting labor subgroups. Except for a very small subset of these (i.e. subgroups defined by skill), the econometric basis for formulating labor demand in these categories is weak. We think that in general the assumption of perfect substitutability in demand (implying an efficiency-weighted *additive* treatment of individual labor quantities) is a plausible default. Demand for different categories of labor should only be differentiated if there is evidence that wages do not move in parallel.
- Modeling labor market coordination presents itself as a sharp tradeoff. Ideally, we would like to have a theoretically founded, structural model of involuntary unemployment, which contains enough free parameters to be calibrated to empirical wage curve elasticity parameters. The review of models in Section 26.5.3 has shown that this is not easily available. Any reasonably simple structural model of unemployment has severe difficulty to be calibrated to empirically plausible wage curve elasticities. Working with these elasticities directly, without a structural foundation, is possible, but reduces our resources of providing an economic interpretation of changes in the wage as a response to policy shocks.
- If microsimulation (or any other micro module) is used, we strongly advocate an iterative modeling framework. Iteration between modules is an indispensable tool for detecting model inconsistencies and for finding clues to the explanation of model mechanisms that should not be dispensed with lightly. It might indeed often be the case that feedback from one module to the other is quantitatively small so that it does not contribute much to the qualitative model outcomes. However, the only way to confirm this is to perform the model iteration and compare the results with the one-way linkage.

ACKNOWLEDGMENTS

We thank Peter Dixon, James Giesecke, John Hutton, Egbert Jongen, Andreas Peichl, Sebastian Siegloch and Peter Sørensen for helpful comments on earlier versions of this chapter.

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