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LINKING CGE AND MICROSIMULATION MODELS: METHODOLOGICAL AND APPLIED ISSUES

Tesi di Dottorato di: Giulia Colombo

Matricola: 3280098

Anno Accademico 2006/2007

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ABSTRACT

After an introduction to CGE (Computable General Equilibrium) models and to Microsimulation techniques, this thesis wants to give an assessment and a detailed description of how CGE and MS models can be linked together, taking inspiration from the current literature, with a special focus concerning the literature on developing countries. The main goal for which these two models are linked together is to try to take into account full agents' heterogeneity and the complexity of income distribution, while being able at the same time to consider the macroeconomic effects of the policy reforms.

In current literature there are two main trends in the approach to linking: one that tries to fully integrate the two models, or better the CGE model and a micro dataset or survey (integrated model), while the other develops separately the CGE and the microsimulation models and then links them together through a set of equations and parameters (layered models). We will make a detailed comparison of the two approaches.

In the last chapter, we build a CGE-microsimulation model for the economy of Nicaragua, following the Top-Down approach (see Bourguignon *et al.*, 2003), that is, the reform is simulated first at the macro level with the CGE model, and then it is passed onto the microsimulation model through a vector of changes in some chosen variables, such as prices, wage rates, and unemployment levels. The main reason for this choice is that with such an approach, one can develop the two models (CGE and microsimulation) separately, thus being able to make use of behavioural micro-econometric equations, which are instead of more difficult introduction into a fully integrated model. Moreover, the so called top-down approach appears to be particularly suited to the policy reform we are willing to simulate with the model: the Free Trade Agreement of Central America with the USA is mainly a macroeconomic reform, which on the other hand can have important effects on the distribution of income. With such a model we try to study the possible changes in the distribution of income deriving from the Free Trade Agreement with USA. Our analysis finds only small changes both in the main macroeconomic variables and in the distribution of income and poverty indices.

RIASSUNTO

Dopo aver introdotto i modelli CGE (Computable General Equilibrium, Equilibrio Generale Computazionale) e le tecniche di microsimulazione, questa tesi offre una descrizione dettagliata di come i modelli CGE ed i modelli di microsimulazione possano essere utilizzati congiuntamente, partendo dalla letteratura piú recente sull'argomento, e focalizzando in particolare l'attenzione sulla letteratura riguardante i paesi in via di sviluppo. Lo scopo principale dell'utilizzo di questi due modelli in maniera congiunta é quello di voler tenere in considerazione l'eterogeneitá degli agenti economici e la complessitá della distribuzione del reddito, e di essere in grado allo stesso tempo di valutare gli effetti macroeconomici delle riforme.

Nella letteratura attuale troviamo due tendenze principali: la prima cerca di integrare completamente i due modelli, o meglio il modello CGE ed il dataset microeconomico (modello integrato), mentre la seconda sviluppa separatamente i due modelli per poi collegarli attraverso un insieme di equazioni e di parametri (modelli stratificati). Eseguiremo un confronto dettagliato dei due approcci sopra descritti.

Nell'ultimo capitolo costruiremo un modello CGE-microsimulazione per l'economia del Nicaragua, seguendo l'approccio cosiddetto Top-Down (si veda Bourguinon *et al.*, 2003) che simula la riforma dapprima ad un livello macro con il modello CGE, e poi passa i risultati di questo al modello di microsimulazione attraverso un vettore di variazioni di prezzi, salari e livello di disoccupazione. La ragione principale per la quale è stato scelto questo approccio è che grazie ad esso è possibile sviluppare i due modelli separatamente, potendo cosí fare libero uso di equazioni comportamentali che sarebbero invece di difficile implementazione in un modello pienamente integrato. Inoltre, l'approccio Top-Down è particolarmente adatto alla riforma di politica economica che vogliamo simulare con il modello: l'accordo di libero scambio commerciale tra i paesi dell'America Centrale e gli Stati Uniti è una riforma di tipo macroeconomico, che potrebbe tuttavia avere effetti significativi sulla distribuzione del reddito. Con questo modello proveremo infatti ad analizzare gli effetti derivanti dall'accordo commerciale con gli Stati Uniti sulla distribuzione del reddito. I risultati dell'analisi dimostreranno che tale accordo commerciale porterá soltanto a piccole variazioni sia delle principali variabili macroeconomiche che della distribuzione del reddito e degli indici di povertá.

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Giulia Colombo

INTRODUCTION

Computable General Equilibrium (CGE) models are multi-sector numerical models based on concepts associated with Walrasian general equilibrium theory. They are designed to analyze the effects of policy reforms or of economic shocks on the economy in a national, multi-national or global economy. Major fields of application include fiscal policy and optimal taxation, trade policy and international trade regimes, income distribution, sector development, and the economic impact of technological change. In addition, CGE models have been fruitfully used for analyses of environmental and natural resource problems and policies[1]. CGE models have proved to be useful instruments for studying the effects of a reform or of a shock on the whole economy, especially when a simultaneous change of more than one parameter is necessary. Anyway, one of the limits of CGE models is that, as they generally follow the representative household approach, they are often unable to capture within-group inequality and some specific individual agents' behaviour. This is particularly important when we want to carry on income inequality and poverty analysis[2].

[1] The earliest CGE models of developing countries were designed to examine issues of income distribution. Adelman and Robinson (1978) analysed the case of South Korea, and Lysy and Taylor (1980) built a model for Brazil. For applications concerning optimal taxation, see for instance Ballard *et al.* (1985) and Ballard and Medema (1993). CGE models about trade policies are very numerous. For example, on the occasion of the negotiations for the North American Free Trade Agreement (NAFTA) among the United States, Canada and Mexico (1993), there appeared several studies relying on CGE models, surveyed by Brown (1992). CGE on environmental issues include measurements of intergenerational and multisectoral effects of policies such as cutting tolerated toxic emissions levels, raising green taxes, etc. See for example Bohringer and Rutherford (1997), Rutherford (2000) and Bohringer *et al.* (2000 and 2003).

[2] After Mookherjee and Shorrocks' (1982) study of UK, there are now other examples of "within/between" decomposition analysis of changes in inequality that indicate that changes in overall inequality are usually due at least as much to changes in within-group inequality as to changes in the between-group component. Among the applications to developing countries, see Ahuja *et al.* (1997), who applied this decomposition analysis to the case of Thailand, and Ferreira and Litchfield (2001) for Brazil.

Microsimulation (MS) models are instead tools that allow the simulation of the effects of a policy on a sample of economic agents (individual, households, firms) at the individual level. Usually, MS models are based on two fundamental elements: a micro dataset containing the economic and socio-demographic characteristics of a sample of individuals or households (household surveys), and the rules of the policies to be simulated, and especially their impact on the budget constraint faced by each agent. Their field of application ranges among the ones included in the broader area of redistribution policies: indirect and direct taxation, social security system reforms, etc.

Microsimulation (MS) techniques are accurate instruments for studying the effects on individual behaviour (such as labour supply or consumption) of a change in the tax-benefit system at a very detailed level. In this respect, microsimulation models are very useful and precise when studying income distribution and poverty issues, as they work at the level of the individual or of the single household. However, the main drawback of these models is that they are just a partial equilibrium analysis, and they are not able to capture the general equilibrium impact of a reform. However this could be significant in the case we are analysing a reform or a shock that could have important effects on the structure of the economy under study.

In principle, the idea of linking CGE and MS models looks as the best solution to overcome the limits of both models, as they are somehow complementary. The CGE model will provide the macro structure of the economy, while the MS model is providing a detailed micro dataset at the individual and household level. This way, the new modelling tool resulting from the link of the two models should be able to consider full agents' heterogeneity and general equilibrium effects at the same time. In particular, recent literature has focused on the possibility of combining these two types of models in order to account simultaneously for structural changes of the economy, general equilibrium effects of economic policies, and for their impacts on households' welfare, income distribution and poverty[3]. This way, the modeller will be able to implement

[3] The literature that follows this approach is quite flourishing in recent years: there are, among others, the important contributions by Decaluwé *et al.* (1999a) and (1999b), Cogneau and Robilliard (2000), Agénor *et al.* (2001), Cockburn (2001), Cogneau (2001), Bourguignon, Robilliard and Robinson (2003), Boccanfuso *et al.* (2003a) and Savard (2003).

structural or macroeconomic policies/shocks while taking into account their effects on microeconomic behaviour (at the individual or household level).

This thesis wants to give an assessment and a detailed description of how CGE and MS models can be linked together, taking inspiration from the current literature (with a special focus concerning the literature on developing countries).

In particular, one could think of introducing thousands of individuals/households taken from a household survey directly into the CGE model. We will call this an integrated approach. Another way would be to develop the two models separately, and then link them in a layered fashion through a vector of changes in some important variables (prices and/or quantities). Of course the main disadvantage or drawback of this approach is that it requires much more time and effort in the building of the entire model, as one has to go through two completely different modelling techniques and two different databases, the national accounts and the household survey.

But a question arises at this point: in which direction should go the link? Or better, should the link be in one direction only (for instance, from the macro onto the micro level of analysis), or the feedback effects (from the micro to the macro level) are also important for the final general equilibrium results?

In this work we will make a first attempt in trying to answer to some of these questions, and we will compare the three main approaches used in the literature to link CGE and MS models: the integrated approach, which uses thousands of households as agents in a standard CGE framework; the so called Top-Down approach, which imposes the results of a CGE model onto the microsimulation model, and draws from the latter poverty and inequality analysis; the Top-Down/Bottom-Up (TD/BU) approach, as it was developed by Savard (2003). This approach, after the injection of macroeconomic changes from the CGE onto the MS model, tries to take into account also the feedback effects from the micro to the macro level of analysis.

In linking these two types of models we encounter several difficulties, one of which is of course the problem of data inconsistency between the two datasets. This problem is openly faced by modellers that build integrated models, through the so-called “data reconciliation process”, but has not been treated so far in the other two approaches. This will be of particular relevance for the TD/BU approach.

In general, however, when building such models one has also to take into account other possible advantages and drawbacks of the various approaches: for instance, the layered approach requires time and effort in the building of the entire model, as one has to go through two different modelling techniques and two different databases. On the other side, one of the main advantages of the integrated approach is its simplicity and easiness of implementation. Its easiness allows what is instead still missing in the framework of a layered approach: dynamics. Indeed, while with integrated models dynamics is already introduced in a few examples[4], one of the main things still missing up to now in a layered framework is a dynamic featuring, which in the future will need further effort[5].

The work is organized as follows.

In the **first chapter**, after an introduction to microsimulation techniques, we will give a technical and detailed overview on how to link CGE to microsimulation models, describing in detail the practical implementation of the three main approaches cited above.

In the **second chapter** we investigate further the three approaches, and build three models for the same economy to compare and investigate results from the three different models. We will go in special detail with the TD/BU approach and draw some conclusions on its possible drawbacks. We will also propose an alternative way of taking into account feedback effects from the micro to the macro level of analysis.

Finally, in the **last chapter**, we will apply the technique to a real economy: we will study the effects that the introduction of the Free Trade Agreement of Central America with USA will have on poverty and inequality in Nicaragua. For this we have built a CGE-MS model for the Nicaraguan economy using a Top-Down approach. We will analyse both the macroeconomic effects and the changes in poverty and inequality that will take place after the introduction of the Treaty in Nicaragua.

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[4] See for instance the integrated dynamic model of Annabi *et al.* (2005) for Senegal, and the model for Philippines developed by Corong (2005). Other information about this approach can be found in Cockburn and Decaluwé (2006).

[5] A first attempt in this direction was made by Bibi and Chatti (2006) with their dynamic layered model for Tunisia.

- Chapter 1 -

CGE MODELS AND MICROSIMULATION TECHNIQUES

1. INTRODUCTION

Since the pioneering work by Adelman and Robinson (1978) for South Korea and Lysy and Taylor (1980) for Brazil[1], many CGE models for developing countries combine a highly disaggregated representation of the economy within a consistent macroeconomic framework and a description of the distribution of income through a small number of representative households (RH) meant to represent the main sources of heterogeneity in the whole population with respect to the phenomena of the policies under study. Models were initially static and rigorously Walrasian. They now often are dynamic (in the sense of a sequence of temporary equilibria linked by asset accumulation, or recursively dynamic) and often depart from Walrasian assumptions so as to incorporate various macro-economic features or "closures" as well as imperfect competition features.

Several "representative households" are necessary to account for heterogeneity among the main sources of household income (or among the changes in income) due to the phenomena or the policies being studied. Despite the need for variety, the number of RH is generally small in these models, however (usually less than 10). The chosen taxonomy and the level of disaggregation depend critically on the questions that the model is expected to answer: the household account is to be broken down into a number of relatively homogeneous household groups reflecting the socioeconomic characteristics of the country or region under consideration. The degree of homogeneity is crucial in the design of classifications, especially in a classification of household groups, where one would like to identify groups that are relatively homogeneous in terms of income sources and levels and expenditure patterns, and that may be able to reproduce the socioeconomic and structural stratification observed within the society and the economy under study. It is noteworthy that a household classification based on income or expenditure brackets does not satisfy any of these requirements – except perhaps the last one. Indeed, consider for instance the poorest segment of society (say the bottom decile of the income pyramid): it may include very different household heads, such as a landless

[1] See also the work by Gunning (1983) for Kenya. Other significant examples are represented by the models built in connection with the OECD research program on "Structural Adjustment and Poverty": Thorbecke (1991) for Indonesia, Morrisson (1991) for Morocco and Bourguignon *et al.* (1991) among others.

agricultural worker and a urban informal sector worker, and policies aimed at improving conditions in the two cases are likely to be very different.

There is no unique (standard) classification scheme or way of disaggregating the household data in a CGE model. The taxonomy used in any given model depends on the prevailing country or region specific characteristics and the objectives of the studies underlying the building of the model. Major criteria and sub-criteria used in the classification and disaggregation of the different household accounts are[2]:

a) location (e.g. rural vs. urban);
b) asset and productive factor ownership (particularly land ownership in the rural areas and human capital in urban areas);
c) characteristics of the head or main earner, such as his/her employment status, occupation, branch of industry and educational attainment, skill level, sex, main language, race (tribal) kinship[3].

For what concerns the degree of heterogeneity among agents, the CGE/RH framework sometimes explicitly considers that households within a RH group are heterogeneous in a "constant" way. That is, in order to capture within-group inequality, it is often assumed that each RH group represents an aggregation of households in which the distribution of relative income follows an exogenously fixed statistical law[4]. However, if households within a group are different, why should they be affected in the same way by a policy or by a shock? The empirical analyses conducted on household surveys support this doubt: the within-group component of observed changes in income distribution generally is at least as important as the between-group component of these changes[5]. Thus, the RH

[2] See Decaluwé *et al.* (1999a).

[3] For an interesting discussion of the importance of an appropriate households' taxonomy, see Duchin (1996).

[4] For early applications of this type of models, see Adelman and Robinson (1978) and Dervis, de Melo and Robinson (1982), who specified lognormal within-group distributions with exogenous variances. For a survey of CGE models applied to developing countries see Decaluwé and Martens (1988) and Robinson (1989). More recent examples of this kind of models can be found in de Janvry *et al.* (1991), Chia *et al.* (1994), Decaluwé *et al.* (1999a), Colatei and Round (2000) and Agénor *et al.* (2001).

[5] After Mookherjee and Shorrocks' (1982) study of UK, there are now other examples of "within/between" decomposition analysis of changes in inequality that indicate that changes in overall inequality are usually

approach based on the assumption that relative incomes are constant within household groups may be misleading in several circumstances, and this is especially true when studying poverty. This argument may be better understood by presenting an example: consider a shock which reduces the world price of a specific commodity, say maize; under the small country assumption (that is, the country is price-taker on the world market), a country exporting this good will see a decrease in its exports and a domestic contraction of this sector. After the simulation of the shock with a CGE/RH model of this country, suppose that we find a little change in the mean income of a RH group, say workers in the agricultural sector; however, in this case, poverty might be increasing by much more than suggested by this drop in the income of this group: indeed, in some households there may be individuals that have lost their job after the shock, or there may be some households that encounter more difficulties to diversify their activity or their consumption than others. For these individuals or families, the relative fall in income is necessarily larger than for the whole group, and this fall in their income is not represented by the slight fall in the mean income of the whole group: the RH approach does not allow to catch the effects that a shock or a policy change may have on single individuals or households. Suppose moreover that the initial income of these individual was low; then poverty may be increasing by much more than what predicted by a simple RH model, which is based on the assumption of distribution neutral shocks.

As it is explained in Savard (2003), another significant drawback in linking the intra-group distribution change to a statistical law that is completely exogenous is that no economic behaviour is considered behind this change in within-group distribution[6].

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due at least as much to changes in within-group inequality as to changes in the between-group component. Among the applications to developing countries, see Ahuja *et al.* (1997), who applied this decomposition analysis to the case of Thailand, and Ferreira and Litchfield (2001) for Brazil.

[6] The intra-group distribution change is usually linked to a theoretical statistical relationship between average (μ) and variance (σ^2) of the lognormal distribution. Savard (2003) also underlines the fact that the average behaviour of a specific group is biased towards the richest in the group. Standard CGE models, indeed, use household groupings that take into account the total income and expenditure of each group and the behavioural parameters which are generally calibrated at the base year. In most of the models these parameters reflect the aggregate and not necessarily the average behaviour. Thus, as the richest of a group are endowed with most of the factors, their behaviour will be dominant in the group. Moreover, keeping in mind that when doing poverty analysis is very important to consider the behaviour around the poverty line,

In order to overcome these problems, recent literature has tried to develop new modelling tools which should be able at the same time to account for heterogeneity and for the possible general equilibrium effects of the policy reform (or the exogenous shock) under study. In view of the fact that most of the available economic models have either a microeconomic or a macroeconomic focus[7], and they do not address the question adequately, recent literature has focused on the possibility of combining two different types of models. Since most of the economic policies (structural adjustment programs or trade liberalizations, for example) and exogenous shocks commonly analyzed for developing countries (such as fluctuations in the world price of raw materials and agricultural exports) are often macroeconomic phenomena (or may have, at least, some structural effects on the economy), while poverty and inequality are mainly microeconomic issues, this approach, which takes into account important micro-macro linkages, seems to be the right answer to the problem. In particular, some authors have tried to link microsimulation models to CGE models[8], in order to account simultaneously for structural changes of the economy and general equilibrium effects of economic policies, and for their impacts on households' welfare, income distribution and poverty. The literature that follows this approach is quite flourishing in recent years: there are, among others, the important contributions by Decaluwé *et al.* (1999a) and (1999b), Cogneau and Robilliard (2000), Agénor *et al.* (2001), Cockburn (2001), Cogneau (2001), Bourguignon, Robilliard and Robinson (2003), Boccanfuso *et al.* (2003a) and Savard (2003).

In this chapter, after a functional introduction to microsimulation modelling techniques, we'll go into the details of the different approaches used in literature to model the data coming from household surveys into a general equilibrium framework: in particular, we will analyze, respectively, the integrated approach, the Top-Down or Sequential

nothing really demonstrates that the average of aggregated behaviour will be representative of the households around the poverty line.

[7] These models include macro models, microsimulation models, multiplier models and computable general equilibrium (CGE) models.

[8] More generally, this current of the literature develops the use of micro-data drawn from household surveys in the context of a general equilibrium setting, which is usually but not necessarily a CGE model.

approach and the approach developed by Savard, known also as Top-Down/Bottom-Up approach. Finally, in the last section, we will see in detail how to build a behavioural microsimulation model, and how to link it to a CGE model.

2. INTRODUCTION TO MICROSIMULATION MODELS

Guy Orcutt is known as the originator of microsimulation as an instrument for economic analysis[9], but it is only since early 1980s that the use of microsimulation models developed, undoubtedly as a consequence of the increasing availability of large and detailed datasets on individual agents and the continuous increase in, and falling cost of, computing power; in fact, during the last twenty years, this kind of models have been increasingly applied in qualitative and quantitative analysis of public policies[10]. Their field of application ranges among the ones included in the broader area of redistribution policies: indirect and direct taxation, social security system reforms, etc.

Microsimulation (MS) models are tools that allow the simulation of the effects of a policy on a sample of economic agents (individual, households, firms) at the individual level. Usually, MS models are based on two fundamental elements: a micro dataset containing the economic and socio-demographic characteristics of a sample of individuals or households (household surveys), and the rules of the policies to be simulated, and especially their impact on the budget constraint faced by each agent.

Consider for instance a simple MS model which aims at computing the disposable income of a sample of households, given a tax-benefit system; in general, the disposable income of household h, which is made up of m individuals at working age, will be computed as follows:

$$YD_h = \sum_{i=1}^{m} w_{ih} \cdot L_{ih} + y_h^0 + NT\left(w_{ih} L_{ih}, y_h^0, z_h, \tau\right),$$

[9] See Orcutt (1957), Orcutt *et al.* (1961) and Orcutt *et al.* (1976).

[10] For the history and developments of microsimulation in economic analysis see, among others, Harding (1996) and Gupta and Kapur (2000).

where w_{ih} is the wage rate received by individual i, L_{ih} is individual i's labour supply, y_{ih}^{0} is the non-labour income (for example, rent from capital), and $NT(\cdot)$ is the tax-benefit system function, or "net tax" rule, which computes the net taxes to be paid given gross incomes ($w_{ih}L_{ih}, y_{h}^{0}$). Taxes and benefits depend on the characteristics of the household represented by the vector z_h (which may contain variables such as the number of individuals and the number of kids living in the household, the region/province of residence, the number of dependents, etc.), on the labour and non-labour incomes received by each agent belonging to that household, while τ stands for the parameters of the tax-benefit system (various tax rates, means-testing of benefits, etc.). In order to see how this function $NT(\cdot)$ may work in practice, consider a very simple tax-benefit system, and a household composed by two adults and a child, in which only one individual (i) works, while the other (j) is unemployed; the household receives also an income from a capital asset K_h, and a cash transfer from the welfare system (an unemployment benefit for the non-working adult, for example):

$$YD_h = (1-\sigma)\cdot w_{ih}\cdot L_{ih} + (1-\delta)\cdot r\cdot K_h - \gamma\cdot\left[(1-\sigma)\cdot w_{ih}\cdot L_{ih} + (1-\delta)\cdot r\cdot K_h - D_h\right] + TF_{jh}\,,$$

where σ is the social contribution rate, δ is the tax rate on capital income, r is the interest rate, γ is the direct income tax rate for the income class to which household h's income level belongs, D_h is the deduction for the presence of two dependents, and TF_{jh} is the unemployment benefit received by the non-working individual (transfers from the government are supposed to be tax free). It is easy to see that, in this simplified world, a reform of the tax-benefit system may influence the disposable income of household h in different ways: a reform of the income tax rates or a reform of the deduction system will directly affect its disposable income, a reform of the social security contributions will influence the labour income, directly or through a change in the labour supply of the individuals, and a reform of capital taxation may affect the non-labour income of the household, while a reform of the unemployment benefit system will affect the amount of transfers received by the household (see Figure 1).

In the real world, there are many possible measures which may have an influence upon the disposable income of the households and individuals in a country, either directly or through a change in the economic behaviour of individuals (labour supply, consumption behaviour, savings and income allocation, tax evasion, etc.): all these policy and fiscal reforms are thus expected to have an effect on the distribution of income of the population under study, and consequently on poverty and inequality indices. The main task for which most of MS models are built is in fact that of capturing this expected change in income distribution, trying to evaluate it by using the microdata coming from a sample survey of the population, enlightening who are the gainers and losers of the reform, while computing at the same time what are the costs or the gains of the reform in terms of revenue for the government.

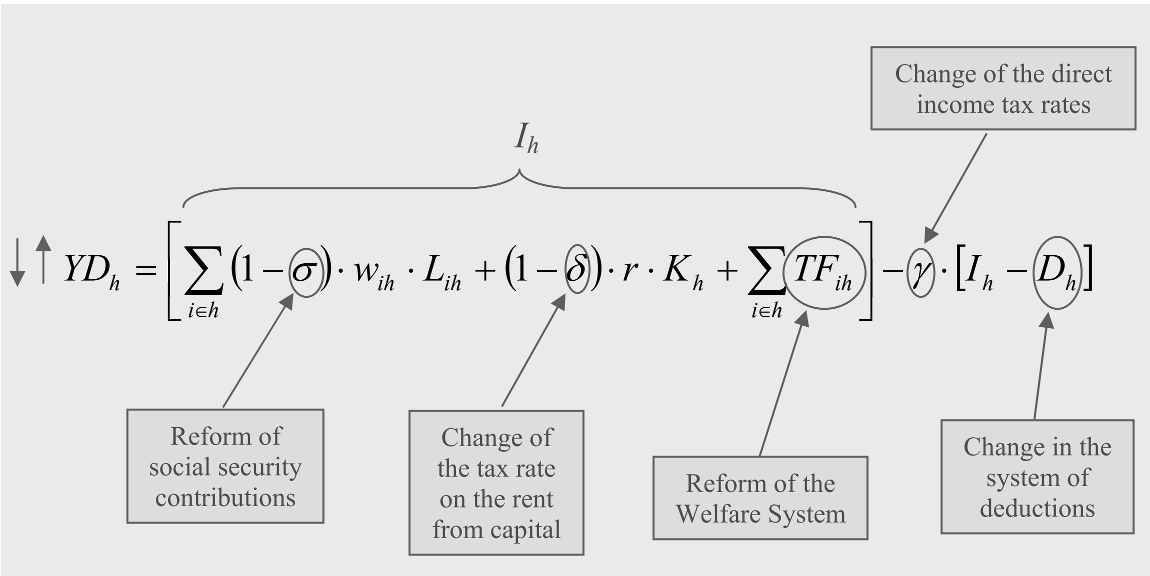

Figure 1 – An Arithmetical Model of a Tax-Benefit System

As said before, models simulating the household sector typically begin with a microdata file. Such a file may be based upon administrative data (such as tax or social security records) or upon a sample survey of the population. In both cases, the microdata usually contain thousands of individual or family records, with a list of variables describing the demographic, labour force, income and other characteristics of each individual or family. These data usually come from a sample of the population; nonetheless, it is possible to obtain also the values for the entire population by using “ad hoc” weights, which allow to know how many households of the population are represented by each observation in the survey. These *sampling weights* (also known as *expansion* or *raising factors*) simply depend on the selection probabilities of each observation in the sample (and, thus, the sample design[11]); they are usually reported in the surveys, so that it is always possible to pass from sample to population data.

Different stages are in general included in sampling methodology: typically, they are stratification and sampling. Stratification involves the division of the population into sub-groups, or strata, from which independent samples are taken (there may be a need to adapt these categories according to the local context)[12]. This ensures that a representative sample will be drawn with respect to the stratifiers (i.e. the proportions of units sampled from any particular stratum will equal the proportion in the population with that characteristic: stratification ensures that proportions of the sample falling into each group reflect those of the population). A separate random sample can thus be selected from each group. Some adjustments should be done for particularly small or large groups: the desired sample size will be determined by the expected variation in the data. The more varied the data are, the larger the sample size needs to be to obtain an adequate level of accuracy in generalizing the results. Using group sampling will ensure a balanced representation of the different household categories. Stratification of a sample can lead to substantial improvements in the precision of survey estimates. Optimal precision is achieved where the factors used as strata are those that correlate most highly with the survey variables[13].

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[11] Sample design is about choosing how many households to include in a survey in order to provide a good basis for measuring economic and social phenomena in the whole population.

[12] For example, the 1997-98 Family Expenditure Survey (FES) for Great Britain is a voluntary sample survey of private households. The FES sample for Great Britain is a multi-stage stratified random sample with clustering. It is drawn from the Small Users file of the Postcode Address File – the Post Office's list of addresses. Postal sectors (ward size) are the primary sample unit. 672 postal sectors are randomly selected during the year after being arranged in strata defined by standard regions (subdivided into metropolitan and non-metropolitan areas) and two 1991 Census variables – socio-economic group and ownership of cars. See the website of the UK Office for National Statistics www.statistics.gov.uk, and some documentation about UK Family Expenditure Surveys at www.data-archive.ac.uk/findingData/fesTitles.asp

[13] For a more detailed treatment of sampling procedures and on how to build a household survey, one can turn to the Living Standard Measurement Study (LSMS) manual, which is specifically designed to guide the many collaborators involved in planning surveys through the process of planning and implementing an LSMS survey. The manual provides practical information about, among other topics, questionnaire

We can make a very simple example in order to clarify this procedure. Suppose that in a given country there are 10,000 households from census data, and we have to select a representative sample from this population. We can start by stratifying the population into different regional areas, say North-East (2300 households from census data, 23% of household national population), North-West (1000 households, 10% of the whole population), South-East (4000 households, 40%) and South-West (2700 households, 27%). We can further stratify the population by the sub-division of these regions into rural and urban areas, for instance, thus obtaining 8 sub-groups in total. After this stratification, we can select a sample from each of these groups (we will draw a 10% sample from each sub-group, except for the urban North-Western sub-group, from which we take a 30% sample, given the small size of this sub-group with respect to the others). In this way, we get a sample of 1024 households (See Table 1). Once we will have the data (on income, expenditure, etc.) from the survey corresponding to each household in our sample, in order to get the corresponding population values we have to multiply each value by the weight corresponding to that representative household. In this case, to get these weights we must divide each sample size by the total sample size, and multiply this number by the household population. Now, for instance, each household in the first group is representative of 351 households in the whole population, each household in the second group is representative of 859 population households, and so on (see Table 1 and Figure 2). We can thus say that we have a representative sample of the given population[14].

The fundamental information contained in the weighting factors is that every family in the survey represents a given number of households of the population; only in this case we can say that we are dealing with a representative sample survey of the population. These particular numbers are usually supplied by the original data providers, and they

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formatting and development, sample design, and data management. One can also have a look at the LSMS website: www.worldbank.org/lsms.

[14] In a real household survey, however, one has to take into account also the fact that some of the households in the selected sample could not be reached, some others will not co-operate, or will not give full response to the questionnaire. Obviously, the weights need to be adjusted to take into account also this kind of problems. For a complete description of the techniques and full methodology used to build a real household survey, see for example the General Household Survey for Great Britain conducted by the Office for National Statistics, http://www.statistics.gov.uk

can be modified by the model builder only to account for possible socio-demographic or economic changes occurred since the time of the survey (this procedure is also known as *reweighting* or grossing-up procedure, see below).

Apart from this, the data frequently require further amendment by central statistical agencies or microsimulation modellers before they can be used. For example, this may include adjustment for under-reporting or misreporting of income or expenditure, the imputation of missing values, and the adjustment of weights for non-response.

Microsimulation thus involves a set of distinct processes, which include data cleaning and validation, imputation of missing data required for particular policy simulations, updating and re-weighting the data in order that they represent the desired population as closely as possible, applying detailed rule-modelling to simulate different policy regimes, and designing methods of presenting the results.

Table 1 – Stratification and Sampling: an Example

Geographic Area (GA)	*Number of Households (population)*	*% w.r.t. the whole pop.*	*Region*	*Number of Households (population)*	*% w.r.t. House-holds in GA*	*Sample*	*Sample size*	*Group sample size/Total sample size*	*Weight*
North-West	1000	10 %	Urban	120	12 %	30 %	36	0.0352	351.56
			Rural	880	88 %	10 %	88	0.0859	859.38
North-East	2300	23 %	Urban	460	20 %	10 %	46	0.0449	449.22
			Rural	1840	80 %	10 %	184	0.1797	1796.88
South-West	2700	27 %	Urban	1890	70 %	10 %	189	0.1846	1845.70
			Rural	810	30 %	10 %	81	0.0791	791.02
South-East	4000	40 %	Urban	2400	60 %	10 %	240	0.2344	2343.75
			Rural	1600	40 %	10 %	160	0.1563	1562.50
Total	10000	100 %		10000			1024	1.0000	10000.00

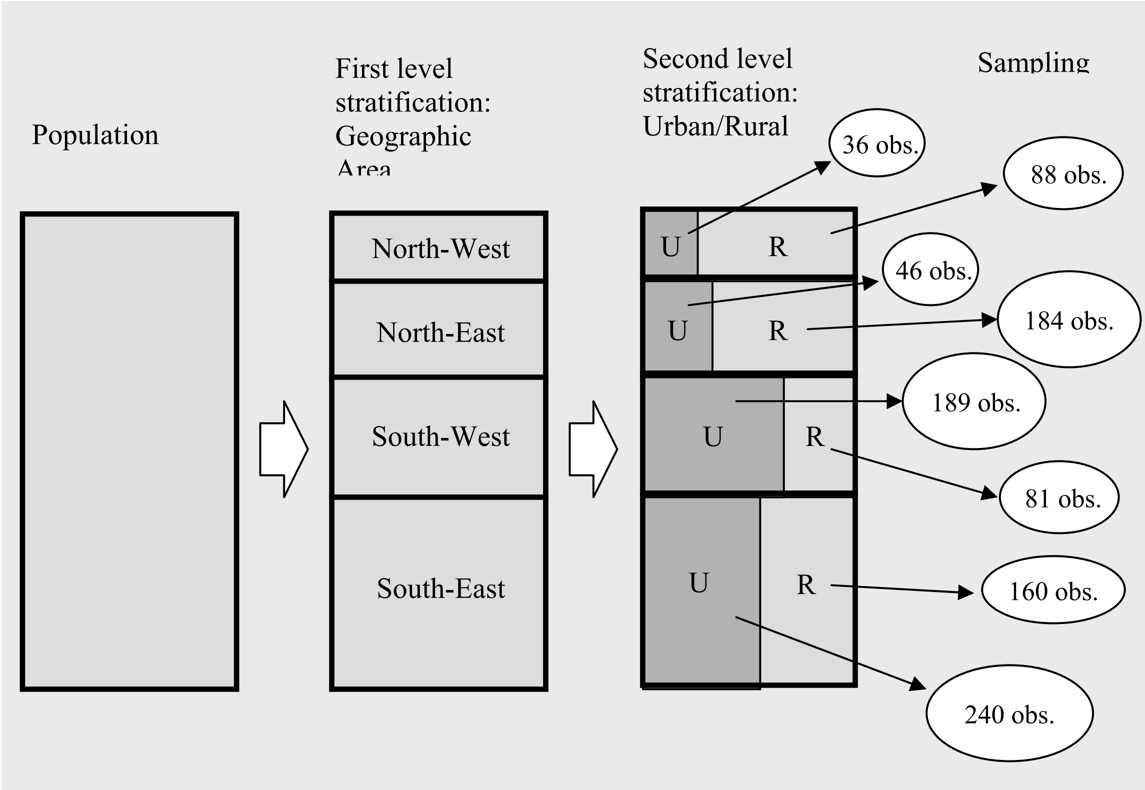

Figure 2 – Stratification and Sampling

Uprating and *reweighting* procedures are also known as static "ageing" techniques[15]; they are defined as methods attempting to align the available micro-data with other known information (such as changes in population aggregates, age distributions or unemployment rates), without modelling the *processes* that drive these changes (e.g., migration, fertility, or economic downturn), which is instead the intention of dynamic MS models (for more details on the differences between static and dynamic models see sub-section 1.3). There are several reasons why these procedures may be considered as necessary before using the data, but the most common one is that tax-benefit models are used to analyse the effects of social and fiscal policies in a period t^*, while the most recent data which are available usually come from some earlier period t. The micro-data from some previous period may thus need to be adjusted ("aged") to approximate the

[15] For this part on static data "ageing" techniques and their evaluation, see Immervoll *et al.* (2005).

population in period t^*. It is of course possible that, for the purpose of achieving a "good" approximation of taxes and benefits payable in period t^*, data from period t are already sufficiently close to period t^* population. But it is useful to ask whether we can improve on this to any meaningful extent by further enhancing the degree to which data available for modelling describe the target population in period t^*.

In thinking about the correlation between period t data and period t^* population, it is useful to separate the factors that determine how representative sample S_t (taken in period t) will be of population P_{t^*}.

One can, for this purpose, look separately at:

1. the degree to which S_t is representative of P_t, and
2. the processes causing P_t to differ from P_{t^*}.

With regard to the first point, we have already mentioned the fact that each observation in the sample represents a certain number of population members in the sense that the variable values recorded for a given observation approximate the characteristics of a certain fraction of the population. We will denote the group in the population represented by observation i in sample S_t as G_{ti}. The changes in the population (point 2) can then be broken down further into:

2a. Processes altering the <u>average value of a variable</u> in group G_{ti}: given the conceptualization of each observation i in the sample as representing G_{ti}, this translates into changing the value of the relevant variable of observation i in sample S_t.

2b. Processes causing the <u>composition</u> of G_{ti} to change. That is, some population members who have fitted into group G_{ti} may, due to changes in the population structure, be better represented by another group in population P_{t^*} (or may no longer be part of the population in time period t^* at all). Similarly, group G_{t^*i} may encompass population members which were not part of G_{ti} before.

Each of these factors will be discussed in turn.

<u>2a. Adjusting variable values of individual observations ("uprating")</u>

A common reason why we would consider a procedure of "ageing" (that is, an adjustment to the original data) as necessary is that our tax-benefit model will be used to analyse the effects of a fiscal reform in period t^*, while the most recent data that are available come from some earlier period t. For instance, let us suppose that we observe in some national statistics referred to period t^* that the average value $\bar{v}$ of a variable observed in a given group G_{ti} has changed between t and t^*. Then, for observation i to still be representative of G_{t^*i} in period t^*, this change will need to be reflected in the variable value recorded for that observation. For monetary variables, this can be achieved by "uprating" (i.e. inflating or deflating) each value by an appropriate index (such as price indices or indices based on income growth) describing how the value of the variable, averaged across the population group represented by i, has behaved between t and t^*. In doing so, it is important to separate changes in the average value of the variable averaged across members of G_{ti} from changes in the number of population members with certain variable values. To illustrate, let us consider an example. Let us suppose that in our sample S_t, which is representative of population P_t, in region "South" we have a certain number of observations and for all of them the registered wage level is zero, with the exception of observation i, whose wage level is 100. If we observe in the statistics for period t^* that the average wage level in this region has raised of 10% and, at the same time, the occupational level between t and t^* has been stable in that region, then we would want the wage of observation i to be "uprated" by the observed change in the average wage (+10%), rather than an "uprating" of all the wages earned in region "South".

Of course, indices capturing the change in variable values separately for each group G_{ti} will often not be available. One will, for instance, usually see more than one observation with non-zero wages in a given region and if there is only one index of average earnings available for the region as a whole, then the same index will need to be applied to all wage earners of that region in the sample. In other words, we cannot hope to perfectly replicate the distribution of all relevant variable changes occurring between t and t^*. Moreover, it is often a common choice among MS modellers to assume that the distribution of the variables among households remains constant, and therefore they just "uprate" average variables by multiplying them by a constant term (such as the inflation rate or the real growth rate of income).

2b. Adjusting the relative sizes of sub-populations ("re-weighting")

"Re-weighting" (that is, altering the "weights" of different observations in the data) can be used to align weighted frequencies of subgroups in sample S_t with external control totals (the true number of population members with certain characteristics) related to time period t^*; that is, the original weights can be forced to correspond to these new numbers. While the process of "uprating" discussed above aims at correcting the information of observations in sample S_t, so that they are still approximately representative of equivalent population members in P_{t*}, re-weighting sample S_t can be used to correct for the difference in probabilities of drawing an observation i (which is already part of S_t) if another sample were to be taken of population P_{t*}. When moving from period t to t^*, it is possible and, indeed, likely that both the probability of drawing observation i and the average values of variables in the group represented by this observation will have changed. To exploit all available information, it will generally be desirable to use both *uprating* and *re-weighting*.

Clearly, there are many ways in which a sample could be weighted in order to match a given set of control totals. How then should the weights be re-computed? Since no exact solution exists to the re-weighting problem and since the original weights provided in the dataset prior to any re-weighting contain a great deal of information about the population, a natural approach is to achieve the control totals by changing the existing weights as little as possible.

Indeed, adding information about the target population by altering the statistical weights in a dataset comes at the cost of potentially distorting information that the original weights represent. The likelihood of such distortions grows with the number of dimensions used for re-weighting as well as with the magnitude of the change along each individual dimension. If the size or number of relevant changes becomes very sizable, then forcing the data to correspond to the observed values in the target period can compromise the representativity along several dimensions. In such a situation, ageing techniques do not provide a reliable approximation of the population of interest (clearly, large changes will also render the "unadjusted" data non-representative of the target population).

For what concerns the process of *validation*, it includes a range of internal and external checks on the reliability of model inputs, model procedures, and model outputs[16]:

- *Model inputs*: validation of the reliability of the underlying microdata, which could involve internal checks such as an assessment of the degree of the estimation and imputation in responses to individual questions, or external checks such as the comparison of grossed up aggregates or distributions with official data.
- *Model procedures*: validation of the reliability of the simulations; this could involve internal case-by-case testing of simulated entitlements and liabilities against legally correct outcomes, or it could involve external comparisons which compare the taxes and benefits simulated for the same individuals and families by two models of the same country.
- *Model outputs*: the results of the simulations could be validated internally by comparison with recorded entitlement or liability taken directly from the microdata, or they could be validated externally. This could entail a comparison of the simulated aggregates and distributions for actual policy in force with official statistics or forecasts; alternatively, validation of model outputs could involve a study of the effect of sampling error on the reliability of outputs, or sensitivity testing of key assumptions[17].

However, there are several reasons why one should not expect model outputs to match exactly estimates from alternative sources. For instance, there may be structural changes between the survey year and the modelled year that are not captured by the methods that are used to gross up survey respondents to represent the population as a whole in the modelled year. There may, for example, be a change in unemployment rates or in patterns of households' expenditures, or structural changes in the volume of some income streams. However sophisticated the grossing-up technique that is used, the method will be unable to capture all the complexity of structural shifts that occur. Other reasons for which model outputs may be in disagreement with other sources may depend on the quality and completeness (miscoding and misreporting of information is always possible) of collected data, and on how much representative they are.

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[16] For this part on validation techniques see Redmond *et al.* (1998), chapter 9.

[17] For a discussion about validating procedures of model outputs, see, among others, Pudney and Sutherland (1994) and Lambert *et al.* (1994).

MS models are called *behavioural* when they include a theoretical model of the behavioural response of agents to changes in their budget constraint[18]: these models allow individuals to adjust their behaviour in response to the simulated policy change. The behaviours which are most frequently taken into account are consumption and labour supply. In order to compute the optimal consumption and labour supply of each agent, a model of consumption and labour supply must be estimated (or "calibrated") and incorporated into the microsimulation framework. There is then a choice between the popular "reduced form" approach and the more challenging and problematic structural approach. The latter requires making assumptions about the functional forms of preferences and specifying constraints facing households and individuals carefully, in a world where these steps may be arbitrary and difficult. We will focus on all these procedures and, more in general, on the setting up of a behavioural MS model in the following sub-section.

MS models that do not include behavioural responses are called *arithmetical* (or accounting) models, because they simply derive in an arithmetical way the disposable income and net tax payments of each agent, given the rules for the computation of taxes and benefits in the simulated policy: for each household in the database, information on income, expenditure and personal and family characteristics are used to perform the arithmetic necessary to calculate liability for personal taxes and entitlement to social security benefits under a given tax-benefit system (or some other default policy)[19]. These are contrasted with parallel sets of calculations for an alternative regime. From these calculations, the distribution of changes in income resulting from the alternative policy regime can be established. From the government's point of view, the sum of these changes represents the impact of the alternative policy on revenue. Viewed from the

[18] Behavioural responses that may be quite relevant when dealing with redistributional issues are, for example, labour supply, savings and household family composition (i.e. marriage, fertility, ...). We will see in more detail how to build a behavioural model that allows for labour supply responses in the next sub-section.

[19] There is an extensive literature on the application of arithmetical MS models to the analysis of reforms of tax-benefit systems. Atkinson and Sutherland (1988), Harding (1996), Sutherland (1998) and Gupta and Kapur (2000), among others, offer surveys of MS models and their use in Europe and United States. On tax incidence and on the incidence of public spending in areas like education or health see for instance Creedy (1999) and Demery (2003).

perspective of households, instead, it is the impact on the total tax burden, net of social security benefits. Throughout all these calculations, no change in behaviour is modelled following a policy change: the estimates computed are of the immediate (or "morning after") effect of the change, before individuals, households and the economy adjust in response[20]. Thus, in this kind of models, one takes detailed account of taxes and transfers to model household income distribution and consumption, leaving household behaviour exogenous. Better said, this kind of models is limited to "first round effects" and disregards second round effects due to the behavioural responses of agents. This approach is particularly useful for the analysis of the "morning after" effects of a policy change; that is, when the individual behaviour is assumed to remain the same as before the change.

For a practical application of a simple arithmetical MS model to a household survey, see in particular the section dedicated to the description of the Top-Down approach (the equations of the MS model are reported in Table 10, while the description of the model is at page 41; one can find instead the household survey on which the model is based in the preceding sub-section, Table 2, page 34) in the next paragraph about the linking methods of MS and CGE models.

The primary outputs of tax-benefit models are estimates of the revenue impact of a policy reform and of the distribution of associated income gains and losses across households.

Arithmetical MS models that are representative of the population allow the revenue and distributional impacts to be estimated together, taking full account of the interactions of different policy components and, at the same time, considering the range of all possible

[20] For a detailed description of an arithmetical tax-benefit model, see for instance POLIMOD, an arithmetical MS model for UK, which is described in detail in Redmond *et al.* (1998). A lot of material about this topic can also be found on the website of EUROMOD, a tax-benefit MS model that estimates the effects of changes in social and fiscal policies on measures of personal income and household welfare; it is an integrated model covering all 15 European Union countries. See: http://www.econ.cam.ac.uk/dae/mu/emod.htm. Another good description of an arithmetical model is given in Oliver and Spadaro (2004), who describe GLADHISPANIA, a MS model for the study of the effects of the 1999-2003 Spanish income tax reforms and other hypothetical scenarios based on the adoption of proportional tax rates. See also the website: http://www.gladhispania.es

circumstances in which families find themselves. The simultaneous generation of these estimates provides a powerful aid to policy design, allowing the policy maker to consider how expenditure aimed at achieving a particular distributional objective is to be paid for, or alternatively, how the impact of a measure aimed at raising a particular amount of revenue is distributed and how unintended losers might be compensated[21].

However, taking into account behavioural responses may be of great importance for poverty incidence analysis, since they may increase or, on the contrary, mitigate the first round effects revealed by the accounting approach. The difficulty of course is to identify this behavioural response and to understand its determinants properly in order to integrate it into the analysis. To have an idea of the possible applications of behavioural MS models, consider for example the "conditional cash transfers programs", a policy adopted in several developing countries: it consists of a cash transfer to households whose income per capita is below a certain threshold, conditionally on their effective keeping to some particular behaviour, such as sending their kids to school or carrying out regular visits to health care facilities[22].

2.1. Behavioural Models[23]

As arithmetical models, behavioural MS models rely on micro household databases. Nevertheless, they add an important component to the analysis: the point is not only to count how much more, or less, everyone is receiving or paying because of a reform in his/her budget constraints, but to take into account the behavioural response of the agents to this change in the budget constraint. This may be done through the estimation of a *structural econometric model* on the cross-section of households available in the survey being used, and/or through the *calibration* of a behavioural model with some

[21] See Redmond *et al.* (1998).

[22] For an application of this type, see for instance Bourguignon *et al.* (2003c) with their simulations of the *Bolsa Escola* program in Brazil. To have an idea of the potential of behavioural MS models for the evaluation of public policies, see also Labeaga *et al.* (2005).

[23] The source from which part of this paragraph is taken is Bourguignon and Spadaro (2006).

predetermined structure so as to make it consistent with behaviour actually observed in the survey, and meant to correspond to the status quo (see below).

Tax-benefit models with labour supply response are the archetypical example of behavioural MS models. Because of the recurring importance placed on labour supply responses to tax and benefit reforms[24], we will mainly focus our attention on the modelling of labour supply behaviour, the understanding of which continues nowadays to attract considerable research interest[25]. Changes in the tax-benefit system in these models affect the budget constraint of households. They modify their disposable income with unchanged labour supply, but through the corresponding income effects, and also through the changes in the after tax price of labour, they also modify labour supply decisions. By how much is determined through simulating a model of labour supply behaviour and factor.

The behavioural MS model approach comprises three main steps: specifying the logical economic structure of the model being used, estimating or calibrating the model and simulating it with alternative reforms of the tax-benefit system.

There are two main trends in the literature on behavioural models of labour supply: the traditional continuous approach pioneered by Hausman (1980 and 1985), and the discrete choice approach, developed by Van Soest (1995) and Aaberge *et al.* (1995).

The standard continuous approach

The logical economic structure is that of the textbook maximizing utility of the consumers. An economic agent, i, with characteristics z_i chooses his/her volume of consumption, c_i, and his/her labour supply, L_i, so as to maximize his/her preferences represented by the utility function $u(\cdot)$ under a budget constraint that incorporates the whole tax-benefit system[26]. Formally, this is represented by:

[24] Here we would like to remark the fact that labour supply strongly depends on structural factors and institutional features, and not only on individual choices and preferences.

[25] Blundell and MaCurdy (2000) present a detailed state of the art.

[26] For simplicity, we suppose that no savings are possible and all the disposable (after tax) income is spent for consumption.

$$\begin{aligned} &Max \quad u(c_i, L_i; z_i; \beta, \varepsilon_i) \\ &s.t. \quad c_i \le y_{0i} + w_i L_i + NT(w_i L_i, L_i, y_{0i}; z_i; \gamma) \qquad (1) \\ &\qquad L_i \ge 0 \end{aligned}$$

In the budget constraint, y_{0i} stands for (exogenous) non-labour income, w_i for the wage rate and $NT(\cdot)$ for the tax-benefit or "net tax" schedule, which represents the way in which the tax-benefit system transforms gross income into disposable income. This function actually stands for a fairly complex set of rules for the computation of taxes and benefits, which depend on the characteristics of the agent z_i, his/her non-labour income and his/her labour income, $w_i L_i$. It may also depend directly on the quantity of labour being supplied, as in workfare programs. γ stands for the parameters of the tax-benefit system (various tax rates, means-testing of benefits, etc.). Likewise, β and ε_i are coefficients that parameterise preferences, the latter being idiosyncratic. The solution of that program yields the following labour supply function:

$$L_i = F(w_i, y_{0i}; z_i; \beta, \varepsilon_i; \gamma)$$

This function is non-linear. In particular, it is equal to zero in some subset of the space of its arguments, i.e. the non-participation solution.

Suppose now that a sample of agents is observed in some household survey. The problem is to estimate the function $F(\cdot)$ above, or, equivalently, the preference parameters, β and ε_i, since all the other individual-specific variables or tax-benefit parameters are actually observed. To do so, preference parameters are broken down into a set of coefficients β common to all agents, and a set ε_i that is idiosyncratic. The latter plays the usual role of the random term in standard regressions.

Estimation proceeds as with standard models, minimizing the role of the idiosyncratic preference term in explaining cross-sectional differences in labour supply. This leads to a set of estimates $\hat{\beta}$ for the common preference parameters and $\hat{\varepsilon}_i$ for the idiosyncratic preference terms. By definition of the latter, it is true for each observation in the sample that:

$$L_i = F(w_i, y_{0i}; z_i; \hat{\beta}, \hat{\varepsilon}_i; \gamma) \qquad (2)$$

It is now possible to simulate alternative tax-benefit systems. This simply requires modifying the set of parameters γ. In absence of general equilibrium effects on wages and labour demand, the change in labour supply due to moving to the set of parameters γ^s is given by:

$$L_i^s - L_i = F\left(w_i, y_{0i}; z_i; \hat{\beta}, \hat{\varepsilon}_i; \gamma^s\right) - F\left(w_i, y_{0i}; z_i; \hat{\beta}, \hat{\varepsilon}_i; \gamma\right)$$

The change in the disposable income (which, in our case, corresponds to the consumption level, as we do not have the possibility of saving, see note 26) may also be computed for each agent. It is given by:

$$C_i^s - C_i = w_i\left(L_i^s - L_i\right) + NT\left(w_i L_i^s, L_i^s, y_{0i}; z_i; \gamma^s\right) - NT\left(w_i L_i, L_i, y_{0i}; z_i; \gamma\right).$$

Then, one may also derive changes in any measure of individual welfare.

Several difficulties in the preceding model must be emphasized. Its estimation generally is uneasy. It is highly non-linear because of the non-linearity of the budget constraint and possibly its non-convexity due to the tax-benefit schedule, $NT(\cdot)$, and corner solutions at $L_i=0$. Functional forms must be chosen for preferences[27], which may introduce some arbitrariness in the whole procedure. Finally, it may be feared that imposing full economic rationality and a functional form for preferences severely restrict the estimates that are obtained.

Moreover, the labour supply model based on the traditional continuous approach has been recognized to suffer from several problems. First, it works well with convex budget sets (i.e. those generated by progressive taxation) and a two-good application (e.g. c_i and L_i in the individual labour supply application), but it tends to become computationally cumbersome when the agents face non-convex budget sets and when more than two goods are object to choice (e.g. when the agent is a many-person household). Second, in view of the computational problems, the above approach essentially forces the researcher to choose relatively simple specifications for the utility function or the labour supply

[27] Without specifying a functional form for preferences, we might still be able to characterize the optimal solution as a function of w_i and y_{0i}: $L_i^* = F^{NT}\left(w_i, y_{0i}; z_i; \beta, \varepsilon_i; \gamma\right)$ and estimate $F^{NT}(\cdot)$. However, $F^{NT}(\cdot)$ depends on the current tax-benefit rule $NT(\cdot)$ and therefore it cannot be used to simulate policies that introduce a different tax rule, say $NT'(\cdot)$. The problem is that the behavioural function $F^{NT}(\cdot)$ in general mixes up preferences and constraints. More generally, the opportunity set might be defined by complicated budget and quantity constraints that do not even allow recovering a closed form solution for L_i^*. What we really need is the estimate of the utility function $u(c_i, L_i)$ itself. Once preferences are estimated, in principle we are able to simulate the effect of any policy by solving Max $u(c_i, L_i)$ subject to the appropriate constraints.

functions (see MaCurdy *et al.*, 1990). However, the principal inconvenience of using this methodology is that the behavioural restrictions it imposes are too strong, requiring that the labour supply function globally satisfies the Slutsky conditions[28]. As a result, the estimation results suffer from a lack of robustness, which reduces their usefulness for policy evaluation (see MaCurdy *et al.*, 1990, and MaCurdy, 1992)[29].

Such weaknesses have pushed researchers towards the estimation of total income elasticities or the estimation of direct utility functions by a discretisation of the labour supply alternatives (Van Soest, 1995, Aaberge *et al.*, 1995, Hoynes, 1996, Keane and Moffit, 1998, and Blundell *et al.*, 2000). This second approach has been heavily employed in the recent analysis of tax reforms. Since behavioural changes probably occur at the corner or kink points of the labour supply function, this method has the advantage of capturing them, providing the analyst with an estimation of the elasticity at the extensive margin. Moreover, this methodology allows us to avoid the computational and analytical difficulties associated with utility maximization under non-linear and non-convex budget constraints. This is because the budget constraint is now directly modelled in the utility function. It also enables to consider fixed costs, simultaneous participation and the intensity of work choices, as well as spouses' joint labour supply decisions[30].

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[28] Computational and statistical consistency of Maximum Likelihood estimation of the model requires imposing a priori quasi-convexity of preferences (see Aaberge *et al.*, 2006). The Slutsky equation, which gives the scomposition of the price effect (the effect of a change in the price of good *k* on the demand for good *l*) into substitution and income effect:

$$\frac{\partial h_l(p,u)}{\partial p_k} = \frac{\partial x_l(p,w)}{\partial p_k} + \frac{\partial x_l(p,w)}{\partial w} \cdot x_k(p,w), \qquad \text{for all } l, k \text{ (goods)},$$

where $h(p, u)$ is the Hicksian demand function, which is derived from the dual problem of utility maximization, i.e. the expenditure minimization problem: $\{\min p \cdot x \ \text{ s.t. } u(x) \leq \bar{u}\}$, where $\bar{u}$ is a given level of utility, while $x(p, \mathrm{w})$ is the Marshallian demand function, derived from the utility maximization problem (see Note 30), and $w > 0$ is the wealth level of individual *i*. The satisfaction of the Slutsky equation requires a continuous utility function $u(\cdot)$ representing a locally nonsatiated and strictly convex preference relation.

[29] Other problems presented by this approach are the lack of identification of the responses of hours to marginal changes in taxes (see, for instance, Van Soest, 1995), and the under-identification of wage effects due to misspecification of dynamic components (see MaCurdy, 1992).

[30] An excellent application of behavioural MS based on discrete choice models, which illustrates very well the potential of this approach, is that of Blundell *et al.* (2000), which evaluates the likely effect of the

Discrete choice models of labour supply

Specifications used in recent work consider labour supply as a discrete variable that may take only a few alternative values, and evaluate the utility of the agent for each of these values and the corresponding disposable income given by the budget constraint. As before, the behavioural rule is then simply that agents choose the value that leads to the highest level of utility. However, the utility function may be specified in a very general way, with practically no restriction. Such a representation is therefore as close as possible to what is revealed by the data.

The approach essentially consists in representing the budget set with a set of discrete "points". Let [0, *D*] be the (continuous) range of possible values for hours of work D_j. Let us pick *J* points d_1, d_2, …, d_s to represent [0, *D*]. The utility level attained by individual *i* at point *j* is $U_i^j\left(c_i^j, d_j\right)$, where c_i^j is obtained through some budget rule such as in *(1)*.

Formally, a specification that generalizes what is most often found in the recent tax and benefit labour supply literature is the following:

$$L_i = d_j \quad \textit{if} \quad U_i^j = f\left(z_i; w_i, c_i^j; \beta^j, \varepsilon_i^j\right) \geq U_i^k = f\left(z_i; w_i, c_i^k; \beta^k, \varepsilon_i^k\right) \qquad \text{for all } k \neq j, \quad (3)$$

where d_j is the duration of work in the j^{th} alternative and U_i^j the utility associated with that alternative, c_i^j being the disposable income given by the budget constraint in *(1)*:

$$c_i^j = y_{0i} + w_i L_i + NT\left(w_i d_j, d_j, y_{0i}; z_i; \gamma\right).$$

This problem is discretized in the sense that the choice of working hours is supposed to be made between few alternatives. This approach is computationally very convenient when compared to the continuous one, since it does not require going through complicated Kuhn-Tucker conditions involving derivatives of the utility function and of the budget constraint. As a consequence, it is not affected by how complex it is the rule that defines the budget set or by how many goods are contained in the utility function. When the function *f(·)* is linear with respect to its common preference parameters, β^j, additive with respect to the idiosyncratic terms, ε_i^j, and when those terms are *iid* with a

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introduction of the Working Families Tax Credit (WTFC) in the UK. They estimate, separately, a discrete labour supply model for married couples and single parents on a sample of UK households in the Family Resources Survey for 1995 and 1996.

double exponential distribution, this model is the standard multinomial logit. It may also be noted that it encompasses the initial model *(1)*. It is sufficient to make the following substitution:

$$f\left(z_i; w_i, c_i^j; \beta^j, \varepsilon_i^j\right) = u\left(c_i^j, d_j; z_i; \beta^j, \varepsilon_i^j\right). \qquad (4)$$

This specification, which involves restrictions across the various duration alternatives, is actually the one that is most often used. The idea is that there generally are commonly agreed durations of work in the labour market – full-time, ¾ full-time, half-time, etc. – so that employees have indeed a limited finite set of options, including the possibility not to work at all. Thus, the set of alternatives (j = 1, 2, …, J) now corresponds to J work durations or to J combinations of spouses' labour supplies in the case of joint decisions by a couple[31].

Within the literature adopting this approach there are however two potentially important issues. A first issue concerns the procedure by which the discrete alternatives are chosen. For example, Van Soest (1995) and Blundell *et al.* (2000) choose (non probabilistically) a set of fixed points identical for every individual. This is by far the most widely adopted method. By contrast, Aaberge *et al.* (1995) adopt a sampling procedure and also assume that the choice set may differ across the households.

A second issue concerns the availability of the alternatives. Most authors assume all the values of hours-of-work in [0, D] are equally available. At the other extreme, some authors assume only two or three alternatives (e.g. non-participation, part-time and full-time) are available for everyone. Aaberge *et al.* (1995) assume instead that not all the hour opportunities in [0, D] are equally available to everyone; they specify a probability density function of opportunities for each individual and the discrete choice set used in the estimation is built by sampling from that individual-specific density function[32].

Even under its more general form, the preceding specification of discrete choice models might be still found to be restrictive because it relies on some utility maximizing assumption. Two remarks are important at this respect. First, it must be clear that ex-ante incidence analysis of tax-benefit systems cannot dispense with such a basic assumption:

[31] For an extensive discussion of these specifications, see Bargain (2005).

[32] For more details on the implications of alternative methods of representing the choice set within the discrete choice approach, see Aaberge *et al.* (2006).

the ex-ante nature of the analysis requires some assumption to be made about the way agents choose between alternatives. The assumption that agents maximize some criterion defined in the most flexible way across alternatives is not really restrictive. Second, it must be clear that, if no restriction is imposed across alternatives, then the utility maximizing assumption is compatible with the most flexible representation of the way in which labour supply choices observed in a survey are related to individual characteristics, including the wage rate and the disposable income defined by the tax-benefit system, *NT(·)*.

One important thing is that model *(3)* fits the data as closely as possible: the only restriction with respect to that objective in the general expression *(3)* is the assumption that the utility associated with each alternative depends on the wage rate and on the non-labour income of an individual only through c_i^j, that is the disposable income given by the budget constraint and the tax-benefit schedule, *NT(·)*[33]. The economic structure of this model thus lies essentially in the way in which the income effect is specified. If it were not for that property, it would be simply be a reduced form model aimed at fitting the data as well as possible.

The recent literature on tax policy analysis relies heavily on discrete choice modelling that permits escaping the computational and analytical difficulties linked to utility maximization in a continuous setting. Discrete models still rely on an explicit parameterization of consumption-leisure preferences. Yet, reducing maximization to choosing the optimal alternative among a discrete set of possibilities considerably simplifies the problem and allows to rather easily account for the nonconvexities implied by actual tax-benefit systems or by fixed costs of work. In addition, it simultaneously explains participation decision and choice in work hours and enables joint labour supply decisions of spouses to be dealt with in a straightforward way.

[33] It is also necessary to check that utility is monotonically increasing with disposable income for this general specification to make any sense.

Conclusions about the behavioural approach

The role of the idiosyncratic terms, $\hat{\varepsilon}_i$ or $\hat{\varepsilon}_i^j$ in the whole approach must not be downplayed: they represent the unobserved heterogeneity of agents' labour supply behaviour. Thus, they may be responsible for some heterogeneity in response to a reform of taxes and benefits. It may be seen in *(4)* that agents who are otherwise identical might react differently to a change in disposable incomes, despite the fact that these changes are the same for all of them. For this, it is sufficient for the idiosyncratic terms, $\hat{\varepsilon}_i^j$, to be different enough.

Estimates of the idiosyncratic terms result directly from the econometric estimation of the common preference parameters, $\hat{\beta}$ in the continuous specification *(2)* or $\hat{\beta}^j$ in the discrete model *(3)*. These are standard regression residuals in the former case and so-called "pseudo-residuals" in the latter. However, one may also opt for a "calibration" rather than an econometric estimation approach. With the former, some of the coefficients are not estimated but given arbitrary values deemed reasonable by the analyst. Then, as in the standard estimation procedure, estimates of the idiosyncratic terms are obtained by imposing that predicted choices, under the status quo, coincide with actual choices.

It is important to emphasize that there is some ambiguity about who the "agents" behind the standard labour supply model *(1)* should be. Traditionally, the literature considers individual agents, even though the welfare implications of the analysis concern households. Extending the model to households requires considering simultaneously the labour supply decision of all members at working age. This makes the analysis more complex. It becomes practically intractable with the continuous representation (see, for instance, Hausman and Ruud, 1994) but only lengthens computation time with the discrete approach.

Applications of the preceding models now are numerous. They are surveyed in Blundell and MaCurdy (2000) and in Creedy and Duncan (2002a). The discrete approach underlined above is best illustrated by Van Soest (1995), Hoynes (1996) or Keane and

Moffit (1998)[34]. An application of the "calibration" approach may be found in Spadaro (2005).

In addition to labour supply and consumption patterns[35], there are other dimensions of household behaviour mattering from a welfare point of view and that may be affected by tax-benefit systems. *Oportunidades* in Mexico[36], *Bolsa Familia* in Brazil[37] and similar "conditional cash transfer programs" in several other countries, offer a clear example of policies in developing countries that can be evaluated ex ante by behavioural microsimulation models.

However, some limitations of the behavioural approach to MS modelling must be stressed. First, it has to be recognized that this approach is difficult to implement because it generally requires the estimation of an original behavioural model that fits the policy to be evaluated or designed, and of course the corresponding micro data. Because of this, it is unlikely that an analysis conducted in a given country for a particular policy can be applied without substantial modification to another country or in the same country to another type of policy. The methodological investment behind this approach may thus be important. This justifies applying first a pure arithmetical MS approach or a simpler behavioural model based on calibration. Second, the fact that the behavioural approach relies necessarily on a structural model that requires some minimal set of assumptions is to be emphasized. In general, there is no way these assumptions may be tested. In the labour supply model with a discrete choice representation, the basic assumption is that wage and non-labour income variables matter for occupational decisions only through the net disposable income they command, as given by the tax-benefit system. On the contrary, a reduced form model would be based independently on wage and non-labour income. Econometrically, the difference may be tenuous, but the implications in terms of

[34] An interesting example of discrete choice models of labour supply applied to the Spanish tax reforms can also be found in Labeaga *et al.* (2005). In particular, it can be of great interest the comparison between the results obtained from an arithmetical model such as GLADHISPANIA (see note 19), and those from a behavioural model applied to the same country and simulating a similar scenario.

[35] See Symons and Warren (1996).

[36] For more detailed information, see the website of the International Food Policy Research Institute (IFPRI): http://www.ifpri.org/themes/progresa.htm

[37] See Bourguignon *et al.* (2003c).

microsimulation results of specific policies may be huge. Finally, the strongest assumption is that cross-sectional income effects, as estimated on the basis of a standard household survey, coincide with the income effects that will be produced by the program or the reforms under study. In other words, time income effects for a given agent are assumed to coincide with observed cross-sectional income differences. Here again, this is an hypothesis that is hard to test, and yet absolutely necessary for ex-ante analysis: nothing is possible without it. The only test one can think of would be to combine ex-ante and ex-post analysis: coincidence between the results obtained in the two evaluations of a given program would support the assumption that cross-sectional and time individual specific income effects are identical[38].
Some other general issues about the modelling of behavioural responses may be taken into account. First of all, it is important to have in mind the fact that modelling human behaviour is extraordinary difficult: there are too many dimensions in which rationality may exist, too many interrelated factors involved for the task to be straightforward. Nor is it clear that the effort involved is justified by an improvement in reliability[39]. Furthermore, the advantages of transparency should not be forgotten. The greater the choice of inputs in the form of estimates of behavioural effects, the larger the scope for manipulation of model results.

Because of some possibly strong assumptions there unavoidably is some uncertainty about the prediction that comes out of ex-ante incidence analysis based on behavioural MS models. This being said, such a tool is absolutely necessary in order to reflect on the optimal design of policies that are most likely to generate strong behavioural responses. However, modelling the labour-supply response to policy changes within a model that only addresses the household sector raises the question of the supply of jobs and how this is affected, in the first place by the policy change and in the second place by the shift in labour supply. Similar problems arise in the detailed modelling of other household

[38] Rather satisfactory results have been obtained in that direction by Todd and Wolpin (2002) and Attanasio *et al.* (2003).

[39] For example, Pudney and Sutherland (1996) show that incorporating a typical simulation of female labour supply into POLIMOD, an arithmetical microsimulation model for UK (see Redmond *et al.*, 1998), can greatly increase the uncertainty with which some of POLIMOD's estimates are made.

responses to policy changes. Modelling the full or equilibrium effect of any policy change requires a model of the whole economy.

Behavioural MS models and applied optimal redistribution theory

Including behavioural response in a MS framework allows for an explicit analysis of the equity-efficiency trade-off in the spirit of standard optimal redistribution analysis. In arithmetical models, that analysis could be performed only in a very indirect way, for instance comparing social welfare indicators and the distribution of marginal effective rates across alternative tax-benefit systems, the latter being taken as an indicator of the disincentives and distortions caused by these systems. A more rigorous treatment can be used once a behavioural model has been specified. This is discussed below in the case where the behaviour of interest is labour supply.

The specification of labour supply behaviour implicitly refers to preferences represented by some utility function, as in model *(1)* above. With the same notations, let $V(w_i, y_{0i}; z_i; \beta, \varepsilon_i; \gamma)$ be the corresponding indirect utility function for individual i[40]. The social welfare function corresponding to a tax-benefit system with parameters γ may then be defined as:

$$SWF(\gamma) = \sum_{i=1}^{n} G\left[V\left(w_i, y_{0i}; z_i; \beta, \varepsilon_i; \gamma\right)\right],$$

where n is the number of agents in the population and $G[\cdot]$ is the social valuation of individual welfare. $G[\cdot]$ is an increasing and concave function, its concavity being an indicator of the level of aversion towards inequality of the redistribution authority.

Following a methodology proposed by King (1983), it is often convenient to replace the indirect utility function $V(\cdot)$ by a money metric, y_e, defined as the non-labour income that must be given to the agent in some benchmark situation to raise his/her utility to the level actually achieved with a given policy. More precisely, one may use as a benchmark the

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[40] Given the utility maximization problem budget constraint for individual i, under his/her budget constraint, as: {Max $u(x)$ s.t. $p{\cdot}x \leq w$}, where $w > 0$ is the wealth level of individual i and $p > 0$ the vector of good prices, the solution to this problem is the Marshallian demand function $x(p,w)$, which is a function of prices and wealth level. For each $(p,w)>0$, the utility value of the problem is denoted $v(p,w) \in \Re$, and it is equal to $u(x^*)$ for any $x^* \in x(p,w)$. The function $v(p, w)$ is called the indirect utility function.

case where the individual does not work because his/her productivity is too low, say zero, and the tax-benefit system is defined by the set of parameters γ^0. Let $V_i = V(w_i, y_{0i}; z_i; \beta, \varepsilon_i; \gamma)$ be the utility actually achieved by individual i when the parameters of the tax-benefit system are γ. Then, a money metric $y_e(V_i)$ of V_i using the tax-benefit system γ^0 and the case $w_i = 0$ as a benchmark, is given by the solution to the equation:

$$V\left[0, y_e(V_i); z_i; \beta, \varepsilon_i; \gamma^0\right] = V_i . \qquad (5)$$

The social welfare function may then be defined on the money metric of utility, rather than on the utilities themselves:

$$SWF(\gamma) = \sum_{i=1}^{n} \Gamma\{y_e[V(w_i, y_{0i}; z_i; \beta, \varepsilon_i; \gamma)]\},$$

where $\Gamma(\cdot)$ may now be given the usual interpretation of the social utility of individual "income". The obvious advantage of that transformation of the initial expression of social welfare is that it does not depend any more on the cardinalisation of the utility function used to represent individual preferences.

Within such a framework, it is possible to perform comparative social evaluation of alternative redistribution policies, as summarized by sets of parameters γ^A and γ^B. This only requires being able to compute the indirect utility functions for each individual i in the population, inverting it as in *(5)* thanks to some numerical algorithm, and evaluating the social welfare function associated to each system.

Behavioural MS models and the computation of social welfare according to the equations above make possible some simple application of the optimal taxation literature. The simplest application consists of comparing two tax-benefit systems, as characterized for instance by two sets of parameters, γ^A and γ^B, and to determine which system leads to the highest level of social welfare. Of course, the comparison makes sense only if the budget of the redistribution authority is the same in the two systems, that is if tax receipts net of transfers are the same with γ^A and γ^B [41]. This corresponds to the standard "government budget constraint" in optimal taxation models.

A very similar type of application consists of investigating the effects of modifying some subset of the parameters, γ, of a tax-benefit system and to see whether this improves the

[41] An example of this approach is provided by Spadaro (2005), where the 1995 French and British tax-benefit systems are micro-simulated respectively on samples of French and UK households in order to find which system is the "best" for a given level of social aversion to inequality and for each population.

social welfare function, allowing, of course, for constant government budget. If this exercise is repeated for a broad enough set of alternative definitions of the social welfare function, this is equivalent to investigating "Pareto-improving" reforms of the initial tax-benefit system[42].

2.2. Static *vs* Dynamic Models

The data on which MS models usually rely on are based upon administrative data or upon a sample survey of the population. In both cases, the microdata usually contain thousands of individual or family records, with a host of variables describing the demographic, labour force, income and other characteristics of each individual or family. As a consequence of the fact that there is frequently a lag of several years between the collection of microdata and its public release by an agency, the data have to be "aged" to simulate the impact of current (or future) government policy. Whether the data are aged "statically" or "dynamically" is a major difference between the various types of MS models[43].

In a *static* framework, the size and demographic characteristics of the population are fixed; these models are most frequently used to provide estimates of the immediate distributional impact of policy changes. On the other hand, *dynamic* settings consider in an endogenous way the demographic phenomena that affect the original population, such as changes in the mortality and fertility rates, in the intertemporal consumption allocation, in retirement or in the time taken out for education[44].

The ageing in *static* MS models involves two basic steps: *reweighting* and *uprating*. The first one, sometimes also called grossing-up, as outlined previously, implies changing the weight attached to each individual record in the microdata, to reflect economic and social change since the data were collected. For example, when a survey was originally

[42] Ahmad and Stern (1984) have pioneered this type of application of MS models in the case of indirect taxation.

[43] See the introductory chapter to Harding's (1996) book on MS.

[44] For a detailed literature review on dynamic MS modelling see O'Donoghue (2001).

conducted, the central statistical agency might have decided that there were 400 people in a particular country with similar characteristics to the first person on a particular microdata file. Four years later, due to an increase in, say, unemployment or the incidence of sole parenthood, more recent data might suggest that there are now 450 people with similar characteristics to the first person in the microdata file. The weight of the first person would thus be increased to reflect this, while the weights of other records in the file might be decreased. Reweighting has typically been used to age sample surveys by a few years, in order to bring them up to date, but in general they have not been used for exploring some decades into the future.

The principal aim of the other key technique, *uprating*, is instead to adjust monetary values within the original microdata to account for estimated movements since the time of the survey. For example, earnings or rent paid are typically increased to account for growth since the survey, although there are different possible approaches of uprating procedures.

After these two steps, static modellers typically impute the receipt of social security and other benefits and/or income tax or other liabilities, by applying the rules for eligibility or liability to each of the microunits. At this point, a baseline data file has been generated; most static models allow then the analyst to vary these rules, and produce output showing the gains or losses, and the cost to revenues and the government budget from the policy change. In this case we have an arithmetical or accounting model as described before; when instead the modeller attempts to simulate the changes in the behaviour of the individuals directly affected by a policy shock (for example, by allowing the labour supply and consumption patterns to vary in response to a tax change), we have a behavioural model.

The time dimension of MS models depends on the object of the analysis and the kind of behavioural response that is incorporated in the model. For instance, evaluating the effects of a reform of the income tax that would modify the treatment of children will have little effects on household composition in the short-run; however, long-run effects require simulating the impact on fertility decisions of the tax reform, and a dynamic framework may then become necessary. Likewise, changes in the parameters of the tax-benefit system that affect intertemporal consumption allocation, retirement, training, schooling, etc., must be analysed with dynamic MS models rather than static models.

Dynamic MS models applied to economics were first introduced in the United States at the end of the 1960's. Since the 1980's, they have been rapidly developing due to the increase in computational capabilities and to the availability of longitudinal data (or "panel data"). However, such data frequently are not easily accessible and, moreover, they necessarily are historically dated and consequently may not be of very much relevance for simulating the forward-looking effects of a change in policy. Rather than relying on actual panel data, thus, *dynamic* MS models often start from the same cross-section sample surveys as *static* models. However, the individuals within the original microdata are then progressively moved forward through time by making major life events – such as death, marriage, divorce, fertility, education, labour force participation, etc. – happen to each individual according to the probabilities of such events happening to real people within a particular country. In such a way, the characteristics of each individual are recalculated for each time period. Transition probabilities themselves are obtained from different sources – for example from comprehensive longitudinal or panel surveys which would allow one to set such probabilities with some confidence; they are assumed to be constant[45], so that the society is supposed to be in some kind of steady state, and they are supposed to be independent of the policy being analyzed. Thus, this kind of models age each person in the microdata file from one year to the next by probabilistically deciding whether or not that person will get married, get divorced, have a child, drop out of school, get a job, change jobs, become unemployed, retire, or die.

There are two major types of dynamic MS models. *Dynamic population* models involve ageing a sample of an entire population, and typically begin with a cross-section sample survey for a particular point in time. Such dynamic models have been used for different purposes, such as the analysis of retirement incomes, future health status, the long-term impact of social security amendments, and the lifetime redistributive impact of the social security system.

Dynamic cohort models use exactly the same type of ageing procedures, but usually age only one cohort rather than the many cohorts represented in an entire population. Typically, one cohort is aged from birth to death, so that the entire lifecycle is simulated.

[45] In a dynamic behavioural MS model, transition probabilities should partly become endogenous and reactive to the intertemporal budget constraint faced by agents. Browning *et al.* (1999) and Blundell and MaCurdy (2000) contain an excellent discussion about these problems.

For some applications, such models are more cost-efficient than ageing an entire population in terms of computational costs. Such models have been used to analyse lifetime income redistribution, lifetime rates of return to education, and repayment patterns for student income-contingent loans[46].

2.3. Conclusions

One of the peculiarities of MS models is that they allow to identify precisely who are the gainers and losers of a reform, as they provide information on the way every individual or household in a sample is affected by the reform. However, in order to obtain some significant information at the policy level, the changes in disposable income due to the reform are usually given for groups, which are derived from the aggregation of individuals or households according to their socio-demographic characteristics. Most models also provide changes in several welfare indicators computed on the whole population: these include, among others, the mean disposable income per adult equivalent, a number of inequality indices (Gini, Theil and Atkinson's measures), several poverty indicators (FGT indices[47], for instance), and the application of relative or absolute Lorenz dominance criteria[48].

The importance and usefulness of microsimulation techniques in the analysis of public policies come essentially from two aspects: first of all, microsimulation models allow the explicit accounting for the heterogeneity of economic agents as they are observed in micro-data sets; the second aspect concerns the possibility of accurately evaluating the aggregate financial cost/benefit of a reform: indeed, the results obtained with a MS model at the level of individual agents can be aggregated at the macro level allowing the analyst to evaluate the effect of the policy on the government budget constraint. Because

[46] For instance, Baldini (1997) analyses the redistributive impact of the Italian tax-benefit system over the life cycle utilizing a dynamic cohort model.

[47] It's the commonly used Foster-Greer-Thorbecke (FGT) class of indices for the measurement of poverty. See Foster, Greer and Thorbecke (1984).

[48] For a complete survey on welfare dominance theory, see Lambert (1993).

of these strong advantages over the representative agent approach, and also because of continuing progresses in data availability and computing facility, the microsimulation approach to economic policy analysis is bound to intensify and to deepen in next future.

One of the principal limits of MS models is that they are usually partial equilibrium models with a particular focus on the household side of the economy: the explanatory power of MS models generally ends with the determination of changes to disposable income. They do not simulate the response of the production side of the economy and further economic activity thereby generated, missing out a significant part of the economic process: the possible general equilibrium effects of a policy reform. In particular, when dealing with substantial policy changes, it is essential to take into account their macroeconomic effects because they are likely to influence the microeconomic outcomes[49].

This is one of the reasons why, in last years, a growing group of works is focusing on the introduction of heterogeneous consumers and workers, whose characteristics are specified by reference to micro data (and especially to household surveys), in general equilibrium models.

3. LINKING MICROSIMULATION AND CGE MODELS[50]

The idea of linking the two approaches appeared for the first time in the work by Dervis, de Melo and Robinson (1982). Nonetheless, their idea had to wait until the end of the 1990s to see its first realizations by Decaluwé *et al.* (1999b) and Cogneau (1999). It's only from then on that the literature on this subject has been flourishing[51]. The aim of

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[49] For example, consider the case of a reform of the tax system which generates large enough labour supply effects: then, changes in the structure of wages and prices may be expected to take place.

[50] Parts of this paragraph draw on Savard (2003) and on Bourguignon *et al.* (2003b).

[51] See for instance Bourguignon *et al.* (2003b) with their model for Indonesia, Cogneau and Robilliard (2004) who built a model for Madagascar, and, among the most recent works, see Hérault (2005) with a

combining these models is to exploit the advantages of CGE and MS models and to offset their main drawbacks, which are essentially the limitations arising from the representative household assumptions for CGE models and the lack of general equilibrium effects for MS models. The existing literature on this subject has followed different ways in the attempt of linking the two types of models[52]. We present an analysis of the advantages and drawbacks of the various approaches that are nowadays implemented in the literature. The main advantages of all the approaches, compared to the RH approach, are that they allow for intra-group distribution analysis and that it is not necessary to adopt any prior grouping of households or individuals. This way, all the approaches leave the modeller free from pre-selecting households grouping or aggregation, and thus able to investigate the sensitivity of results to different policy reforms.

3.1. The Integrated Approach

The first and most immediate possibility of linking CGE and MS models consists in moving from representative to "real" households within the CGE approach: it suffices to replace the small number of RHs by the full sample in the household survey in order to capture the heterogeneity of households' characteristics[53]. With such a model, one can explore how household heterogeneity combines with market mechanisms to produce more or less inequality in economic welfare as a consequence of shocks or policy changes. With the fast development of computing efficiency over the last few years,

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study on South Africa, Cororaton and Cockburn (2005) on Philippines, and Chitiga *et al.* (2005) on Zimbabwe.

[52] See Savard (2003 and 2004), Davies (2004) and Cororaton and Cockburn (2005) for a more extensive survey of the different approaches.

[53] The first attempt in this direction was made by Decaluwé *et al.* (1999b). Among the models following this approach there are the works by Cockburn (2001) for Nepal, by Cogneau and Robilliard (2001) for Malagasy economy, by Boccanfuso *et al.* (2003a) for Senegal, and the more recent work by Cororaton and Cockburn (2005), who studied the case of Philippine economy.

these so-called integrated CGE-MS models can incorporate as many households as found in household surveys. The logic according to which this approach of linking a household survey with a CGE model does work is illustrated in Figure 3.

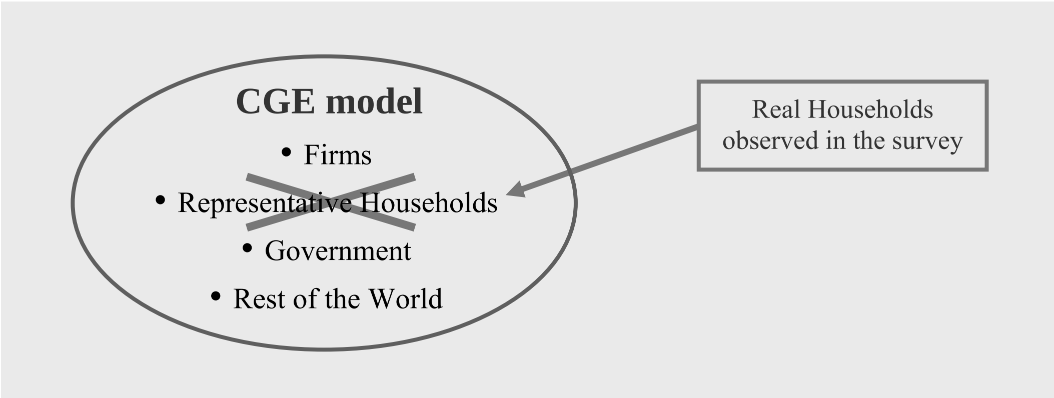

Figure 3 – Integrated CGE-MS Models

The main disadvantages of this approach are the limits it imposes in terms of microeconomic behaviour[54] and the fact that the size of the model can quickly become problematic, thus making the data reconciliation process relatively difficult. Indeed, a procedure for reconciling household survey data (incomes and expenditures) and their adjustment with the social accounting matrix (SAM) must be adopted to balance out both accounts. The literature on data reconciliation offers different alternatives. One may keep the structure of the SAM and adjust the household survey. This method has the advantage to save the structure of the economy but it is likely to change the structure of income and expenditure in the household survey. The other alternative is to adjust the SAM to meet the totals of the household survey, loosing in this way some information

[54] Certain types of equations that are commonly included in a behavioural model, and especially switching regime equations, are not easily modelled within standard CGE modelling softwares (to this regard, see Savard's discussion about the limits and advantages of the various approaches of linking, 2003), so that CGE-MS models that follow the fully integrated approach are not always able to capture the behavioural responses of the agents to the policy reforms that are implemented.

contained in the structure of national accounts[55]. Another alternative may be that of using an intermediate approach. For example, one may keep the initial structure of consumption from the household survey and adjust the corresponding accounts in the SAM, and with regards to income one can adjust the household survey to meet the national data based on the SAM[56]. Whatever the method used, however, it is clearly best to adjust least those estimates in which researchers have greatest confidence.

After these changes in the initial SAM, one has also the problem of re-balancing it (row totals must be equal to column totals). In order to do this, one can use a SAM balancing program designed for this purpose. These programs can be based on different principles, such as on the "Row and Sum", or RAS, method (see Bacharach, 1971), on a least squares minimization principle, known also as Stone-Byron method[57], or on the cross-entropy approach proposed by Robinson *et al.* (2001) and Robilliard and Robinson (2003).

A practical example may be useful to understand better the problem of data reconciliation. We will consider a very simple survey with a sample of five households, who are supposed to be representative of the whole population. Of course, this is only a simplified example; household surveys are usually made up of samples containing thousands of observations. Moreover, as this is a simplified example, we do not consider the procedure of stratification which is normally used to draw a sample (this procedure is anyway described in detail in section 2). The population is composed of 1000 families, in which live 2500 adults and 2900 children as a whole. The household survey is reported in Table 2. The economy considered here is a very simple one: households' income is obtained by the employment of two factors, labour and capital, plus some public transfers, and the only tax levied by government is a direct income tax; the monetary data may be, for instance, in ten thousands of a given monetary unit. Now, in order to carry the micro-data (which are referred to a single household) forward to population data, we have to use an equivalence scale. Indeed, it is obvious that a family composed of one

[55] The first alternative of modifying the structure of the household survey may be preferred to the latter in some cases, due to the fact that one will often find some under or over reporting for items in the household surveys.

[56] See for example Annabi *et al.* (2005).

[57] See Stone (1977) and Byron (1978).

individual who perceives an income of one thousand monetary units has not the same purchasing power as could have a family receiving the same income with four children dependent. One solution could be that of dividing the household income by the number of family members. However, one should also consider the fact that some scale economies are likely to arise when people live in the same house (for instance, the electricity consumed by a two-members family is not double of that consumed by one individual), and in special way when there are some children living in the family (in the common meaning, children are considered to consume less than what can spend an adult). There are different measures one can adopt. We have chosen the following equivalence scale:

$ES = 1 + 0.7 \cdot (Adults - 1) + 0.5 \cdot Children$

Thus, given our population, we can build an "average" family with 2.5 adults and 2.9 children:

$ES = 1 + 0.7 \cdot (2.5 - 1) + 0.5 \cdot (2.9) = 3.5$ *Adult Equivalents*

Thus, in our economy there are in total 3500 adult equivalents. We can now compute the sample weights ω_h for each of the families in the survey: after having calculated the number of adult equivalents for each household (for example, in H_1 there are 2.2 adult equivalents), it is sufficient to divide it by the total number of adult equivalents of our representative sample (15.2). The results are reported in Table 3 below. Now, we know that the adult equivalents of the first household in the survey, H_1, represent the 14.47 % of all the adult equivalents in the population, the 22.37 % of population adult equivalents are represented by the adult equivalents in the second family of the sample, H_2, and so on. This way, by multiplying these weights by the total number of adult equivalents in the population, we obtain the number of population adult equivalents living in that type of representative household (H_1, H_2, etc.). Thus, after having computed the per-capita per adult equivalent values of the variables in the survey (for this, it is sufficient to divide income, consumption expenditure, labour and capital income, public transfers, etc. of each household in the survey by the corresponding number of sample adult equivalents; see Table 4), and multiplying them by the number of population adult equivalents, we can find the population values corresponding to each household type. The results for our sample are reported in Table 5.

Table 2 – Household Survey, an Example

	CE_1	CE_2	S	Y	LY	KY	TF	TY
H_1	0.4343	0.7817	-	1.2160	0.5646	0.4343	0.2171	-
H_2	1.0423	1.0857	0.0751	2.5623	1.3029	1.1726	0.0869	0.3592
H_3	0.8686	1.1726	0.0560	2.3886	1.1726	1.0857	0.1303	0.3348
H_4	1.3029	2.1714	0.8056	5.8629	2.1714	3.6914	-	1.5830
H_5	1.7371	2.1714	0.4095	5.2983	3.0400	2.2583	-	0.9802

CE_i: consumption expenditure for commodity *i*; ***S***: savings; ***Y***: income; ***LY***: labour income; ***KY***: income from capital; ***TF***: transfers received from government; ***TY***: amount of income taxes paid to government (direct taxes).

Table 3 – Adult Equivalents and Sample Weights

	Number of Adults	Number of Children	Sample Adult Equivalents	Sample Weights (ω)	Population Adult Equivalents
H_1	2	1	2.2	14.474%	506.579
H_2	3	2	3.4	22.368%	782.895
H_3	1	3	2.5	16.447%	575.658
H_4	2	3	3.2	21.053%	736.842
H_5	3	3	3.9	25.658%	898.026
Total	11	12	15.2	100.000%	3500.000

Table 4 – Per-capita Per Adult Equivalent Values

	CE_1	CE_2	S	Y	LY	KY	TF	TY
H_1	0.1974	0.3553	-	0.5527	0.2566	0.1974	0.0987	-
H_2	0.3066	0.3193	0.0221	0.7536	0.3832	0.3449	0.0255	0.1056
H_3	0.3474	0.4690	0.0224	0.9554	0.4690	0.4343	0.0521	0.1339
H_4	0.4071	0.6786	0.2518	1.8321	0.6786	1.1536	-	0.4947
H_5	0.4454	0.5568	0.1050	1.3585	0.7795	0.5790	-	0.2513

Table 5 – Weighted (Population Values) Household Survey

	CBUD	CE_1	CE_2	S	YD	Y	LY	KY	TF	TY	ty
H_1	280	100	180	0.0	280.0	280	130	100	50	0.0	0
H_2	490	240	250	17.3	507.3	590	300	270	20	82.7	14.0%
H_3	470	200	270	12.9	472.9	550	270	250	30	77.1	14.0%
H_4	800	300	500	185.5	985.5	1350	500	850	0	364.5	27.0%
H_5	900	400	500	94.3	994.3	1220	700	520	0	225.7	18.5%
Total	2940	1240	1700	310.0	3240.0	3990	1900	1990	100	750.0	

See Table 2. ***CBUD***: consumption expenditure; ***YD***: disposable income; ***ty***: direct income tax rate.

Table 6 – Original SAM of the Economy

	C_1	C_2	S_1	S_2	K	L	G	H	SI	ROW	Total
C_1			300	900			50	1200	250	100	2800
C_2			500	1000			250	1700	50	400	3900
S_1	2800										2800
S_2		3900									3900
K			1475	425			50				1950
L			175	1425			300				1900
G								750			750
H					1950	1900	100				3950
SI								300			300
ROW			350	150							500
Total	2800	3900	2800	3900	1950	1900	750	3950	300	500	

C_i: consumption of commodity *i*; ***S_i***: sector *i*; ***K***: capital account; ***L***: labour account; ***G***: public sector account; ***H***: representative household account; ***SI***: savings-investment account; ***ROW***: foreign sector account.

The data presented in Table 5 can now be compared to the national accounts that we observe in the SAM for this economy, in Table 6. As we can easily see, however, the aggregated data observed in the survey do not coincide with those presented in the SAM. One may think that there is some under or over reporting in survey data and adjust them to national accounts, or choose to save the structure of the household survey and adjust the national data of the SAM. Here, we want to keep fixed the consumption and income data from the survey; thus, we run an appropriate program that minimizes least squares in order to re-balance the SAM, after having introduced into it the data from the survey, and in particular the five household accounts. This way, of course, we will loose part of the original structure of the national accounts. The new balanced SAM is reported in Table 7.

Thus, it must be stressed as one of the main disadvantages of the integrated approach the fact that the data reconciliation process will necessarily lead to changes in structure of either the micro-data on income and expenditures of the household survey, or the national accounts' data contained in the SAM.

Another difficulty of this approach is the problem of identifying the heterogeneity of factor endowments or preferences at the level of a single household or individual. Indeed, as this approach treats with every single household observed in the survey, it automatically loses any possibility of characterization of the socio-economic structure in the model.

Table 7 – Re-Balanced SAM with Five Households

	C_1	C_2	S_1	S_2	K	L	G	H_1	H_2	H_3	H_4	H_5	SI	ROW	Total
C_1			299.314	891.151			49.893	100.0	240.000	200.000	300.000	400.000	255.134	99.926	2835.418
C_2			498.966	992.559			247.548	180.0	250.000	270.000	500.000	500.000	50.215	399.374	3888.662
S_1	2835.418														2835.418
S_2		3888.662													3888.662
K			1512.526	427.518			49.956								1990.000
L			175.141	1427.605			297.254								1900.000
G								0.0	82.731	68.632	367.913	226.645			745.921
H1					100.0	130.0	49.956								280.000
H2					270.0	300.0	19.995								589.995
H3					250.0	270.0	31.275								551.275
H4					850.0	500.0									1350.000
H5					520.0	700.0									1220.000
SI								0.0	17.264	12.643	182.087	93.355			305.349
ROW			349.471	149.829											499.300
Total	2835.418	3888.662	2835.418	3888.662	1990.0	1900.0	745.921	280.0	589.995	551.275	1350.000	1220.000	305.349	499.300	

We can build a little CGE model for our archetypical economy, using the new SAM containing the data from the household survey (Table 7), in order to fully understand how this approach really works in practice. The CGE designed for this aim has the following characteristics:

- five households with a Cobb-Douglas utility function;
- two commodities, used in production and consumption;
- four production factors: capital, labour and both commodities;
- two firms with Leontief technology in value added and intermediate aggregate inputs;
- Cobb-Douglas aggregator function for capital and labour;
- Leontief aggregator function in intermediate inputs;
- capital and labour are mobile among sectors and exogenously fixed;
- public sector: government maximizes a Cobb-Douglas utility function, buys consumption goods, uses labour and capital, raises taxes on income and pays transfers to households;
- savings and investments (investments are savings-driven);
- open economy, with Armington assumption for the composite good aggregation, and exports demand depending on the world price.

The equations relative to this CGE model, called *CGE_HH*, are presented in Table 8.

With this model calibrated on the SAM with five households (Table 7), we simulate an exogenous shock: a 30% increase in the price of imports of the good imported by sector 1. We report in Tables 10 and 11 the resulting changes in some of the variables and the inequality indices (Gini, Atkinson's, Theil, etc.) computed after the shock. We used disposable income per Adult Equivalent (the variable YD_h in the model divided by the number of Adult Equivalents) as reference variable for these computations.

Table 8 – CGE Model Equations

Consumption demand	$P_i \cdot C_{hi} = \alpha H_{hi} \cdot CBUD_h$ $\quad i = 1,2$ and $h = 1,2,3,4,5$
Savings	$S_h = mps_h \cdot (1 - ty_h) \cdot Y_h$
Production function	$XD_i = aF_i \cdot K_i^{\alpha F_i} \cdot L_i^{(1-\alpha F_i)}$
Tangency condition	$\frac{PK}{PL} = \frac{\alpha F_i}{(1-\alpha F_i)} \cdot \frac{L_i}{K_i}$
Investment demand	$P_i \cdot I_i = \alpha I_i \cdot \sum_{h=1}^{5} S_h$
Price of exports (local currency)	$PE_i = PWE_i \cdot ER$
Price of imports (local currency)	$PM_i = PWM_i \cdot ER$
Armington function	$X_i = aA_i \cdot \left[\gamma A_i \cdot M_i^{\frac{\sigma A_i - 1}{\sigma A_i}} + (1-\gamma A_i) \cdot XDD_i^{\frac{\sigma A_i - 1}{\sigma A_i}} \right]^{\frac{\sigma A_i}{(\sigma A_i - 1)}}$
Imports demand	$M_i = \frac{X_i}{aA_i} \cdot \left(\frac{\gamma A_i}{PM_i} \right)^{\sigma A_i} \cdot$ $\left[\gamma A_i^{\sigma A_i} \cdot M_i^{(1-\sigma A_i)} + (1-\gamma A_i)^{\sigma A_i} \cdot XDD_i^{(1-\sigma A_i)} \right]^{\frac{\sigma A_i}{(1-\sigma A_i)}}$
Exports demand	$E_i = EZ_i \cdot \left(\frac{PWE_i}{PWEZ_i} \right)^{\eta_i}$
Market clearing condition for labour	$\sum_{i=1}^{2} L_i + LG = \sum_{h=1}^{5} LS_h$
Market clearing condition for capital	$\sum_{i=1}^{2} K_i + KG = \sum_{h=1}^{5} KS_h$
Market clearing condition for commodity *i*	$XD_i + M_i = \sum_{j=1}^{2} io_{ij} \cdot XD_j + CG_i + \sum_{h=1}^{5} C_{hi} + I_i + E_i$
Income definition	$Y_h = PK \cdot KS_h + PL \cdot LS_h + PL \cdot TF_h$
Disposable income	$CBUD_h = (1 - \gamma_h) \cdot Y_h - S_h$
Zero profit condition in production	$PD_i \cdot XD_i = PK \cdot K_i + PL \cdot L_i + \sum_{j=1}^{2} io_{ji} \cdot XD_i \cdot PD_j$
Zero profit condition in Armington function	$P_i \cdot X_i = PM_i \cdot M_i + PD_i \cdot XDD_i$
Zero profit condition in exports supply	$PD_i \cdot XD_i = PE_i \cdot E_i + PD_i \cdot XDD_i$
Demand of commodity *i* by government	$P_i \cdot CG_i = \alpha CG_i \cdot \left(TAXREV - PL \cdot \sum_{h=1}^{5} TF_h \right)$

Demand of capital by government	$$PK \cdot KG = \alpha KG \cdot \left(TAXREV - PL \cdot \sum_{h=1}^{5} TF_h \right)$$
Demand of labour by government	$$PL \cdot LG = \alpha LG \cdot \left(TAXREV - PL \cdot \sum_{h=1}^{5} TF_h \right)$$
Tax revenues	$$TAXREV = \sum_{h=1}^{5} ty_h \cdot Y_h$$
Number of variables: 76 Number of equations: 56 Number of exogenous variables: 20 Walras' Law is satisfied	Exogenous variables: - exogenous capital endowment (KS_h) - exogenous labour supply (LS_h) - exogenous public transfers (TF_h) - exogenous world prices (PWE_i, PWM_i) - fixing the numeraire (wage rate, PL)
Variables: PK return to capital PL wage rate ER exchange rate P_i Armington composite good prices PD_i production prices PE_i imports prices (local currency) PM_i exports prices (local currency) KS_h capital endowment (exogenous) LS_h labour endowment (exogenous) XD_i gross domestic output X_i sales on the domestic market E_i exports M_i imports K_i capital demand by firms KG capital demand by government L_i labour demand by firms LG labour demand by government I_i investment demand C_{hi} consumer commodity demand CG_i government commodity demand Y_h household *h*'s income S_h household *h*'s savings	PWE_i imports world prices (exogenous) PWM_i exports world prices (exogenous) XDD_i internal production for the domestic market $CBUD_h$ disposable income of household *h* $TAXREV$ tax revenues TF_h real public transfers to household *h* **Parameters:** ty_h direct income tax rate for household *h* mps_h marginal propensity to save of household *h* io_{ij} technical coefficients aF_i efficiency parameter in production function of firm *i* αF_i C-D power of capital in production function of firm *i* αI_i C-D power in bank's utility function αH_{hi} C-D power of commodity *i* in household *h* utility f. αCG_i C-D power of commodity *i* in government utility f. αKG C-D power of capital in government utility function αLG C-D power of labour in government utility function aA_i efficiency parameter in Armington function γA_i share parameter in Armington function σA_i elasticity of substitution in Armington function η_i price elasticity of exports demand

With respect to the limit to microeconomic behaviour, note that CGE modelling imposes that behavioural functions respect certain conditions: for example, modelling switching regimes is not easy to introduce with current CGE modelling softwares, as the equation system of the model cannot change as the iteration process moves along. Indeed, integrated models often rely on relatively simple microsimulation models focusing on only one or two dimensions of household (or individual) behaviour. Yet, it is not clear

that this type of model may be convincingly used to describe the full complexity of household income inequality and the way it may be affected by macroeconomic policies. To this extent, micro-econometric modelling provides much more flexibility in terms of the modelling structure used.
Moreover, when the size of the model becomes problematic, the modeller may be forced to impose some simplifications either on the complexity of microeconomic household behaviours or on the size of the CGE model in terms of the number of sectors and factors of production.

3.2. The Top-Down Approach

The idea of this approach is to develop separately a MS model and then to run the simulation on the basis of changes in consumer/producer prices, wages, and sectoral employment levels as predicted by some macro model, a CGE model in this case. This approach does not try to integrate the two models, but uses instead a CGE and a MS model in a sequential way: first, the policy reform is simulated with the CGE model, and the second step consists of passing the simulated changes in some variables (usually prices, wage rates, self-employment incomes and possibly employment levels[58]) down to

[58] When the assumption of imperfect labour market is adopted, or when the presence of a formal and an informal sector is predicted, the rationing in the labour market is usually carried out in the macro or CGE model, while the main use of the MS module is to select those households or individuals who will actually be barred out of, or let in, employment, or the formal sector.

the MS module[59]. The logical scheme followed by this approach is illustrated in Figure 4[60].

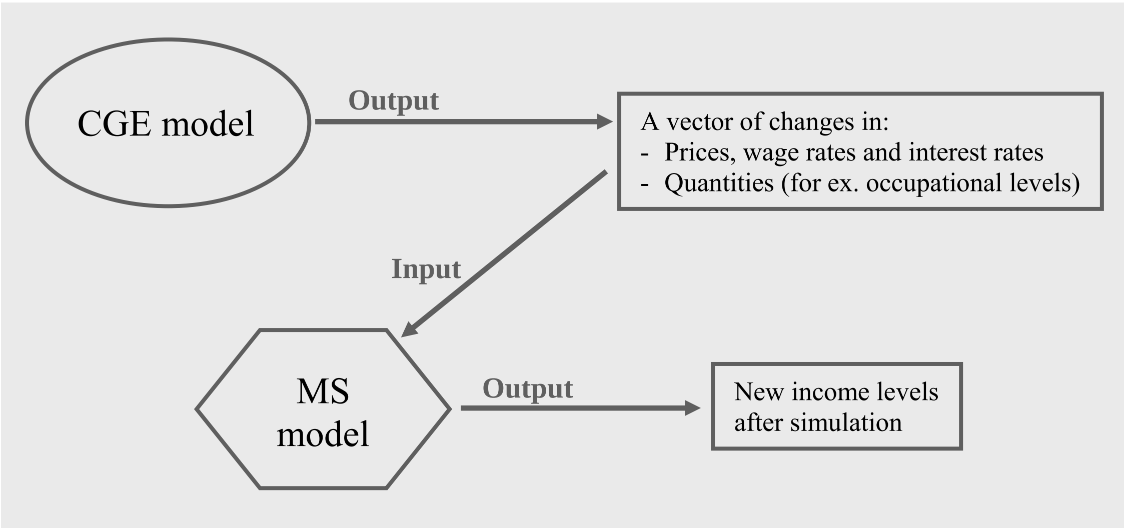

Figure 4 – The Top-Down Approach

[59] This CGE-MS approach was developed by Bourguignon *et al.* (2001) in a model that simulated the effects of the 1997 crisis in Indonesia. However, there are preceding examples of models designed in this two-layered fashion: see for instance Meagher (1993): a dynamic applied general equilibrium model (the well-known MONASH model) for Australia is used together with the 1990 Australian income survey to bear on a forecast of the incomes of various groups of individuals. Another example of linkage between a macro model and a MS model is the analysis of the distributional consequences of China's accession to WTO by Chen and Ravallion (2003).

[60] In principle, one should also mention the possibility of a "Bottom-Up" approach. That is, a framework in which the link between the two models goes in the opposite direction: from the micro to the macro level of analysis. For instance, one could think of implementing a reform of the tax-benefit system with the microsimulation model, then to pass the changes in some relevant variables (such as labour supply, disposable income or consumption levels, for instance) onto the CGE model, and finally to run the CGE model to check the general equilibrium effect of the reform. Anyway, the use of a Top-Down approach is more common, at least in the literature on developing countries.

The basic difficulty of this approach is to ensure consistency between the micro and macro levels of analysis. For this reason, one may introduce a system of micro-macro consistency equations that ensure the achievement of consistency between the two levels[61]. Thus, what happens in the MS module can be made consistent with the CGE modelling by judiciously adjusting parameters in the MS model, but, from a theoretical point of view, it would be more satisfying to obtain consistency by modelling behaviour identically in the two models.

We will build a simple CGE-MS model following this approach, in order to make clear the passages of variable changes from one model to the other and the problem of the so-called consistency equations. Let's consider the economy described in the previous section: the CGE model will be very similar to that one, except for the number of households. In this case, in fact, we will have only one representative household in the CGE model, while the household survey of Table 2 will be used to set up an arithmetical (accounting) MS framework, and will stay out of the CGE model. The SAM on which the CGE is calibrated is the one presented in Table 6, while the equations are the same equations described in Table 8 for the previous model, except for the index *h*, referred to households, which disappears in this model (there is only one representative household). We have now 36 equations and 44 variables; having fixed 8 exogenous variables, we have that the model is fully determined and a redundant equation according to Walras' law.

The MS module is very simple, and it is derived from the micro-data on income and expenditure observed in the survey (Table 2): households' income is obtained by the employment of two factors, labour and capital, plus some public transfers; the only tax levied by government is a direct income tax (to make the model more realistic, one could add also indirect taxes on consumption, social security contributions, capital taxation, etc.). The equations of the MS model are reported in Table 9; they are simple

[61] This way, at the micro level, one adjusts all individual wage rates and all self-employment incomes by the same percentage as obtained in the CGE simulation, and, similarly, the utility from working or being self-employed is adjusted in such a way as to produce employment changes in the MS module equal to those found in the CGE calculations. When the functions involved are not linear, the parameter adjustments needed to achieve consistency with the CGE results are more complicated.

arithmetical computations, as the only behavioural parameters in the model are the marginal propensity to save, mps_h, and the shares of consumption expenditure, η_{hi}, which are fixed on the basis of survey data, and kept constant after simulations. We also assume for simplicity that both prices, the wage rate and the return on capital are all equal to one in the base year, in both the CGE and MS models. This way, in the MS model, we have the same amounts to indicate initial monetary values, CE_{hi}, LY_h, KY_h, and quantities, respectively, C_{hi}, L_h, K_h.

Table 9 – MS Model Equations

Exogenous variables: TF_h: public transfers received by household *h* L_h: labour supply of household *h* K_h: capital endowment of household *h*	
Parameters derived from the survey:	
Share of consumption expenditure for commodity *i*	$\eta_{hi} = CE_{hi}/CBUD_h$
Income tax rate for household *h*	$ty_h = TY_h/Y_h$
Marginal propensity to save of household *h*	$mps_h = S_h/YD_h$
Equations of the model:	
Household *h*'s income	$Y_h = LY_h + KY_h + TF_h$
Household *h*'s disposable income	$YD_h = (1 - ty_h)\cdot Y_h$
Household *h*'s savings	$S_h = mps_h \cdot YD_h$
Household *h*'s consumption expenditure	$CBUD_h = YD_h - S_h$
Consumption expenditure for commodity *i*	$CE_{hi} = \eta_{hi} \cdot CBUD_h$
Amount of taxes paid to government	$TY_h = ty_h \cdot Y_h$
Consumption levels	$C_{hi} = \dfrac{CE_{hi}}{(1+\Delta P_i)}$
Labour supply of household *h*	$L_h = \dfrac{LY_h}{(1+\Delta PL)}$
Capital endowment of household *h*	$K_h = \dfrac{KY_h}{(1+\Delta PK)}$

We will apply to this model the same policy simulation described in the previous section: a positive shock to the price of the good imported by sector 1. First, we run the CGE and obtain some percentage changes in all the variables of the model; however, we are interested only in the variation that we observe in prices, wage rate and capital return (if the model were more complicated, we could also be interested in the variation of employment levels, for instance, or we could observe different wage rates if the model showed the presence of a segmented labour market). In our model we have chosen the wage rate as the numeraire, so that we observe a change only in the two prices, P_i, and in the capital return, *PK*:

$\Delta P_1^{CGE} = 3.058\%$,

$\Delta P_2^{CGE} = -0.054\%$,

$\Delta PK^{CGE} = 0.559\%$.

We take these percentage changes and pass them onto the MS module; we can do this easily, as the MS schedule exhibits exogenous prices and return to capital (equal to one in the base year). Things get a bit more complicated when the variables in the household model are endogenous, and especially when the MS model is a behavioural one. For example, consider a MS model with labour supply response, with the possibility of non-participation (i.e. unemployment). In this case, the unemployment level in the household model is no longer an exogenous variable, but it is determined by the labour supply function; however, changes in the number of workers in the MS model must match those same changes in the CGE model. Thus, a choice may be to impose these variable changes from the CGE model onto the micro level of analysis (and this is obtained by modifying some specific coefficients of the labour supply function). This particular choice implies that the MS model is allowed to determine which individuals, amongst the entire population, will fill the need for more workers if their number is to increase in the CGE model (on the contrary, if the number of workers is found to decrease, then the MS model will choose the individuals with the highest probability to lose their job). For a more detailed description of these methods, see Bourguignon *et al.* (2003b) and Hérault (2005). We will describe this procedure in more detail in the second chapter, where we will link a behavioural MS model to a CGE.

In order to transfer these changes onto the MS framework, we need the following "linking equations":

Consumption of commodity *i* by household *h*	$C_{hi}^{*} = \frac{CE_{hi}}{\left(1+\Delta P_i^{CGE}\right)}$
Labour income of household *h*	$LY_h^{*} = L_h$
Capital income of household *h*	$KY_h^{*} = K_h \cdot \left(1+\Delta PK^{CGE}\right)$

Notes:
- the wage rate is the numeraire in our CGE model
- the variables with the star are the values referred to the simulation runs

At this point, we can run the MS model (as our model is quite simple and just an arithmetical one, we use an Excel sheet with the appropriate computations to run the model) and obtain a new vector of disposable incomes, from which we compute the inequality indices that are reported in Table 11 (computed on disposable income per Adult Equivalent). The results for the main macroeconomic variables resulting from the CGE model are instead reported in Table 10.

One more thing about the sequential Top-Down approach must be said: with this approach, possible economy-wide feedback effects of the distributional consequences of a given policy are not taken into account. There is indeed complete absence of feedback from the micro to the macro level. «…The cost of adopting this approach is that the causal chain from macroeconomic policies to poverty is in one direction only: we do not capture the feedback effect of changes in the composition of demand (due to shifts in the distribution of income) on macroeconomic balances…»[62].

The main advantage of this approach is instead that it provides richness in household behaviour modelling, while remaining extremely flexible in terms of specific behaviours that can be modelled.

It is also true that, by emphasizing changes in relative prices and in the sectoral structure of the economy, this approach is more adapted to developing than developed countries.

[62] From Devarajan and Go (2003).

3.3. The Top-Down/Bottom-Up (TD/BU) Approach

This method has been recently developed by Savard (2003). It allows to overcome the problem of the lack of consistency between the micro and macro levels of the "top-down" approach by introducing a bi-directional link between the two models: this is the reason why this approach is also called "Top-Down/Bottom-Up". According to this method, indeed, aggregate results from the MS model (for example consumption levels) are incorporated into the CGE model, and a loop is used to run both models iteratively until the two produce convergent results. However, the existence of a converging solution is not guaranteed.

The value added of this approach comes from the fact that feedback effects provided by the MS model do not correspond to the aggregate behaviours of the representative households used in the CGE model. It is interesting to take these feedback effects of the MS model back in the CGE to insure coherence between the two models. The main difficulty in this type of exercise is related to aggregation and coherence between the two models. A scheme of the way in which this approach of linking the two models works is illustrated in Figure 5.

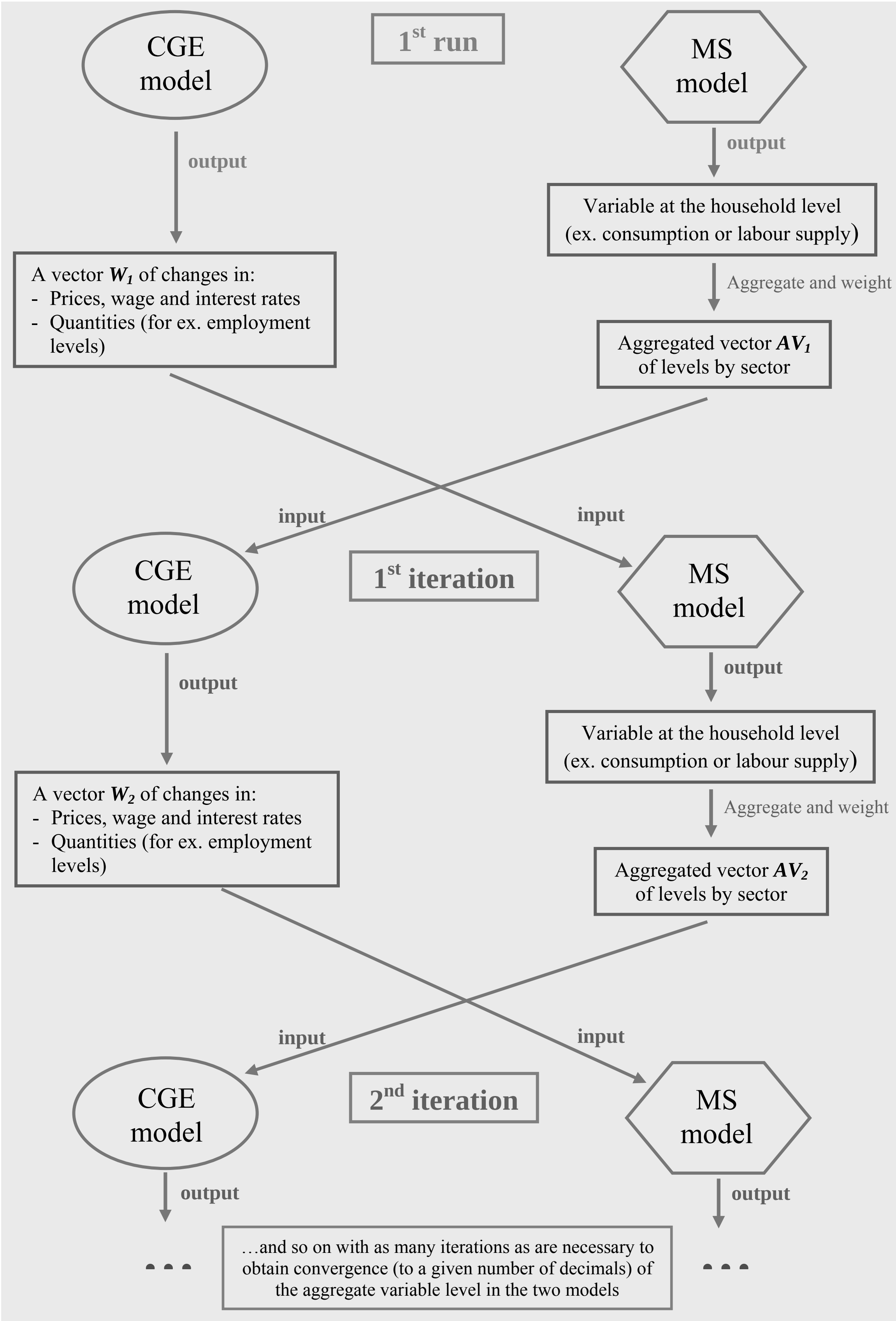

Figure 5 – The Top-Down/Bottom-Up Approach

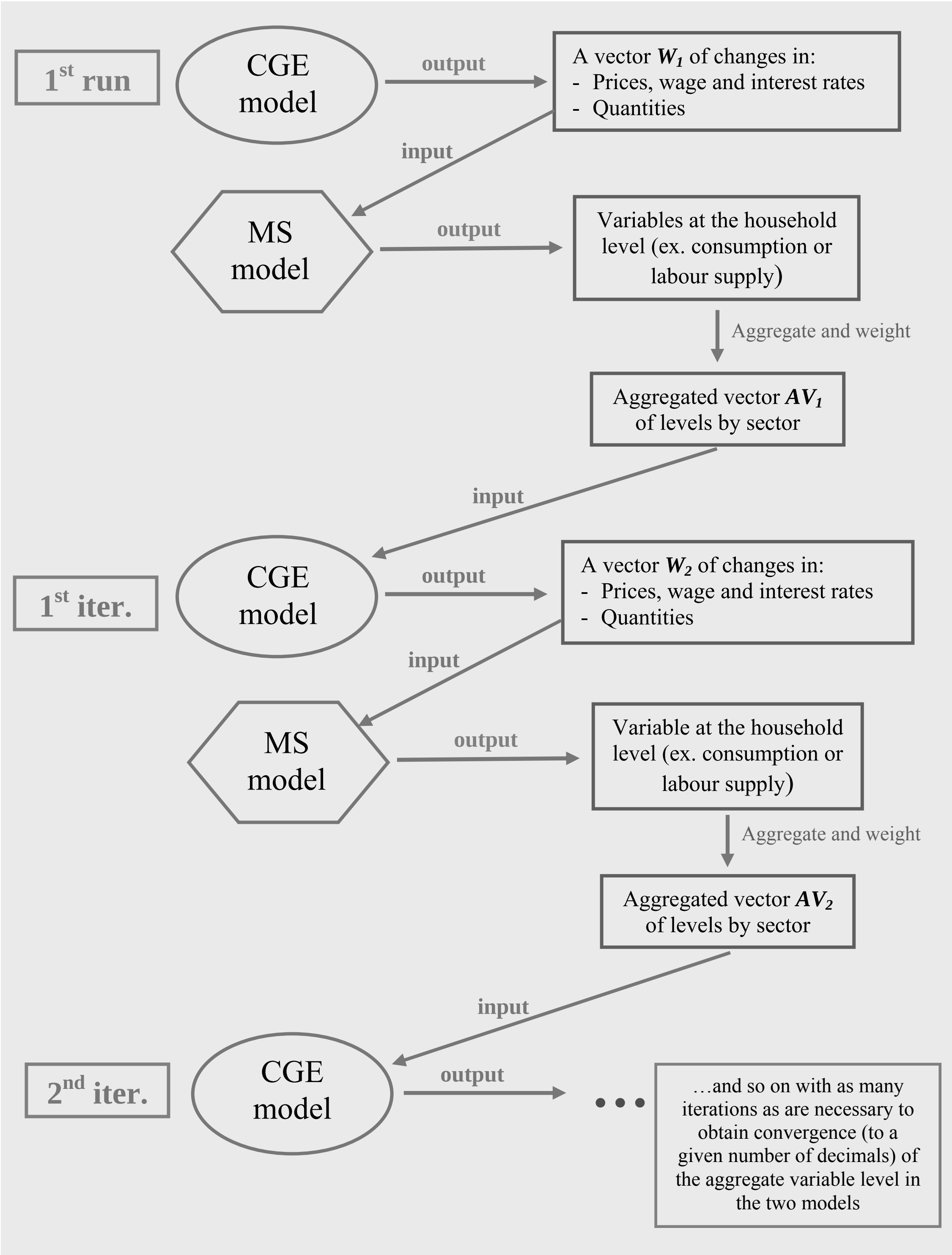

Figure 6 – The Top-Down/Bottom-Up Approach

We will build a little MS-CGE model for our archetypical economy following this approach, believing that illustrating it through a practical example is the most direct way of understanding quickly how it works. The CGE and MS models we will use are the ones we have already described for the sequential Top-Down approach, and again we will run the same policy simulation previously described (increase in the price of the imported good 1). We will follow the indications proposed by Savard (2003)[63]. Anyway, as our simulation is a macroeconomic one, we can run directly the CGE model at first. This means that our model will follow a simplified scheme with respect to the one presented in Figure 5. The new simplified scheme is shown in Figure 6. We follow this scheme because our simulation (shock to the price of the imported good for sector 1) cannot be run in the microsimulation framework only.

So, we will start running first the CGE model. Thus, we will pass the resulting changes in prices ΔP_i^1, and in capital return, ΔPK^1 onto the microsimulation model, as it is described in the previous section. After this, running the microsimulation model, we can compute the new consumption levels, C_{hi}^1;[64] then, in order to obtain the corresponding aggregate consumption levels, AC_i^1, each of these values has first to be divided by the number of adult equivalents in that household (see Table 3), then weighted for its relative sample weight, ω_h, and multiplied by the total number of adult equivalents in the population (3500), and finally aggregated by sector:

$$AC_i^1 = \sum_{h=1}^{5} \omega_h \cdot C_{hi}^1 \cdot 3500 \,.$$

Now, the aggregate consumption vector obtained from the MS model, AC_i^1, is imported into the CGE model. To do this, we have to change the hypothesis of the model to allow it to be fully determined, as now we have exogenous consumption levels for the

[63] Savard will use household consumption as communicating variable from the micro to the macro level. There are other approaches using different variables: for instance, Müller (2004) in his model for Switzerland, and the CGE-microsimulation model for Germany described in Arntz *et al.* (2006), use the labour supply level resulting from the microsimulation model as communicating variable from the micro to the macro level.

[64] This allows us to obtain a matrix of two goods by five households; aggregating over all the households, produces a single vector (2x1) of aggregate consumption levels.

representative household. Therefore, we need to change some of the equations and exogenous variables of the model: first, we will remove the equations determining consumption demand by the representative household, substituting it with the following:

$$CBUD = \sum_{i=1}^{2} P_i \cdot C_i \ .$$

In the initial hypothesis (endogenous consumption) we had 2 endogenous variables (C_i) and 2 equations. Now we have 2 exogenous variables and one equation. As we need to insure the balancing of the household's budget constraint, a variable needs then to be endogenized in the following equation:

$$CBUD = (1 - mps) \cdot (1 - ty) \cdot (PK \cdot KS + PL \cdot LS + TF).$$

Following Savard, we choose to endogenize the marginal propensity to save, *mps*, which is now a variable that changes in order to satisfy the budget constraint.

From this CGE model we will obtain other variations in commodity prices and in capital return, ΔP_i^2 and ΔPK^2. Using the consistency equations described for the sequential model in the previous section, we can introduce these changes into the MS module. This way, we obtain other consumption levels C_{hi}^2 for each household, and in the same way as before we can compute the aggregate consumption levels, AC_i^2 to be again imported into the CGE model, from which we will get ΔP_i^3 and ΔPK^3. In the same way, we take these changes and introduce them into the MS model through the consistency equations, obtaining the vector AC_i^3.

We go on in this way until the two models will produce the same values in the aggregate consumption vector. We obtain convergence at 3 decimals at the 3rd iteration (4th run of the model).

We can now compute the inequality indices for disposable income levels obtained in the last run of the MS model (see Table 11). The macroeconomic variables are reported in Table 10.

The main advantages of this approach are:

1. there is no obligation of scaling the household data to national accounts and no need to balance income and expenditure. Consequently, it allows the modeller to use the exact income and expenditure structure found in the household surveys;
2. there is no limit to the level of desegregation in terms of production sectors or number of factors of production and households to be included in the model;
3. the degree of freedom in choices of functional forms used to reflect micro-economic household behaviour is much higher in this approach;
4. the converging solution, if it exists, produces a numerical validation of the coherence between the CGE and the MS models.

It is however important to note that nothing guarantees a converging solution to be found; therefore, it must be validated and numerically checked for the introduction of each new hypothesis.

3.4. Conclusions

Observing the results of the previous models that are reported in Table 11, we can see that there is no substantial difference in the indices calculated from the same simulation with the three types of models. However, it must be taken into account the fact that these models are really simple, and that there are only five households in the survey. Imagine what would happen with thousands of households surveyed in a sample, and if the model is complicated by the introduction of unemployment, of other fundamental variables such as savings and investments, or of other agents such as the foreign sector, or the introduction of the hypothesis of imperfect competition, and so on. Moreover, in a real economy the taxation system is much more complex than the very simple one that we have implemented in the previous models.

However, even under the extreme minimalism of the three models we have implemented, one can notice that there are some slight differences in the resulting indices reported in Table 11. We can observe, indeed, that the first model, the one following the integrated approach, is the one that leads to the greatest change under the same simulation scenario, and that it brings about the highest (even if not very different from that of the other models) reduction in all the inequality indices.

However, in general, we can see that the three models lead to very similar results in the values of all inequality indices. The reason for this is to be sought mainly in the fact that the MS model is an arithmetical one, that is, all the variables of the model are derived only by simply computing some arithmetical relations, without providing for a reaction in the behaviour of the agents. This way, the results obtained through such a MS model are not that different from those one can obtain by using a standard CGE model. We will see in the next section that things may change with the use of a behavioural MS model, that is, a model that assumes the possibility of a change in the behaviour of the agents following a policy change. The main reason for this is that some of the behavioural responses that could be modelled into a MS framework cannot be included at all into a CGE model. For instance, it is very difficult to model switching regimes such as occupational choices with current CGE modelling softwares, as the equation system of the model cannot change as the iteration process moves along. For this reason, integrated models often rely on relatively simple microsimulation models focusing on only one or two dimensions of household (or individual) behaviour, while the so-called layered approaches (the Top-Down and the TD/BU ones) are able to include more complex equations in their MS module. To this extent, micro-econometric behavioural modelling provides much more flexibility in terms of the modelling structure used, and is much more suitable to describe the complexity of household and individual behaviour, and the way it may be affected by macroeconomic policies.

Table 10 – Changes in Some Macroeconomic Variables

	Integrated Model	Top-Down Model	TD/BU Model
Return to capital	0.530	0.559	0.848
Consumer price index	1.236	1.222	1.402
Labour demand by gov.	0.327	0.318	0.483
Capital demand by gov.	-0.202	-0.239	-0.362
Tax revenues	0.282	0.276	0.419
Exchange rate	-5.852	-6.070	-5.711
*Income**	0.246	0.276	0.419
*Disposable income**	0.246	0.276	0.419
*Consumption expenditure**	0.246	0.276	1.846
*Savings**	0.261	0.276	-13.380

	S_1	S_2	S_1	S_2	S_1	S_2
Commodity prices	3.033	-0.055	3.058	-0.054	3.311	0.076
Domestic sales	-1.520	0.823	-1.490	0.852	-1.369	0.637
Domestic production	0.255	-0.279	0.274	-0.290	0.415	-0.440
Labour demand by firms	0.731	-0.158	0.775	-0.162	1.176	-0.246
Capital demand by firms	0.200	-0.684	0.215	-0.717	0.325	-1.085
*Consumption**	-2.704	0.302	-2.699	0.330	0.476	0.389
Investments	-2.660	0.347	-2.699	0.330	-16.156	-13.445
Price of imports (local currency)	22.392	-5.852	22.109	-6.070	22.576	-5.711
Price of exports (local currency)	-5.852	-5.852	-6.070	-6.070	-5.711	-5.711
Imports	-14.193	10.277	-13.991	10.696	-13.978	10.042

[*] For the integrated model these values are computed as average percentage changes.

Table 11 – Some Inequality Indices on Disposable Income per Adult Equivalent

	Benchmark Situation	After Simulation[*]		
		Integrated Model	Top-Down Model	TD/BU Model
Gini index	18.17	-0.63%	0.13%	0.20%
Atkinson's index, ε = 0.5	2.62	-1.23%	0.24%	0.37%
Coefficient of Variation	32.61	-0.91%	0.13%	0.20%
Generalized entropy measures:				
I(c), c = 2	5.32	-1.82%	0.27%	0.40%
Mean logarithmic deviation, I(0)	5.34	-1.04%	0.24%	0.37%
Theil coefficient, I(1)	5.26	-1.43%	0.25%	0.38%

[*] Percentage changes with respect to the benchmark situation.

4. CONCLUSION

In all the applications presented here, we have worked mainly with fictitious data and small samples of observations. However, the choice of the modelling structure usually depends on the data that are available for the economy under study, then on the objective of the study one is willing to implement, and thus on the kind of policy simulation to be realized.

For what concerns the different types of possible linkages between microsimulation and CGE models, we have seen that most of the differences in the results coming out from the three main approaches arise when working with layered models (Top-Down and TD/BU approaches) rather than with integrated models.

Indeed, if we observe the results reported in Tables 10 an 11, we find that at a macroeconomic level (changes in the main macro variables, Table 10) all the models show very similar results (especially the integrated model and the Top-Down model predict almost identical results), making an exception for the TD/BU approach, in which we obtained different results for what concerns consumption and savings levels. The reason for this lays in the fact that we changed some of the initial assumptions of the CGE model in order to be able to introduce an exogenous vector of consumption levels from the microsimulation model (see section 3.3 for more details).

However, if we take a look at the change in inequality (Table 11, indices computed on disposable income per Adult Equivalent), we can see that the integrated model predicts inequality to decrease, while according to the two layered models inequality is observed to increase, even if of a very small amount. This difference could be of great importance when modelling real economies and it is probably due to the fact that with a layered model we are able to develop separately the microsimulation model, so that we can achieve a higher precision and a more detailed framework for the computations of the tax-benefit system.

We will see in more detail in the next chapter that the possibility of including behavioural responses into the microsimulation framework can lead to even stronger differences in the microeconomic results (and especially for what concerns the changes in poverty).

Bourguignon *et al.* (2001) and Bourguignon *et al.* (2003b) also provide strong arguments for working with layered rather than integrated models. These arguments are most persuasive when, as in their work for Indonesia, it is regarded as very important to simulate realistically variation in labour supply and occupational choice responses to changing prices, wages and employment conditions.

A reasonable conclusion may be that integrated models are best for some purposes and layered models for others. The integrated models, indeed, appear cleaner and more transparent, and they show a better reliability under the point of view of the theoretical consistency between the two levels of analysis. They may have however the drawback of not being able to fully capture even the direction and the relative magnitude of distributional and of other effects in terms of a full microeconomic analysis.

Layered models, in contrast, perhaps have an advantage where the concern is about short-term distributional impacts in a setting where realism is at a premium and theoretical niceties are not so important. In analyzing the impacts of a serious crisis, as in Indonesia, a layered approach may get the job done best.

- Chapter 2 -

LINKING CGE AND MICROSIMULATION MODELS: A COMPARISON OF DIFFERENT APPROACHES

1. INTRODUCTION

In the literature that studies income inequality and poverty, we can observe a recent development of models that link together a macroeconomic model (usually a CGE model) and a microsimulation model[1]. The reason for this lays in the fact that poverty and inequality are typically microeconomic issues, while the policy reforms or the shocks that are simulated have often a strong macroeconomic impact on the economy under study. Thus, an approach that takes into account both aspects of the economy through the use of some micro-macro linkages seems to be the right answer to the problem. The main aim for which CGE and microsimulation (MS) models are linked is indeed to try to take into account full agents' heterogeneity and the complexity of income distribution on one side, while being able at the same time to consider the macroeconomic effects of the policy reforms or of the shocks under study.

As we have already seen in the introduction to the previous chapter, indeed, CGE models following the representative household approach fail in capturing agents' heterogeneity and especially the changes in the distribution within the representative households' groups. On the other side, if we conduct the analysis only in the context of a microsimulation framework, we will just be able to perform a partial equilibrium analysis, thus disregarding all the possible general equilibrium effects of the reform under study on the entire economy.

In order to overcome these problems, the recent literature has tried to develop new modelling tools which should be able at the same time to account for heterogeneity and for the possible general equilibrium effects of the policy reform (or the exogenous shock) under study. In view of the fact that most of the available economic models have either a microeconomic or a macroeconomic focus, and they do not address the question adequately, the recent literature has focused on the possibility of combining two different types of models. In particular, some authors have tried to link microsimulation models to CGE models in order to account simultaneously for structural changes, for general equilibrium effects of the economic policies, and for their impacts on households'

[1] More generally, this current of the literature develops the use of micro-data drawn from household surveys in the context of a general equilibrium setting, which is usually but not necessarily a CGE model.

welfare, income distribution and poverty. The literature that follows this approach is quite flourishing in recent years: there are, among others, the important contributions by Decaluwé et al. (1999a) and (1999b), Cogneau and Robilliard (2001 and 2004), Cockburn (2001), Cogneau (2001), Bourguignon, Robilliard and Robinson (2003b), Boccanfuso *et al.* (2003) and Savard (2003).

The aim of this chapter is to give an assessment of recent developments in this field, with a special concern for the different types of linking that are currently used in the literature. In particular, we will link the micro-data from a survey to a CGE model in three different ways: through a full integration of the survey data into a CGE framework, as it is done for instance in Cockburn (2001); by linking a behavioural microsimulation model to a CGE through a set of specific equations, which is the so called Top-Down method, as it is developed in Bourguignon et al. (2003b), and finally through a method which was developed by Savard (2003), also known as Top-Down/Bottom-Up model.

We will build all the three types of models using the same data from a fictitious economy. After this, by running an identical policy reform in the three models, we will analyse the different outcomes deriving from different types of linking. We will see that, even with the same economy and under the same policy simulation, we can obtain quite different results, especially in terms of income distribution and poverty change.

The choice for the use of fictitious data describing a simple economy is made with the aim of being able to understand better the differences that are observed in the results of the models, and to try to "go behind" these differences and look for the causes that generate them. Of course, this is of more difficult realization when using true data of a real and thus more complex economy, which naturally shows more a complex structure in its economic relationships. The main difference that distinguishes the microsimulation model we are going to use in this chapter from the one described in the previous one is that we will now allow for individual behavioural responses by the agents, with a special concern for labour supply responses.

In particular, we will analyse in more detail the TD/BU approach as developed by Savard (2003) and propose an alternative way of taking into account feedback effects from the micro level of analysis into the CGE model (see paragraph 5.1).

2. THE INTEGRATED APPROACH

The main intuition behind this approach is to simply substitute the Representative Household Groups inside a standard CGE model with the real households that are found in the survey[2]. This way, one passes from a model with, for instance, ten representative agents to a model with thousands of agents, thus increasing the computational effort, but leaving substantially unchanged the modelling hypothesis of a standard CGE model. Basically, this approach does not include a true microsimulation module in the modelling framework, but it tries to incorporate the data from the household survey into the CGE model.

The first step to build such a model is to pass from the representative households' data of the survey to population values; to do this, one should weight each variable at the household level with the weights usually given in the survey, thus obtaining population values for each variable.

After this, we need a procedure to reconcile these population data coming from the survey (incomes and expenditures) with the accounts contained in the social accounting matrix (SAM). The literature on data reconciliation offers different alternatives. One may choose to keep fixed the structure of the SAM and adjust the household survey, or otherwise to adjust the SAM in order to meet the totals of the household survey. Another alternative would be that of using an intermediate approach. Whatever the method used, however, one necessarily loses the structure of the original data, which is one of the main drawbacks of the integrated approach. Our choice was for the alternative of keeping the original composition of households' incomes and expenditures unchanged.

After these changes in the SAM, one encounters the problem of re-balancing it (row totals must be equal to column totals). To do this, we used an appropriate program that minimizes least squares[3].

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[2] The first attempt in this direction was made by Decaluwé et al. (1999b). Among the models following this approach there are the works by Cockburn (2001) for Nepal, by Boccanfuso et al. (2003) for Senegal, and by Cororaton and Cockburn (2005), who studied the case of Philippine economy.

[3] There exist different principles on which SAM-balancing programs can be based, such as the "Row and Sum" or RAS method (see Bacharach, 1971), least squares minimization principles, known also as Stone-

The CGE model is the one described in section 3.2, except for the fact that we have added an index which refers to households[4].

A thing should be noted at this point: certain types of equations that are commonly included in a behavioural model, such as switching regime equations, like occupational choice equations, are not easily modelled within the standard CGE modelling softwares[5]. Instead, micro-econometric behavioural modelling provides much more flexibility in terms of the modelling structure used, and it is more suitable to describe the complexity of household and individual behaviour, and the way this may be affected by the changes in the macroeconomic framework that are subsequent to a policy reform or an external shock.

For instance, with a CGE model like the one used for the integrated approach here, we are not able to predict which particular individual will enjoy the reduction (or will suffer from the rise) of the unemployment level on the basis of some characteristics of the individual or of the household that can be observed; this instead can be done with the use of a behavioural microsimulation model. Indeed, the main feature that differentiates a microsimulation model from a standard CGE framework (not only one with representative agents, but even one with thousands of households from a survey, as we have seen) is that it works at the individual level, selecting those individuals that show the highest probability of changing their labour market status, on the basis of their personal or family characteristics. This fact could bring above significant differences in the results between the two types of models, even after the same policy simulation, as we will see below.

To this extent it is important to underline a fact about the treatment of involuntary unemployment. In a common CGE model it is possible to introduce involuntary

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Byron methods (see Stone (1977) and Byron (1978)), or the more recent cross-entropy approach proposed by Robinson et al. (2001) and Robilliard and Robinson (2003).

[4] For instance, the consumption demand function in Table 6 becomes: $P_q \cdot C_{mq} = \alpha H_{mq} \cdot CBUD_m$, where *m* is now the index for households.

[5] For instance, a discrete labour supply choice model in which individuals change their labour market status is not of easy implementation in a system of simultaneous equations like a CGE model. To this regard, see Savard’s (2003) discussion about the limits and advantages of the various approaches of linking.

unemployment due to structural characteristics of the labour market. If we have representative household groups, we can model the unemployment at the macro level (for instance with a Phillips curve) and then "distribute" the after-reform change in the unemployment level to the various groups, according to some proportional law, for instance. But if we have, like in the integrated approach, thousands of individual households, which are not even grouped according to any socio-economic characteristic, it is not clear how we can distribute the change in unemployment at the macro level to the single households. To do it in a proportional way would be inaccurate, because this is not what we observe in reality (we usually observe a person that loses her job, and not a proportional decrease in the worked hours of all the households, especially if the effect we are treating comes from involuntary unemployment and not from labour supply).

3. THE TOP-DOWN APPROACH

We apply now the sequential or Top-Down approach as described in Bourguignon *et al.* (2003b).

The basic idea is to develop separately a MS model and then to run the simulation on the basis of changes in consumer/producer prices, wages, and sectoral employment levels as predicted by the CGE model. This approach thus uses the two frameworks in a sequential way: first, the policy reform is simulated with the CGE model, and the second step consists of passing the simulated changes in some variables such as prices, wage rates, and employment levels[6] down to the MS module, as illustrated in Figure 4 (Chapter 1, page 53).

[6] When the assumption of imperfect labour market is adopted, or when the presence of a formal and an informal sector is predicted, the rationing in the labour market is usually carried out in the macro or CGE model, while the main use of the MS module is to select those households or individuals who will actually be barred out of, or let in, employment, or the formal sector. We will see this in more detail in the simulation section.

3.1. The Microsimulation Module

The main role of the microsimulation module in the linked framework is to provide a detailed computation of net incomes at the household level, through a detailed description of the tax-benefit system of the economy, and to estimate individual behavioural responses to the policy change. For instance, through the use of microeconometric equations, we can model behaviours such as labour supply or consumption.

Behavioural Microsimulation (MS) models are developed to capture the possible reactions of the agents to the simulated policies, so that what happens after a reform can be very different from what is predicted by the simple arithmetical computations included in an accounting model.

In this section we will describe in detail a simple behavioural model, following quite closely the discrete labour supply choice model used in Bourguignon *et al.* (2003b). Another description of a similar MS model for labour supply can be found in Bussolo and Lay (2003) with their model for Colombia, and in Hérault (2005), who built a model for the South African economy.

For the building of the model we will use fictitious data describing a very simple economy. In the household survey we have information about some individual characteristics, such as age, sex, level of qualification, education, labour and capital income, the eventual receipt of public transfers, and the activity status. For the sake of simplicity, we have stated that each individual at working age (16-64) can be allocated according to two alternatives: being a full-time wage worker, or being inactive. There are other variables in the survey that are referred to households rather than to individuals, for example the area of residence, the number of household components, the number of adults (over 18 years old) and children (under 18), and so on.

All consumption goods of the economy are grouped in two main categories[7].

We derive income variables referring to households from initial individual data by summing up individual values for each household member; this way, we obtain

[7] The focus of our distribution and poverty analysis will be on disposable income, even if an inequality and poverty analysis could also be conducted on expenditure rather than on income levels.

households' labour and capital incomes, households' public transfers and households' total income:

Household *m*'s labour income: $YL_m = \sum_{i=1}^{NC_m} YL_{mi}$

Household *m*'s capital income: $YK_m = \sum_{i=1}^{NC_m} YK_{mi}$

Public transfers to household *m*: $TF_m = \sum_{i=1}^{NC_m} TF_{mi}$

Household *m*'s total income: $Y_m = YL_m + YK_m + TF_m$

where YL_{mi} is labour income of individual *i* member of household *m*, YK_{mi} his/her capital income, and TF_{mi} are the public transfers he/she receives from government. All these quantities are summed up for each family over all the individuals belonging to the family (NC_m is the number of components of household *m*); then, household *m*'s total income, Y_m, is the sum of all incomes received by the family: labour income, capital income, and public transfers.

For the benchmark situation, we assume all initial prices normalized at one.

The Model

The core of the behavioural model is represented by the following two equations:

Regression model for log-wage earnings: $Log(YL_{mi}) = a + b \cdot x_{mi} + c \cdot \lambda_{mi} + v_{mi}$ *(B.1)*

"Choice" of labour market status: $W_{mi} = Ind[\alpha + \beta \cdot z_{mi} + \gamma \cdot rw_{mi} + \varepsilon_{mi} > 0]$ *(B.2)*

The rest of the MS module is made up by simple arithmetical computations of price indices, incomes, savings and consumption levels. As the parameters entering the following equations (marginal propensity to save mps_m, income tax rates γ, and budget shares η_{mq}) are constant, this part of the model may be regarded as purely accounting, as it does not contain any possible behavioural response to policy simulations.

Household *m*'s income generation model:	$Y_m = \sum_{i=1}^{NC_m} YL_{mi} \cdot W_{mi} + YK_m + TF_m$	*(B.3)*
Household disposable (after tax) income:	$YD_m = (1-\gamma) \cdot Y_m$	*(B.4)*
Household specific consumer price index:	$CPI_m = \sum_{q=1}^{2} \eta_{mq} \cdot P_q$	*(B.5)*
Real disposable income:	$YDR_m = YD_m / CPI_m$	*(B.6)*
Savings:	$S_m = mps_m \cdot YD_m$	*(B.7)*
Household consumption budget:	$CEBUD_m = YD_m - S_m$	*(B.8)*
Consumption expenditure for commodity *q*:	$CE_{mq} = \eta_{mq} \cdot CEBUD_m$	*(B.9)*
Consumption level of commodity *q*:	$C_{mq} = \frac{CE_{mq}}{P_q}$	*(B.10)*
Household *m*'s capital income:	$YK_m = PK \cdot KS_m$	*(B.11)*

Description of the subscripts:

m	Households	*m* = 1, 2, …, 24	
i	Individuals belonging to household *m*	*i* = 1, …, NC_m	NC_m: number of components of household *m*
q	Goods	*q* = 1,2	

The *first equation* of the model, *(B.1)*, computes the logarithm of labour income (wage) of member *i* of household *m* as a linear function of his/her personal characteristics (vector x_{mi} includes the logarithm of age, sex, skill level and educational attainment) and of λ_{mi}, which represents the inverse Mills ratio estimated for the selection model (for more details on the estimation process see below in the section "Estimation of the Model"). The residual term v_{mi} describes the effects of unobserved components on wage earnings.

The *second equation* represents the "choice" of the labour status made by household members[8]. Each individual at working age has to "choose" between two alternatives:

[8] In the literature this kind of equation is known as occupational choice model, or selection model (and also discrete choice model of labour supply). However, it must be specified that in our modelling context this equation is not really intended to explain the individual *choice* between being occupied and unemployed, but rather it tries to find out which characteristics strengthen the *probability* of being in one condition

being a wage worker, or being inactive. The variable W_{mi} is a dichotomic variable taking value one if individual *i* of household *m* is a wage worker, and zero otherwise. The allocation of each individual is made according to some criterion, the value of which is specific to the alternative, and the alternative with the highest criterion value is selected. A natural economic interpretation of this criterion value is utility: each individual is assigned to the alternative with the highest associated utility. Indeed, we will estimate the selection model using a binomial logit specification, which assigns each individual to the alternative with the highest associated probability[9]. In our model we have arbitrarily set to zero the utility of being inactive. Function "*Ind*" is an indicator function taking value one if the condition is verified, and zero otherwise. Vector z_{mi} of explanatory variables includes some personal characteristics of individual *i* of household *m*, that is: age, sex, skill and educational level, the area of residence and the number of children under 6 living in the household. Variable rw_{mi} is the logarithm of real labour income. The equation is defined only for individuals at working age.

The ***third equation*** is an accounting identity that defines total household income, Y_m, as the sum of the wage income of its members YL_{mi}, of the exogenous household capital income YK_m, and of the total amount of public transfers received by household *m*, TF_m. In this equation, variable W_{mi} stands for a dummy variable that takes value one if member *i* is a wage worker and zero otherwise.

The ***fourth equation*** computes household disposable (after tax) income by applying income tax rates according to the rule reported in Table 1. In order to simplify computations, we have assumed that in this economy direct income taxes are imposed on households' total income Y_m, and not on individual incomes.

Equation (B.5) computes an household specific consumer price index through the consumption shares η_{mq}. Real disposable income is then obtained by dividing households' disposable income by this index (***equation (B.6)***).

rather than in the other one for each individual, as it is described in more detail in the estimation section below. This is the reason why in the rest of the chapter we will use the word "choice" in quotation marks.

[9] See the next sub-section for more details on economic interpretation of logit models.

Table 1 – Direct Income Tax Rates

Income brackets:	*Tax rate*
Up to 10,000	0%
Up to 15,000	15%
Up to 26,000	24%
Up to 70,000	32%
Over 70,000	39%

Then, to find out household *m*'s savings level, equation (B.7) multiplies this disposable income by the marginal propensity to save of each household, mps_m. The assumption underlying this equation is that household savings behaviour is unvarying, as the savings level is a fixed fraction of household disposable income. Then, subtracting savings from disposable income one obtains the budget that each household spends for consumption (equation (B.8)), which is spent on the two goods of the model according to the budget shares η_{mq} by equation (B.9). Again, the assumption in this equation is that consumption behaviour is not flexible, that is, households spend a constant fraction of their consumption budget for each of the two goods.
To get the values of these exogenous parameters (marginal propensity to save mps_m and budget shares η_{mq}), we use the initial data from the survey in the following way:

Household *m*'s marginal propensity to save: $$mps_m = \frac{S_m}{YD_m}$$

Household *m*'s consumption budget shares: $$\eta_{mq} = \frac{CE_{mq}}{CEBUD_m}$$

Equation (B.10) derives then the consumption levels for each household by dividing the expenditure for each good by its price.
Finally, income from capital is obtained by multiplying capital endowment of each family, KS_m, by the return to capital, *PK* (equation (B.11)).
The initial values of the variables C_{mq} and KS_m (consumption levels and capital endowments, respectively) are derived from the initial data of the survey by making use of the assumption that in the benchmark situation all prices and returns are equal to one:

Household *m*'s consumption level of commodity *q*: $C_{mq} = CE_{mq}$ *(B.12)*

Household *m*'s capital endowment: $KS_m = YK_m$ *(B.13)*

Moreover, we assume that public transfers paid to households and household capital endowments are exogenously given. They are fixed at the level reported in the survey, for public transfers, and at the level as computed in equation *(B.13)*, for capital endowment, respectively.

Economic Interpretation of a Binomial Logit Model

This model can be interpreted as follows. Suppose an individual *i* assigns utility U_{Wi} to the alternative of being a wage worker (in order to simplify the analysis, we drop subscript *m* referred to the household), on the basis of his/her personal characteristics z_i, and that he/she assigns utility U_{Bi} to the alternative of being unoccupied. Furthermore, suppose that these utilities are linear functions of z_i, that is:

$$U_{Wi} = \alpha_W + \beta_W \cdot z_i + \varepsilon_{Wi} \qquad (B.14)$$

$$U_{Bi} = \alpha_B + \beta_B \cdot z_i + \varepsilon_{Bi} . \qquad (B.15)$$

One may now define that an individual *i* selects the alternative of being a wage worker if the utility of being a wage worker exceeds that of being unemployed, that is:

$$\begin{aligned}\Pr[OCS_i = 1 \mid Z_i] &= \Pr[U_{Wi} > U_{Bi} \mid Z_i] \\ &= \Pr[\alpha_W - \alpha_B + (\beta_W - \beta_B)\cdot z_i > \varepsilon_{Bi} - \varepsilon_{Wi} \mid Z_i] \\ &= \Pr[\varepsilon_i < \alpha + \beta \cdot z_i \mid Z_i],\end{aligned} \qquad (B.16)$$

where OCS_{mi} is the occupational status of individual *i* of household *m*, which takes value one if individual *i* is a wage worker, and zero otherwise, while ε_i is equal to $(\varepsilon_{Bi} - \varepsilon_{Wi})$, β equals $(\beta_W - \beta_B)$, and α is $(\alpha_W - \alpha_B)$. This shows that one cannot identify the individual parameters in *(B.16)*; one can only identify the difference between the parameters. Hence, one way to look at the parameters α and β is to see these as measuring the effect of z_i on the "choice" for being wage worker *relative* to that of being inactive[10].

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[10] For more details on this interpretation of a binomial model, see Franses and Paap (2001).

In this sense, equation *(B.2)* can be seen as expressing in an implicit way the utility associated with each of the two labour market alternatives.

In our model we have arbitrarily set to zero the utility of being unemployed, which means setting to zero the coefficients α_B and β_B of equation *(B.15)*. Thanks to this, the error term ε_i in *(B.16)* corresponds now to the error term of equation *(B.14)*, ε_{Wi}, the coefficient β of equation *(B.16)* equals β_W, and the intercept parameter α is now α_W.

This way, equation *(B.16)* becomes:

$$\begin{aligned} \Pr[OCS_i = 1 \mid Z_i] &= \Pr[U_{Wi} > 0 \mid Z_i] \\ &= \Pr[\alpha_W + \beta_W \cdot z_i > -\varepsilon_{Wi} \mid Z_i] \\ &= \Pr[\alpha + \beta \cdot z_i + \varepsilon_i > 0 \mid Z_i], \end{aligned} \qquad (B.17)$$

which is substantially what we have in the equation of the model, *(B.2)*, except for the missing household subscript *m*, which has been dropped before, for simplicity.

Estimation of the Model

The only two equations in the MS module that need to be estimated are equations *(B.1)* and *(B.2)*.

The former, which expresses the logarithm of wage earnings as a linear function of some individual characteristics and of λ_{mi}, the inverse Mills ratio, was estimated using a Heckman two-step model (see Heckman (1976) and (1979)). We follow this approach to correct for the selection bias which is implicit in a wage regression, that is, the fact that we observe a positive wage only for those individuals that are actually employed at the moment of the survey. As we cannot assume that the decision of participating in the labour market is made randomly, but rather it is based, among others, on the level of wage that is offered in the market, the estimate made only on the sub-sample of individuals who have a positive wage will be biased. Indeed, individuals who have low wages are more unlikely to choose to work (as they have a reservation wage that is greater than the wage offered by employers), and thus the sample of observed wages would probably be biased upward.

A solution can be found if there are some variables that strongly affect the chances for observing the reservation wage but not the outcome under study (the offer wage), such as the number of children living in the household, for example.

In this case, one has to estimate two equations: one, the wage regression equation, which expresses the wage as a function of individual characteristics such as age or education (in our case, the logarithm of wage is a function of the logarithm of age, of the skill level and of the educational attainment), and the other one, the selection equation, which measures the likelihood of observing the wage (i.e. the likelihood of working) as a function of some individual characteristics. In the estimation of our selection equation, we used as explanatory variables sex and the logarithm of age, which is in turn supposed to determine the wage too.

With the two-step procedure, the selection equation is estimated through a probit model, and then the estimated parameters are used to calculate the Inverse Mills Ratio. The value of the latter is included as an additional explanatory variable in the wage equation, which is then estimated with a simple OLS procedure. The results are reported in Table 2 below. The estimation was conducted on the sub-sample of individuals at working age (16-64).

Table 2 – Heckman Selection Model, Two-Step Estimates

Dependent variable: logarithm of wage				
	Coefficient	*Std. Error*	*z*	*P>|z|*
constant	7.032117	0.3145104	22.36	0.000
ln(age)	0.697818	0.0833084	8.38	0.000
sex	-0.466210	0.1018222	-4.58	0.000
qualification	0.396613	0.0771516	5.14	0.000
education	0.525011	0.0871646	6.02	0.000
Mills ratio	0.216005	0.1473164	1.47	0.143
Selection				
ln(age)	0.338583	0.0807227	4.19	0.000
sex	-1.549158	0.2802896	-5.53	0.000
qualification	1.020388	0.2728658	3.74	0.000
children under 6	0.168214	0.2368365	0.71	0.478
region	-0.751549	0.2980307	-2.52	0.012
rho	0.762760			
sigma	0.283187			

The interpretation of the coefficients for the wage equation thus follows that of a simple linear regression. As we can observe in Table 2, age, schooling and skill level have a positive effect on the wage, while being a woman shows a negative effect.

It is important to say that the aim of the wage equation within the model is that of obtaining an efficient estimate for an eventual wage income only for those individuals that are observed to be inactive in the survey, in the case that, after a policy reform, one or more of them will change their labour market status and become wage workers. In this case, through these estimates, we will be able to assign an estimated wage to the individual that has changed his/her labour market status after the simulation run.

For all the other individuals that are observed to receive a wage in the survey, we use instead the observed wage level and not the estimated one.

Parameters of equation *(B.2)* were obtained through the estimation of a binomial logit model, assuming that the residual terms ε_i are distributed according to the Extreme Value Distribution – Type I[11]. The estimation was conducted on the sub-sample of individuals at working age (16-64).

Our explanatory variables include individual characteristics such as the logarithm of predicted real wage, sex, skill and education level, the region of residence and a variable accounting for the presence or not of children under 6 years old in the household. The model is estimated by Maximum Likelihood. Results are presented in Table 3.

A binomial model states that the probability of observing the dependent variable assuming value one, given the explanatory variables ($OCS_{mi} = 1|Z_{mi}$), is equal to the cumulative distribution function of ε_i (the Extreme Value Type I distribution in our case), evaluated at $\beta \cdot Z_{mi}$, that is:

$$\Pr\left[OCS_{mi} = 1 \mid Z_{mi}\right] = F(\beta \cdot Z_{mi}) = \exp\left(-e^{-\beta \cdot Z_{mi}}\right). \qquad (B.18)$$

[11] The Extreme Value distribution (Type I) is also known as Gumbel (from the name of the statistician who first studied it) or double exponential distribution, and it is a special case of the Fisher-Tippett distribution. It can take two forms: one is based on the smallest extreme and the other on the largest. We will focus on the latter, which is the one of interest for us. The standard Gumbel distribution function (maximum) has the following probability and cumulative density functions, respectively:

pdf: $f(x) = \exp\left(-x - e^{-x}\right)$

CDF: $F(x) = \exp\left(-e^{-x}\right)$.

Table 3 – Binary Logit Model for Labour Status' Condition

Dependent Variable: Activity Status				
	Coefficient	*Std. Error*	*z-Statistic*	*Prob.*
ln(real wage)	0.197215	0.046458	4.245037	0.0000
sex	-1.894812	0.407759	-4.646894	0.0000
qualification	1.440805	0.425709	3.384482	0.0007
region	-0.718504	0.329501	-2.180586	0.0292
children under 6	0.269124	0.297251	0.905378	0.3653
education	-0.763275	0.671696	-1.136341	0.2558
Mean dependent var	0.664706		S.D. dependent var	0.473488
S.E. of regression	0.376673		Akaike info criterion	0.901535
Sum squared resid	23.26880		Schwarz criterion	1.012210
Log likelihood	-70.63049		Hannan-Quinn criter.	0.946446
Avg. log likelihood	-0.415473			

The effects that the explanatory variables have on the dependent binomial variable are not linear, because they get channelled through a cumulative distribution function. Thus, by observing the values and signs of the estimated coefficients, we can say something about the effect that explanatory variables have on the probability that the dependent binomial variable takes value one (wage worker), relatively to the probability that it takes value zero, but not in a linear way.

For instance, expected real wage and qualification seem to influence in a positive way the probability that the dependent variable takes value one (the more qualified the individual is, the higher is the probability for him/her to be employed), as well as the presence of children under 6 does, which is the opposite of what was expected, but anyway this result is not significant. Moreover, for men the probability of being employed is higher than for women, as the variable *SEX*, which takes value zero for men and one for women, shows a negative coefficient. The same can be said about the region of residence: people living in the first region have a higher probability of being employed than people living in the second one. The variable referring to education, instead, seems to have a negative influence on the probability of being employed, which is the opposite of what we expected, and anyway it is not highly significant.

However, with the estimated coefficients we cannot perfectly predict the true labour market statuses that are actually observed in the survey. Thus, following the procedure described in Duncan and Weeks (1998), we drew a set of error terms ε_i for each individual from the extreme value distribution, in order to obtain an estimate that is consistent with the observed activity or inactivity conditions. From these drawn values, we select 100 error terms for each individual, in such a way that, when adding it to the deterministic part of the model, it perfectly predicts the activity status that is observed in the survey. In other words, the residual term for an individual that is observed to be a wage earner in the survey should be such that:

$$\hat{\alpha} + \hat{\beta}_1 \cdot Log(RW_{mi}) + \hat{\beta}_2 \cdot SEX_{mi} + \hat{\beta}_3 \cdot Q_{mi} + \hat{\beta}_4 \cdot AREA_m + \hat{\beta}_5 \cdot CH6_{mi} + \hat{\beta}_6 \cdot SCH_{mi} + \varepsilon_{mi} > 0,$$

while, for an individual that is observed to be inactive in the survey, the same inequality should be of opposite sign (≤).

After a policy change, only the deterministic part of the model is recomputed. Then, by adding the random error terms previously drawn to the recomputed deterministic component, a probability distribution over the two alternatives (being a wage worker or being inactive) is generated for each individual. This implies that the model does not assign every individual from the sample to one particular alternative, but it gives the individual probabilities of being in one condition rather than in the other. This way, the model does not identify a particular alternative for each individual after the policy change, but generates a probability distribution over the different alternatives[12].

3.2. The CGE Model

The CGE model for the fictitious economy is characterized by a representative household who maximizes a Cobb-Douglas utility function with three arguments: leisure and two consumption goods. These commodities are also used as inputs, together with capital and labour, in the production process, which is operated by two firms following a Leontief technology in the aggregation of value added and the intermediate composite good, a Constant Elasticity of Substitution (CES) function for assembling capital and labour into value added, and a Leontief function in the aggregation of intermediate goods. Both

[12] This procedure is also described in Creedy and Kalb (2005). See also Creedy et al. (2002b).

factors of production, capital and labour, are mobile among sectors. The capital endowment is exogenously fixed, while labour supply is endogenously determined through household's utility maximization (subject to fixed time endowment). The wage elasticity of labour supply is estimated from the household survey, in order to have consistency in labour supply behaviour between the two models. Investments are savings-driven, while government maximizes a Cobb-Douglas utility function to buy consumption goods and uses labour and capital. The public sector also raises taxes on household's income and tariffs on imported goods, while it pays transfers to the representative household. For the foreign sector we have adopted the Armington assumption of constant elasticity of substitution for the formation of the composite good (domestic production delivered to domestic market plus imports) which is sold on the domestic market. Domestic production is partially delivered to the domestic market and partially exported, according to a Constant Elasticity of Transformation (CET) function. The small country hypothesis is assumed (the economy is price taker in the world market).

Table 4 – SAM of the Economy

	C_1	C_2	S_1	S_2	K	L	H	G	SI	RoW	Total
C_1			57.5	15.5			95.2	61.2	30.3	23.5	283.3
C_2			17.1	23.5			312.8	48.5	14.2	76.5	492.5
S_1	283.3										283.3
S_2		492.5									492.5
K			72.2	23.0				13.1			108.3
L			83.2	353.8				116.4			553.4
H					108.3	553.4		39.8			701.5
G			12.3	17.7			249.0				279.0
SI							44.5				44.5
RoW			41.0	59.0							100.0
Total	283.3	492.5	283.3	492.5	108.3	553.4	701.5	269.9	44.5	100.0	

C_q: consumption of good q; S_q: sector q; ***K***: capital account; ***L***: labour account; ***H***: representative household account; ***G***: public sector; ***SI***: savings-investments account, ***RoW***: Rest of the World account.

In the model there are in total 49 variables and 41 equations, which, with the 8 exogenous variables (capital endowment, *KS*, time endowment, *TS*, public transfers, *TF*, the four world prices PWE_q and PWM_q, and the numeraire, *PC*), fully determine the model and allows for satisfaction of Walras' law (we have a redundant equation).
The calibration of the parameters of the CGE model is done on the basis of a Social Accounting Matrix (SAM) for the economy, in such a way that the benchmark situation is consistent with that of the microsimulation module (for instance, in the benchmark of the two models we have the same average income tax rate, the same average marginal propensity to save, the same budget shares for consumption of the two goods, and so on).
The SAM for the economy under study and the initial values of some other variables are reported in Tables 4 and 5, while the equations of the model can be found in Table 6 below. The data in the SAM are in millions of the monetary unit we have used for the survey.

Table 5 – Values of Parameters for CGE Model

	Sector 1	**Sector 2**
Elasticity of substitution in production function (aggregation of capital and labour)	0.7	0.5
Elasticity of substitution for Armington composite good	0.7	1.2
Elasticity of transformation for exports and domestic production delivered to the domestic market	-2.0	-3.0
Initial tariff rates on imports	0.3	0.3
Initial time endowment	656.69	
Wage elasticity of labour supply (estimated from the household survey)	-0.18665	

Table 6 – Equations for the CGE Model

Demand for consumption goods	$P_q \cdot C_q = \alpha H_q \cdot CBUD$ q = 1,2	*C.1*
Leisure	$C_l = [(1-ty)\cdot PL]^{-1} \cdot \frac{\alpha H_l}{(1-\alpha H_l)} \cdot CBUD$	*C.2*
Labour supply	$LS = TS - C_l$	*C.3*
Savings	$S = mps \cdot (1-ty) \cdot Y$	*C.4*
Consumer price index	$PC = \prod_{q=1}^{2} P_q^{\alpha H_q}$	*C.5*
CES production function	$XD_q = aF_q \cdot \left[\gamma F_q \cdot K_q^{\frac{(\sigma F_q - 1)}{\sigma F_q}} + (1-\gamma F_q)\cdot L_q^{\frac{(\sigma F_q - 1)}{\sigma F_q}} \right]^{\frac{\sigma F_q}{(\sigma F_q - 1)}}$	*C.6*
CES FOC for capital	$K_q = \frac{XD_q}{aF_q} \cdot \left(\frac{\gamma F_q}{PK} \right)^{\sigma F_q} \cdot \left[\gamma F_q^{\sigma F_q} \cdot PK^{(1-\sigma F_q)} + (1-\gamma F_q)^{\sigma F_q} \cdot PL^{(1-\sigma F_q)} \right]^{\frac{\sigma F_q}{(1-\sigma F_q)}}$	*C.7*
Demand for investment goods	$P_q \cdot I_q = \alpha I_q \cdot S$	*C.8*
Price of imports in local currency	$PM_q = (1+tm_q) \cdot PWM_q \cdot ER$	*C.9*
Price of exports in local currency	$PE_q = PWE_q \cdot ER$	*C.10*
Armington function	$X_q = aA_q \cdot \left[\gamma A_q \cdot M_q^{\frac{(\sigma A_q - 1)}{\sigma A_q}} + (1-\gamma A_q)\cdot XDD_q^{\frac{(\sigma A_q - 1)}{\sigma A_q}} \right]^{\frac{\sigma A_q}{(\sigma A_q - 1)}}$	*C.11*
Armington FOC for imports	$M_q = \left(X_q / aA_q \right) \cdot \left(\gamma A_q / PM_q \right)^{\sigma A_q} \cdot \left[\gamma A_q^{\sigma A_q} \cdot PM_q^{(1-\sigma A_q)} + (1-\gamma A_q)^{\sigma A_q} \cdot PDD_q^{(1-\sigma A_q)} \right]^{\frac{\sigma A_q}{(1-\sigma A_q)}}$	*C.12*

CET function	$XD_q = aT_q \cdot \left[\gamma T_q \cdot E_q^{\frac{(\sigma T_q - 1)}{\sigma T_q}} + (1 - \gamma T_q) \cdot XDD_q^{\frac{(\sigma T_q - 1)}{\sigma T_q}} \right]^{\frac{\sigma T_q}{(\sigma T_q - 1)}}$	*C.13*
CET FOC for exports	$E_q = \left(XD_q / aT_q \right) \cdot \left(\gamma T_q / PE_q \right)^{\sigma T_q} \cdot \left[\gamma T_q^{\sigma T_q} \cdot PE_q^{(1-\sigma T_q)} + (1 - \gamma T_q)^{\sigma T_q} \cdot PDD_q^{(1-\sigma T_q)} \right]^{\frac{\sigma T_q}{(1-\sigma T_q)}}$	*C.14*
Market clearing condition for labour	$\sum_{q=1}^{2} L_q + LG = LS$	*C.15*
Market clearing condition for capital	$\sum_{q=1}^{2} K_q + KG = KS$	*C.16*
Market clearing condition for commodity *q*	$XD_q + M_q \cdot (1 + tm_q) = \sum_{s=1}^{2} io_{qs} \cdot XD_q + CG_q + C_q + I_q + E_q$	*C.17*
Income definition	$Y = PK \cdot KS + PL \cdot LS + PC \cdot TF$	*C.18*
Disposable income minus savings	$CBUD = (1 - ty) \cdot Y - S$	*C.19*
Zero profit condition in production function	$PD_q \cdot XD_q = PK \cdot K_q + PL \cdot L_q + \sum_{s=1}^{2} io_{sq} \cdot XD_q \cdot PD_s$	*C.20*
Zero profit condition in Armington function	$P_q \cdot X_q = PM_q \cdot M_q + PDD_q \cdot XDD_q$	*C.21*
Zero profit condition in CET function	$PD_q \cdot XD_q = PE_q \cdot E_q + PDD_q \cdot XDD_q$	*C.22*
Demand of commodity *q* by government	$P_q \cdot CG_q = \alpha CG_q \cdot (TAXREV - PC \cdot TF)$	*C.23*
Demand of capital by government	$PK \cdot KG = \alpha KG \cdot (TAXREV - PC \cdot TF)$	*C.24*
Demand of labour by government	$PL \cdot LG = \alpha LG \cdot (TAXREV - PC \cdot TF)$	*C.25*
Tax revenues	$TAXREV = ty \cdot Y + \sum_{q=1}^{2} (tm_q \cdot PWM_q \cdot ER)$	*C.26*
Number of variables: 49 Number of equations: 41 Number of exogenous variables: 8 Walras' law satisfied Model homogeneous of degree one	Exogenous variables: - capital endowment (*KS*) - time endowment (*TS*) - public transfers (*TF*) - world prices (PWE_q and PWM_q) - numeraire: consumer price index (*PC*)	

Variables:	
PK	return to capital
PL	wage rate
P_q	Armington composite good price
PD_q	output price
PM_q	import prices in local currency
PE_q	export prices in local currency
ER	exchange rate (numeraire)
PC	consumer price index
KS	capital endowment (exogenous)
LS	labour supply (endogenous)
TS	time endowment (exogenous)
X_q	domestic sales-Armington composite
XD_q	domestic output
M_q	imports
E_q	exports
K_q	capital demand by firms
KG	capital demand by government
L_q	labour demand by firms
LG	labour demand by government
I_q	demand for investment goods
C_q	demand for consumption goods
C_l	demand for leisure
CG_q	government commodity demand
Y	RH's income
S	RH's savings
$CBUD$	RH's disposable income
TF	public transfers to RH (exogenous)
PDD_q	price of domestic production delivered to domestic market
XDD_q	domestic production delivered to domestic markets
PWE_q	export prices in foreign currency (exogenous)
PWM_q	import prices in foreign currency (exogenous)
$TAXREV$	tax revenue
Parameters:	
ty	direct income tax rate
tm_q	tariff rate on imports
mps	RH's marginal propensity to save
io_{qs}	technical coefficients
aF_q	efficiency parameter of firm *q*'s production function
γF_q	share parameter in CES production function
σF_q	elasticity of substitution in CES production function
αH_q	C-D power of commodity *q* in RH's utility function
αH_l	C-D power of leisure in RH's utility function
αI_q	C-D power of good *q* in Bank's utility function
αCG_q	C-D power of commodity *q* in gov.'s utility function
αKG	C-D power of capital in government's utility function
αLG	C-D power of labour in government's utility function
aA_q	efficiency parameter in Armington function
γA_q	share parameter in Armington function
σA_q	elasticity of substitution in Armington function
aT_q	efficiency parameter in CET function
γT_q	distribution parameter in CET function
σT_q	elasticity of transformation in CET function
ε_LS	wage elasticity of labour supply

3.3. Linking the Models

The basic difficulty of this approach is to ensure consistency between the micro and macro levels of analysis. For this reason, one may introduce a system of equations to ensure the achievement of consistency between the two models[13]. In practice, this consists in imposing the macro results obtained with the CGE model onto the microeconomic level of analysis. In particular:

1) changes in the commodity prices, P_q, must be equal to those resulting from the CGE model;

[13] This way, what happens in the MS module can be made consistent with the CGE modelling by adjusting parameters in the MS model, but, from a theoretical point of view, it would be more satisfying to obtain consistency by modelling behaviour identically in the two models.

2) changes in average earnings with respect to the benchmark in the micro-simulation must be equal to changes in the wage rate obtained with the CGE model;
3) changes in the return to capital of the micro-simulation module must be equal to the same changes observed after the simulation run in the CGE model;
4) changes in the number of wage workers in the micro-simulation model must match those observed in the CGE model.

For our model, these consistency conditions translate into the following set of constraints, which could be called linking equations:

Consumption levels: $$C_q = \frac{CE_q}{\left(1 + \Delta P_q^{CGE}\right)} \qquad (M.1)$$

Logarithm of wage earnings: $$Log(YL_{mi}) = Log\left[\hat{YL}_{mi} \cdot \left(1 + \Delta PL^{CGE}\right)\right] \qquad (M.2)$$

Capital income: $$YK_m = KS_m \cdot \left(1 + \Delta PK^{CGE}\right) \qquad (M.3)$$

Employment level: $$\frac{\sum_{m=1}^{24}\sum_{i=1}^{NC_m} \hat{W}_{mi}}{\sum_{m=1}^{24}\sum_{i=1}^{NC_m} WA_{mi}} \cdot 100 = \Delta EMP^{CGE} \qquad (M.4)$$

The variables with no superscripts are those coming from the microsimulation module; those with the ^ notation correspond to the ones that have been estimated: in particular, $Log(\hat{YL}_{mi})$ is the wage level resulting from the regression model for individual *i*, member of household *m*, while $\hat{W}_{mi}$ is the labour market status of individual *i* of household *m* deriving from the estimation of the binomial choice model.

ΔP_q^{CGE}, ΔPL^{CGE} and ΔPK^{CGE} indicate, respectively, the change in the prices of goods, the change in the wage rate and in the return to capital deriving from the simulation run of the CGE model, while parameter ΔEMP^{CGE} is the employment level percentage change from the CGE.

WA_{mi} is a dummy variable taking value one if individual *i* of household *m* is at working age (16-64), and zero otherwise. From equation *(M.4)*, the number of employed over the total number of individuals at working age resulting from the MS model must be equal to the change in the employment level observed after the CGE run. This implies that the CGE model determines the employment level of the economy after the simulation, and that the MS model selects which individuals among the inactive persons have the highest probability of becoming employed (if the employment level is increased from the CGE simulation result), or either who, among the wage workers, has the lowest probability of being employed after the policy change (if the employment level is decreased)[14].

One possible way of imposing the equality between the two sets of parameters of system of equations *(M)* is through a change in the parameters of the selection and regression models. Following Bourguignon et al. (2003b), we restrict this change in the parameters to a change in the intercept of the two functions *(B.1)* and *(B.2)*. The justification for this choice is that it implies *neutrality* of the changes, that is, changing the intercepts a of equations *(B.1)* just shifts proportionally the estimated wages of all individuals, without causing any change in the ranking between one individual and the other. The same applies for the activity status choice equation: we choose to change the intercept α of equation *(B.2)*, and this will shift proportionally all the individual probabilities of being a wage worker, without changing their relative positions in the probability distribution, only to let some more individuals to become employed (or some less if the employment rate of the CGE model is decreased), irrespectively of their personal characteristics. This change in the intercept will be of the amount that is necessary to reach the number of wage workers resulting from the CGE model. Thus, this choice preserves the ranking of individuals according to their *ex-ante* probability of being employed, which was previously determined by the estimation of the binomial model. For this reason the change in the intercept parameter satisfies this neutrality property.

[14] And, in this case, his/her new wage level will be determined by the regression model of wage earnings.

4. THE TOP-DOWN/BOTTOM-UP APPROACH

This approach was developed by Savard (2003). It allows overcoming the problem of the lack of consistency between the micro and macro levels of the Top-Down approach by introducing a bi-directional link between the two models: this is the reason why this approach is also called "Top-Down/Bottom-Up". According to this method, indeed, aggregate results from the MS model (such as consumption levels or labour supply) are incorporated into the CGE model, and a loop is used to run both models iteratively until the two produce convergent results.

The value added of this approach is that it takes into account the feedback effects that come from the micro level of analysis, which are instead completely disregarded by the Top-Down model. The basic assumption behind this approach is that the microeconomic effects provided by the MS model run do not correspond to the aggregate behaviours of the representative households used in the CGE model, and that it is thus necessary to take these effects back into the CGE model to fully account for the effects of a simulated policy. A stylized scheme of the way in which this approach works can be observed in Figures 5 and 6 (Chapter 1, pages 59-60).

The bilateral communication between the two levels of analysis is achieved through a set of vectors of changes, as in the Top-Down approach: from the macro to the micro level of analysis the communication is guaranteed by the changes in the price, wage and return vector and in the employment levels, as before, while from the micro to the macro level the communication we apply two different strategies: in one version, we will use as input for the CGE model a vector of changes in the aggregate consumption and in the labour supply levels from the MS model[15]; in another version of the same model, only the

[15] The choice for consumption and labour supply as communicating variables is made following Savard (2003). However, as both consumption and labour supply are not exogenous in the CGE model, we have to change some of the initial hypothesis of the model. First, we remove the equations determining consumption demand by the representative household (equation *C.1* in Table 6), substituting them with the following single equation: $CBUD = \sum_{i=1}^{2} P_i \cdot C_i$. In the initial hypothesis (endogenous consumption) we had 2 endogenous variables (C_i) and 2 equations. Now we have 2 exogenous variables and one equation. As we need to insure the balancing of the household's budget constraint, a variable needs now to be endogenized

change in the labour supply level which results from the MS model will be used as input for the CGE model[16]. The process is iterated as many times as it is necessary to come to a convergent point, that is, when convergence (at a certain number of decimals) is obtained in the aggregate variable levels of the two models.

5. SIMULATION

We will now run a policy simulation with each of the three models. The simulation will be an exogenous shock on the world price level of the good exported by sector 2, which is the labour intensive sector in our stylized economy. The world price of good 2 is reduced of 64% from its initial value.

The simulation results for the most relevant macroeconomic variables are reported in percentage changes in Tables 7 and 8. In the tables, also the two different strategies adopted for the TD/BU approach are taken into account, so that we will compare the results coming from the introduction into the CGE model of, respectively, the consumption level and the labour supply coming from the microsimulation module, and only the labour supply.

In general, we can say that we have very similar results for most of the macro variables in all the four simulations. The shock has negative effects on the economy. Indeed, as we can observe in Table 7, the fall in the price of the exported good for sector 2 causes a reduction of the production level for this sector, which reduces its demand for both

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in the following equation: $CBUD = (1 - mps) \cdot (1 - ty) \cdot (PK \cdot KS + PL \cdot LS + PC \cdot TF)$. Following Savard, we choose to endogenize the marginal propensity to save, *mps*, which is now a variable that changes in order to satisfy the budget constraint.

In addition, we introduce an exogenous level of labour supply into the CGE model, and just leave out the equation that determines the demand for leisure (equation *C.2* in Table 6). This way, equation *C.3* will now yield the demand for leisure as the time remaining after having supplied an exogenous level of labour.

[16] In this case, we only introduce an exogenous level of labour supply into the CGE model, just leaving out the equation that determines the demand for leisure (equation *C.2* in Table 6).

factors of production. However, due to the depreciation of local currency, the reduction in the level of exports is lower than the 64% world price reduction. For the same reason, exports for the other production sector become convenient, so that for this sector we observe an increase in the level of the exported good, an increase in the production level, and in the demand for capital and labour. The depreciation of local currency has a negative effect on the level of imports, which contributes to a decrease of the amount of goods sold on the domestic market.

The lower level of labour demand as a whole (the second sector is labour-intensive, as can be observed in the SAM, Table 4) generates a reduction in the wage rate, which causes a decrease in labour supply. The opposite is observed for capital, as the first sector is more capital-intensive. As a consequence of the change in the price of the factors, government increases its demand for labour input and decreases the demand for capital, as the latter has become relatively more expensive.

As the income of the representative household is based chiefly on the supply of labour, we observe a reduction in nominal income and, as a consequence, of savings and consumption expenditure. The amount of consumption goods always decrease, but the percentage change varies according to the change in their relative price: the commodity produced by the second sector has become relatively more expensive, due to the negative shock that hit the sector.

As investments are savings-driven, we observe also a reduction in the demand for investment goods (again, the investment good produced by the second sector is now relatively more expensive, so we observe a higher reduction for the demand of this good).

Table 7 – Simulation Results: Percentage Changes (CGE Model)

	Integrated Approach	*Top-Down Approach*	*TD/BU Approach (Cons. and LS)*	*TD/BU Approach (Labour Supply)*
Government Surplus	0.00	0.00	0.00	0.00
Wage Rate	-14.87	-14.67	-14.42	-14. 64
Capital return	19.70	19.30	17.91	19.13
Consumer Price Index (num.)	0.00	0.00	0.00	0.00
Exchange rate	53.83	53.76	53.83	53.70
Labour Supply	-1.00	-1.18	-1.32	-1.32
Government Use of Labour	4.82	4.23	3.72	4.06
Government Use of Capital	-25.45	-25.45	-24.72	-25.43
*Income**	-9.50	-9.39	-9.50	-9.48
*Disposable Income**	-9.50	-9.39	-9.50	-9.48
*Consumption Expenditure**	-9.50	-9.39	-7.90	-9.48
Marginal Propensity to Save	0.00	0.00	-16.22	0.00
*Savings**	-9.28	-9.39	-24.18	-9.48
Tax Revenues	-9.28	-9.48	-9.63	-9.58

[*] For the integrated model, these changes are computed as average percentage changes across households.

Table 8 – Simulation Results: Percentage Changes (CGE Model)

	Integrated Approach		*Top-Down Approach*		*TD/BU Approach (Cons. and LS)*		*TD/BU Approach (Labour Supply)*	
	Sector 1	*Sector 2*	*Sector 1*	*Sector 2*	*Sector 1*	*Sector 2*	*Sector 1*	*Sector 2*
Commodity Prices	-0.99	0.30	-1.23	0.38	-1.70	0.52	-1.27	0.39
Domestic Sales	-8.69	-12.52	-8.81	-12.54	-10.21	-12.05	-8.88	-12.64
Domestic Production	27.81	-14.20	27.91	-14.31	26.77	-13.86	27.84	-14.43
Labour Demand	43.52	-13.22	43.05	-13.36	41.08	-12.94	42.88	-13.48
Capital Demand	13.07	-26.82	13.14	-26.72	12.72	-25.84	13.15	-26.76
*Consumption**	-8.60	-9.78	-8.26	-9.73	-6.58	-8.30	-8.32	-9.84
Investments	-7.65	-8.84	-8.26	-9.73	-22.87	-24.57	-8.32	-9.84
Imports	-32.92	-47.63	-33.11	-47.57	-34.37	-47.21	-33.16	-47.60
Exports	207.36	-78.38	209.23	-78.53	209.10	-78.48	209.11	-78.59

[*] For the integrated model, these percentage changes are computed as average percentage changes across households.

However, a particular result needs further explanations: savings and investments in the TD/BU-Consumption model decrease much more than in the other three models. The reason for this lays in the fact that, in order to be able to introduce exogenous consumption levels into the CGE model, we must endogenize one variable in the households' budget constraint to keep the equilibrium in this constraint. Savard's choice is for the marginal propensity to save, and we follow his approach. But the consequence of this will be a change in the household behaviour with respect to the initial assumptions made for the benchmark. Indeed, the marginal propensity to save of the household will decrease, and thus also households' savings. As in our model investments are savings-driven, this will generate a further reduction of investments. We will analyse this aspect further in the next subsection (5.1).

With respect to the microeconomic results, and mainly the changes in poverty and inequality, we can observe in Table 9 and 10 that the differences are generally significant only for the case of the integrated model.

The underlying variable for the computation of the indices is per-capita real disposable income, obtained by dividing disposable income by the household specific consumer price index[17], and then dividing it again by the number of adult equivalents resulting by the "Oxford" or "Old OECD" scale (see OECD, 1982). This equivalence scale calculates the number of adult equivalents living in a household by assigning a value of 1 to the first household member, of 0.7 to each additional adult and of 0.5 to each child:

$AE = 1 + 0.7 \cdot (\#Adults - 1) + 0.5 \cdot (\#Children)$.

First of all, we observe that the Top-Down and the TD/BU-Labour Supply approach show almost identical results for what concerns both poverty and inequality indices.

The TD/BU-C&LS model we observe a smaller effect on inequality, but in the same direction as for the other two models, and the same is true for poverty.

The biggest difference in the microeconomic results is to be detected in the integrated approach, where we observe a higher increase both in the inequality and poverty indices. The increase in inequality for the integrated approach is also confirmed by the higher level of the Severity of Poverty Index, which measures the degree of inequality among the poor, while a higher Poverty Gap Index indicates that the gap between the income of the poor and the poverty line has increased (see Appendix A for more details on poverty indices).

[17] The household specific price index is computed using households' consumption shares and the change in prices deriving from the CGE model, as follows: $CPI_m = \sum_{q=1}^{2} \eta_{mq} \cdot \left(1 + \Delta P_q^{CGE}\right)$.

Table 9 – Inequality Indices on Disposable per Adult Equivalent Real Income (MS Model)

	Benchmark Values	Integrated Approach*	Top-Down Approach*	TD/BU Approach (C & LS)*	TD/BU Approach (LS)*
Gini Index	33.96	2.81%	1.62%	1.47%	1.60%
Atkinson's Index, ε = 0.5	9.60	4.51%	2.73%	2.48%	2.70%
Coefficient of Variation	71.80	3.13%	2.29%	2.14%	2.27%
Generalized Entropy Measures:					
I(c), c = 2	25.78	6.36%	4.64%	4.32%	4.60%
Mean Logarithmic Deviation, I(0)	19.93	3.85%	2.05%	1.81%	2.02%
Theil Coefficient, I(1)	20.55	5.17%	3.38%	3.11%	3.34%

* Percentage deviations from benchmark values.

Table 10 – Poverty Indices on Disposable per Adult equivalent Real Income (MS Model)

	Benchmark Values	Integrated Approach*	Top-Down Approach*	TD/BU Approach (C & LS)*	TD/BU Approach (LS)*
General Poverty Line					
Headcount Index, P_0	39.34	16.67%	8.33%	8.33%	8.33%
Poverty Gap Index, P_1	9.88	40.09%	28.48%	28.07%	28.42%
Poverty Severity Index, P_2	0.00	39.99%	29.42%	28.98%	29.36%
Extreme Poverty Line					
Headcount Index, P_0	4.92	33.33%	33.33%	33.33%	33.33%
Poverty Gap Index, P_1	0.96	3.34%	3.18%	3.04%	3.15%
Poverty Severity Index, P_2	0.00	-0.36%	-0.34%	-0.27%	-0.34%

* Percentage deviations from benchmark values.

5.1. More on the TD/BU Approach

In this subsection we want to investigate further what happens within the TD/BU approach in general, and in particular we will try to understand which is the main cause of the unusual deviation that is observed in the level of savings under the TD/BU-C&LS approach.

At a first intuition, such a deviation could be generated either by a problem of initial data inconsistency between the two datasets (the SAM and the survey), or by what we will refer to as “feedback effects” from the microeconomic level of analysis. With this concept we intend to incorporate all the effects that derive from a response (behavioural or not) of the agents in the MS model that is different from the one observed in the CGE model for the Representative Household (RH). This difference could be due either to a different way of modelling a particular behaviour in the two models (for instance, in the case of labour supply, the MS model uses a discrete and individualized concept of labour supply, while in the CGE model we have a continuous labour supply defined for the RH), or simply to the fact that in the MS model we consider single households as the unit of modelling, while in the CGE model we have a unique RH (as for consumption and savings, for instance).

In order to check whether the problem derives from an initial data inconsistency, we will run the same model using a new Social Accounting Matrix, which has been built in such a way that it is fully consistent with the data observed in the survey appropriately aggregated. As we can observe in Table 11, the variables that were adjusted to survey data are those in the grey cells, while all the other columns and rows were then rebalanced to obtain full consistency[18]. By comparing this SAM with the original one in Table 4, we can observe that in our case initial data inconsistencies were not very big (the biggest inconsistency is observed in the savings level).

Table 11 – SAM of the Economy made consistent with the Household Survey

	C_1	C_2	S_1	S_2	K	L	H	G	SI	RoW	Total
C_1			57.8	15.6			95.4	62.6	28.1	23.6	283.0
C_2			17.1	23.5			313.2	48.8	13.6	76.6	492.8
S_1	283.3										283.0
S_2		492.5									492.8
K			73.4	23.2				13.2			109.8
L			81.7	353.8				117.5			552.6
H					109.8	552.6		38.7			701.2
G			12.3	17.7			250.8				280.8
SI							41.7				41.7
RoW			40.8	59.4							100.2
Total	283.0	492.8	283.0	492.8	109.8	552.6	701.2	280.8	41.7	100.2	

C_q: consumption of good *q*; ***S_q***: sector *q*; ***K***: capital account; ***L***: labour account; ***H***: representative household account; ***G***: public sector; ***SI***: savings-investments account, ***RoW***: Rest of the World account.

[18] To rebalance the SAM a least square minimization method was used.

With the SAM shown in Table 11, we will run the shock on the export price of sector 2 as before (-64%). Results are reported in Tables 12 and 13 for the TD/BU-C&LS (consumption and labour supply levels are reported from the MS model into the CGE model) and the TD/BU-LS (only labour supply is reported from the micro level) approaches. Observing the result for savings in the TD/BU-C&LS approach, we can see that in our case data inconsistencies were responsible only for a 2% change in the marginal propensity to save and in the savings level. This means that the remaining change of around 13% (the difference between the change observed in the other approaches, around 9%, and the one observed in this approach, 22.24%) is to be attributed to the feedback effects from the MS model.

Observing the results for the TD/BU-LS approach we discover instead that the change in labour supply that was observed after the first iteration (-1.32% instead of -1.18% of the first iteration) was due only to a problem of data inconsistency and not to feedback effects from the MS model. This means that modelling labour supply as a discrete choice and individually in the MS model does not affect the results of the macro model in a significant way, at least for what concerns our particular case.

Table 12 – Simulation Results with Consistent Data: Percentage Changes

	TD/BU Approach (Cons. and LS)	***TD/BU Approach (Labour Supply)***
Government Surplus	0.00	0.00
Wage Rate	-14.63	-14. 81
Capital return	18.36	19.37
Consumer Price Index (num.)	0.00	0.00
Exchange rate	53.90	53.80
Labour Supply	-1.18	-1.18
Government Use of Labour	4.13	4.42
Government Use of Capital	-24.89	-25.48
Income	-9.45	-9.43
Disposable Income	-9.45	-9.43
Consumption Expenditure	-8.14	-9.43
Marginal Propensity to Save	-14.13	0.00
Savings	-22.24	-9.43
Tax Revenues	-9.57	-9.52

Table 13 – Simulation Results with Consistent Data: Percentage Changes

	TD/BU Approach (Cons. and LS)		*TD/BU Approach (Labour Supply)*	
	Sector 1	***Sector 2***	***Sector 1***	***Sector 2***
Commodity Prices	-1.44	0.44	-1.07	0.33
Domestic Sales	-9.86	-12.06	-8.89	-12.55
Domestic Production	26.77	-13.80	27.65	-14.27
Labour Demand	41.65	-12.85	43.17	-13.30
Capital Demand	12.70	-25.99	13.05	-26.76
Consumption	-7.13	-8.45	-8.45	-9.73
Investments	-21.11	-22.58	-8.45	-9.73
Imports	-34.12	-47.30	-33.10	-47.63
Exports	207.50	-78.34	207.46	-78.43

Once we have established that in the case of the TD/BU-C&LS approach most of the deviation in the savings level (13% against a 2% due to data inconsistencies) is to be attributed to feedback effects coming from the micro level of analysis, we want now to understand which is the variable or the parameter that affects mostly this deviation. Intuitively, as we have already seen with the TD/BU-LS approach that the different way of modelling labour supply does not have big effects, then this deviation in the savings level must be due to the fact that in the MS model we have expenditure shares and tax parameters that are specific to every single household, while in the CGE model there is only one RH group with "average" shares and parameters (in this sense ours is an extreme case, as we have only one RH in the CGE model). In order to understand which is the parameter that particularly affects the deviation in the savings level, we run the MS model using for all the households the RH's shares taken from the CGE model, instead of the shares and parameters that are observed in the survey for each household. The communicating variables from the MS model to the CGE model will remain the ones used in the TD/BU-C&LS approach, that is consumption levels and labour supply. Results in Table 14 clearly indicate that the main cause of difference between the two models is to be detected in the income tax rate, while labour supply and expenditure shares account only for a small part of it (the change in the savings level remains at 22% in these cases). When we use all the parameters from the CGE model (labour supply change, income tax rate, *mps* and consumption shares), the deviation in the savings level is almost reduced to zero, as it was to be expected.

Table 14 – TD/BU-C&LS approach with consistent data: RH shares from CGE model used in the MS model (Percentage Changes, CGE Model Results)

	only ty	*only ΔLS*	*only η_l & mps*	*ΔLS, ty, mps & η_l*
Marginal propensity to save	2.92	-14.82	-14.47	0.12
Savings	-6.78	-22.87	-22.55	-9.33

These results are not surprising, as the income tax rate in the MS model is modelled in a way that is not linear with respect to the income level, as the rate depends on the income brackets to which household income belongs. Of course this feature is not captured at all in the CGE model, where we have a unique tax rate for the RH that is merely proportional to his income. Under the TD/BU-C&LS approach, while transmitting the consumption level from the MS to the CGE model, we were implicitly transmitting a level of disposable (after tax) income that was incompatible with the one of the CGE model[19].

As a consequence of our modelling choices (made following Savard, 2003), all the effect of the mismatching between the disposable income levels of the two models is going into the change in the marginal propensity to save, then into the savings and investments levels as a consequence, but it was not transmitted in a significant way to the rest of the economy. Indeed, if we observe the results in Tables 7 and 8, we would be tempted to say that, except for these big deviations in savings and investments levels (and a lower difference in the level of consumption), for the rest feedback effects do not appear to bring about significant differences in the results. This is even more evident once we have eliminated the effects coming from data inconsistencies (see Tables 12 and 13 compared with the columns for the Top-Down approach of Tables 7 and 8).

[19] In both our models, consumption and savings are simply modelled as fixed proportions of disposable income.

But the deviation in the savings level is quite big[20], even after having eliminated the problem of data inconsistency, and it allows us to believe that all the effects from the micro level of analysis are absorbed by the change in savings (and consequently of investments), and only in a very small part they are transmitted to the rest of the economy. Thus, a doubt arises: is consumption in our case[21] the right variable to pass the feedback effects onto the CGE model? And then, the choice of letting the marginal propensity to save free to vary in the CGE model was the best channel to transmit these feedback effects to the whole economy?

Which is the parameter we have seen to be driving the biggest change between the micro and the macro level? It is income the tax rate, which is in our case the main determinant of disposable income. So let us try to use this parameter (conveniently "aggregated" into a representative one), together with the change in aggregate labour supply, as communicating variable from the MS model to the CGE model. We will try to use not only the income tax rate from the MS model, but also the marginal propensity to save and the consumption shares.

Results are shown in Tables 15 and 16. As we can see by comparing these results with the ones in Table 7 and 8 for the Top-Down approach, feedback effects from the micro level of analysis can be important. In particular, in our case, we observe a different path for disposable income and tax revenues (due to the reduction of the income tax rate), and for savings and consumption, whose percentage changes are now closer to the ones of the MS model (see Table 17). Anyway, full consistency between the CGE and the MS model results is only obtained when working with consistent data and when all the parameters (change in labour supply, tax rates, marginal propensity to save and consumption shares) are transmitted to the CGE model. However, if we report all these parameters from the MS model into the CGE model without having previously adjusted the data, we can see in Tables 15 and 16 that the problem of data inconsistency comes out again and distorts

[20] In the paper by Savard (2003), where he analyses the case of Philippines using a TD/BU-C&LS approach, «… results of variation of this adjustment variable [the marginal propensity to save, n.d.a.] have shown to be relatively small» (page 21). This probably means that the feedback effects in that case are not particularly important for the results of the model.

the results of the CGE model, and especially the level of savings (and that of investments as a direct consequence)[22].

Here we would like to focus also on another important fact: the Top-Down approach suffers not only from the problem of a lack of feedback effects from the micro level of analysis, but it is not even exempt from the problem of data inconsistency. Indeed, the fact that the results of the two models (the micro and the macro model) do not coincide, as it is in our case, could be due either to a problem of initial data inconsistency or to a different microeconomic behaviour of the agents in the MS model. In any case, one has to decide which results are the most reliable ones in the case they do not coincide.

Table 15 – Simulation Results TD/BU Approach: Percentage Changes (CGE Model)

	ΔLS & ty (inconsistent data)	***ΔLS, ty, mps & η_l (inconsistent data)***	***ΔLS, ty, mps & η_l (consistent data)***
Government Surplus	0.00	0.00	0.00
Wage Rate	-14.70	-14. 62	-14.84
Capital return	19.43	18.95	19.46
Consumer Price Index (num.)	0.00	0.00	0.00
Exchange rate	53.90	53.95	54.02
Labour Supply	-1.18	-1.18	-1.18
Government Use of Labour	2.26	2.13	1.62
Government Use of Capital	-26.96	-26.69	-27.55
Income	-9.39	-9.40	-9.44
Disposable Income	-8.47	-8.48	-8.12
Consumption Expenditure	-8.47	-7.93	-8.14
Marginal Propensity to Save	0.00	-5.53	0.25
Savings	-8.47	-13.54	-7.89
Tax Revenues	-10.95	-10.97	-11.60

[21] We remember that in our case consumption is not modelled in a significantly different way in the two models. However, there could be other cases where the level of consumption can be an important carrier of feedback effects from the micro level of analysis.

[22] Indeed, if we observe the two SAMs (Table 4 and Table 11, respectively), we can see that the level of savings is one of the biggest sources of data inconsistency between the SAM and the survey.

Table 16 – Simulation Results TD/BU Approach: Percentage Changes (CGE Model)

	ΔLS & ty (inconsistent data)		ΔLS, ty, mps & η_l (inconsistent data)		ΔLS, ty, mps & η_l (consistent data)	
	Sector 1	Sector 2	Sector 1	Sector 2	Sector 1	Sector 2
Commodity Prices	-1.21	0.37	-1.38	0.42	-1.09	0.33
Domestic Sales	-8.75	-12.00	-9.27	-11.77	-8.92	-11.73
Domestic Production	28.13	-13.75	27.72	-13.53	27.87	-13.42
Labour Demand	43.37	-12.79	42.66	-12.58	43.46	-12.44
Capital Demand	13.28	-26.30	13.11	-25.93	13.20	-26.07
Consumption	-7.35	-8.81	-6.90	-8.24	-7.45	-8.35
Investments	-7.35	-8.81	-12.33	-13.91	-6.88	-8.19
Imports	-33.09	-47.31	-33.57	-47.16	-33.20	-47.23
Exports	210.17	-78.31	210.17	-78.27	208.79	-78.11

Table 17 – Simulation Results TD/BU Approach: Percentage Changes (MS Model)

	ΔLS & ty (inconsistent data)		ΔLS, ty, mps & η_l (consistent data)		TD Approach (inconsistent data)	
	Sector 1	Sector 2	Sector 1	Sector 2	Sector 1	Sector 2
Consumption	-7.23	-8.28	-7.45	-8.35	-7.21	-8.28
Savings		-7.78		-7.88		-7.78

We report also results on income inequality and poverty changes after the simulation of the shock, for the three models described above (Tables 18 and 19).

As we can see, no big differences are observed with respect to the results reported in Tables 9 and 10. This means that, at least in our case, the fact of taking into account feedback effects does not have a strong influence on the results on income distribution and on poverty change.

In any case, these values confirm once again the fact that the integrated approach tends to overestimate the effects of the shock on income inequality and poverty change, even though at the macro level we do not observe significant deviations in the main macroeconomic variables (see Tables 7 and 8).

Table 18 – Inequality Indices on Disposable per Adult Equivalent Real Income (MS Model)

	Benchmark Values	ΔLS & ty (inconsistent data)*	ΔLS, ty, mps & η_l (consistent data)*
Gini Index	33.96	1.63%	1.64%
Atkinson's Index, ε = 0.5	9.60	2.76%	2.76%
Coefficient of Variation	71.80	2.31%	2.32%
Generalized Entropy Measures:			
I(c), c = 2	25.78	4.68%	4.68%
Mean Logarithmic Deviation, I(0)	19.93	2.08%	2.08%
Theil Coefficient, I(1)	20.55	3.41%	3.42%

* Percentage deviations from benchmark values.

Table 19 – Poverty Indices on Disposable per Adult equivalent Real Income (MS Model)

	Benchmark Values	ΔLS & ty (inconsistent data)*	ΔLS, ty, mps & η_l (consistent data)*
General Poverty Line			
Headcount Index, P_0	39.34	8.33%	8.33%
Poverty Gap Index, P_1	9.88	28.54%	28.92%
Poverty Severity Index, P_2	0.00	29.49%	29.89%
Extreme Poverty Line			
Headcount Index, P_0	4.92	33.33%	33.33%
Poverty Gap Index, P_1	0.96	3.20%	3.31%
Poverty Severity Index, P_2	0.00	-0.35%	-0.34%

* Percentage deviations from benchmark values.

6. CONCLUSION

In this chapter we tried to give an assessment of the recent developments observed in methods that link together CGE and microsimulation models, with a special concern for the different linking approaches existing in the literature. Especially, we have focused our attention only on static models. By using data from a fictitious economy, we have built three models: one that follows the full integrated approach, as in Cockburn (2001); another one that follows the so called Top-Down approach, as it is developed in

Bourguignon et al. (2003b), and the last one that follows the method developed by Savard (2003), also known as Top-Down/Bottom-Up model.

On one side we can say that a simple integrated approach like the one we have implemented in this paper is deficient on the side of the microeconomic specification and behavioural responses by individual agents. Anyway, the introduction of microeconometric behavioural equations into a CGE model looks of hard application and cumbersome for computational aspects.

On the other side, a Top-Down approach completely disregards the possible feedback effects coming from the microeconomic side of the economy, which could affect also the macroeconomic variables, as we have seen in subsection 5.1.

In our opinion, indeed, the TD/BU modelling looks the most complete approach, as on one side it can include all the possible microeconometric estimates to account for behavioural responses by individual agents, and on the other side it also takes into account the feedback effects from the micro to the macro level of analysis. «…The value added of this approach comes from the fact that feedback effects, provided by the household model, do not correspond to the aggregate behaviours of the representative households used in the CGE model» (Savard, 2003, page 20).

However, two main problems arise when using this approach. First of all, the way in which these feedback effects are reported into the CGE model can affect results in a fundamental way. In particular, the fact of using shares or parameters instead of absolute levels (as in Savard's approach, 2003, where consumption levels are used), when possible, seems to lead to more consistent results, especially for the fact that when transmitting absolute levels from the MS model one has to change the initial hypothesis of the CGE model (see section 4). Secondly, eventual data inconsistencies between the micro and the macro datasets can also affect results seriously, and this can be overcome only by adjusting either one or the other dataset, thus going back to the problem of data reconciliation encountered with the integrated model (see section 2). However, while with an integrated model we encounter this problem when building the model, when we run a TD/BU model without previously adjusting the data, we have the problem of data inconsistencies that enters the results and we are not able to distinguish which is the part of the change that is due to feedback effects and which is the part due to data inconsistencies.

- Chapter 3 -

THE EFFECTS OF DR-CAFTA IN NICARAGUA: A CGE-MICROSIMULATION MODEL FOR POVERTY AND INEQUALITY ANALYSIS

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1. INTRODUCTION

In the literature that studies income inequality and poverty, we can observe a recent development of models that link together a macroeconomic model (usually a CGE model) and a microsimulation model. The reason for this lays in the fact that poverty and inequality are typically microeconomic issues, while the policy reforms or the shocks that are commonly simulated have often a strong macroeconomic impact on the economy under study. Indeed, the main advantage of linking these two models is that one is able to take into account full agents' heterogeneity and the complexity of income distribution, while being able at the same time to consider the macroeconomic effects of the policy reforms.

In this paper, we build a CGE-microsimulation model for the economy of Nicaragua, following the Top-Down approach (see Bourguignon *et al.*, 2003b), that is, the reform is simulated first at the macro level with the CGE model, and then it is passed onto the microsimulation model through a vector of changes in some chosen variables, such as prices, wage rates, and unemployment levels. The main reason for this choice is that with such an approach, one can develop the two models (CGE and microsimulation) separately, thus being able to make use of behavioural micro-econometric equations, which are instead of more difficult introduction into a fully integrated model (see for instance Cockburn, 2001, and Cororaton and Cockburn, 2005) change.

Moreover, the so called top-down approach appears to be particularly suited to the policy reform we are willing to simulate with the model: the Free Trade Agreement of Central America with the USA is mainly a macroeconomic reform, which on the other hand can have important effects on the distribution of income[1].

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[1] The choice of a Top-Down approach that a priori disregards the possible feedback effects from the micro to the macro level of analysis is justified also from the fact that the reform we simulate produces very small changes in the microeconomic structure of the country. For instance, the change in the parameter *ty* (tax rate on income), which would be the communicating parameter from the micro to the macro level of analysis (see Chapter 2 for more details on the Top-Down/Bottom-Up approach that takes into account these the feedback effects), is in the range of 0.28 and 0.88 for urban households, and of -0.40 and 1.52 for the rural ones. We believe that these small changes are not sufficient to produce a significant adjustment in the macroeconomic structure of the economy. Moreover, as we do not have any specific information about

With such a model we try to study the possible changes in the distribution of income deriving from the Free Trade Agreement with USA. Our analysis finds only small changes both in the main macroeconomic variables and in the distribution of income and poverty indices.

The Free Trade Agreement between the countries of the American isthmus and the United States (CAFTA) was signed in May 2004 (in August the Dominican Republic joined the Treaty, known from that moment on under the name DR-CAFTA). The Nicaraguan Congress ratified the Agreement in October 2005, and it came into force the 1st April 2006.

United States are a very important trade partner for Nicaragua. According to Sánchez and Vos (2005), in 2000 42% of Nicaraguan exports were directed to the US market, while 22% of Nicaraguan imports came from the USA. The majority of commercial exchanges between the two countries concerns agricultural products. The Trade Agreement provides for a gradual reduction of tariff rates on imports from USA, to be carried on in the first ten years that follow the introduction of the Treaty. Anyway, for most products the biggest reduction will be in the first year. On the other side, Nicaraguan exports toward USA will benefit of gradual increases in the quotas of entry into the US market[2].

The introduction of DR-CAFTA in Nicaragua was controversial. The promoters of the Agreement claimed an improvement in competitiveness and efficiency in production, and also new investment in advanced technology by USA was expected[3]. On the other side, the opposers of the DR-CAFTA are afraid that it will bring about a high number of losers, especially among those working in the traditional sectors, such as the agricultural sector and the small enterprises, which will not be able to compete with the US producers.

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the level of tax evasion in the country, the level of parameter *ty* as it is currently computed in the microsimulation model could reasonably be overestimated. Hence the reason why all the analyses we perform on inequality and poverty measures are based on gross income.

[2] For a more detailed description of the new trade regulation enforced with the Free Trade Agreement, see Sánchez and Vos (2006).

[3] The largest US investments in Nicaragua are in the energy, communications, manufacturing, fisheries, and shrimp farming sectors.

As our model is only a one-country study, we are not going to model the changes in the regime adopted in USA with respect to goods and commodities coming from Nicaragua, as well as we will not take into consideration the quotas imposed on imports from USA, but only the changes in the tariff rates raised on the imported goods from USA. With such a model we try to study the possible changes in the distribution of income deriving from the Free Trade Agreement with the USA. The core of the microsimulation model follows the discrete choice labour supply approach, and it is based on a multinomial logit specification, while the CGE model is basically a standard one.

The rest of the chapter is organized as follows. Section two describes the model in detail, for each of its modules: the microsimulation and the CGE models, and how the two models are linked together. The third section deals with the results of the simulation, and section four concludes.

The Nicaraguan Economy

Nicaragua is one of the poorest countries in the Latin America and the Caribbean region. Almost half of Nicaraguan population lives under the poverty line, while more than 25% of people in the rural areas are extremely poor[4]. The distribution of income shows a Gini index which is estimated to be 43.1 (World Bank, 2006) when computed on consumption, and 57.9 (ECLAC estimate, 2006) when computed on income.

Agriculture employs about 30% of the workforce and accounts for about one fifth of the gross domestic product. The main commercial crops are coffee, cotton, and sugarcane; these, together with meat, are the largest exports.

During the 1980s Nicaragua's economy underwent a strong recession, due both to the civil war, which caused the destruction of much of the country's infrastructure, and to the economic blockade staged by the USA from 1985 onwards.

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[4] Around 46% of the population lives below the poverty line established by the 2001 Living Standards Measurement Survey and 15% of the population lives in extreme poverty (The World Bank, 2003). These indicators are even higher according to other estimates, such as those contained in the Statistical Yearbook published by the Economic Commission for Latin America and the Caribbean (ECLAC, 2006). The differences in the estimates come from different levels of the poverty line, and from the different reference variable adopted (consumption or income).

At the beginning of the 1990s began a significant process toward macroeconomic stabilization. Pacification, international aid, continued foreign investment and the re-establishing of trading relationships with US have contributed to the stabilization process. Moreover, important trade reforms were carried over in those years: most of the quantitative restrictions to imports and exports were removed, and there was a net reduction of tariffs on imports, together with a liberalization of the financial sector.
At the end of the 1990s the economy suffered a slowdown, due to the financing of the reconstruction after the damage caused by Hurricane Mitch in the fall of 1998, and to a simultaneous fall in the price of coffee and an increase in the price of oil.
Nicaragua continues to be dependent on international aid and debt relief under the Heavily Indebted Poor Countries (HIPC) initiative.

2. THE MODEL

2.1. The Microsimulation Model

The main role of the microsimulation module in the linked framework is to provide a detailed computation of net incomes at the household level, through a detailed description of the tax-benefit system of the economy, and to estimate individual behavioural responses to the policy change.
The data source for the building and estimation of the microsimulation model is the "Encuesta Nacional de Hogares sobre Medición de Nivel de Vida" (EMNV) of 2001, supplied by the Instituto Nacional de Estadísticas y Censos and The World Bank (Poverty and Human Resources Development Research Group, LSMS Data).
The survey includes information regarding income and expenditures of 4191 families, in which live 22810 individuals. Of these individuals, 12645 are at working age (15-65). Moreover, we have information on 2079 non agricultural activities and 1547 farm activities.

The microsimulation model follows the discrete choice labour supply approach[5], and it is estimated through a multinomial logit specification (see Bourguignon *et al.*, 2003b and Bussolo and Lay, 2003). Each agent can "choose" among three labour market alternatives: being inactive, being a wage worker or being self-employed.
The equations of the model are the following:

Regression model for log-wage earnings:	$Log(YL_{mi}) = a_{l(mi)} + b_{l(mi)} \cdot X_{mi} + c_{l(mi)} \cdot \lambda_{mi} + v_{mi}$	*(1)*
"Choice" of labour market status:	$LM_{mi} = \alpha_{g(mi)} + \beta_{g(mi)} \cdot Z_{mi} + \varepsilon_{mi}$	*(2)*
Household *m*'s income generation model:	$Y_m = \sum_{i=1}^{NC_m} YL_{mi} \cdot W_{mi} + YE_m - taxes_m$	*(3)*
Household specific consumer price index:	$PCI_m = \sum_{s=1}^{10} \eta_{ms} \cdot P_{ms}$	*(4)*
Households' real income:	$Y_m = \frac{Y_m}{PCI_m}$	*(5)*

The *first equation* of the model computes the logarithm of labour income of member *i* of household *m* as a linear function of his/her personal characteristics (vector X_{mi}) and of λ_{mi}, which represents the inverse Mills ratio estimated for the selection model. The residual term v_{mi} describes the effects of unobserved components on wage earnings. The equation is estimated separately for eight different labour market segments, differentiated according to occupation (wage worker or self-employed), gender and skill level. The index function *l*(*mi*) assigns individual *i* of household *m* to a specific labour market segment[6].

[5] The world "choice" can be misleading in our framework, as the model we use does not represent an actual labour market status *choice*, but rather the *probability* of being in one condition or in the other for each individual, who does not actually "choose" endogenously the labour market alternative. This is the reason why from now on we will use the word "choice" in quotation marks.

[6] In the original model implemented in Bourguignon *et al.* (2003b) there is a specific equation which estimates family income deriving from self-employment activity on the base of household's characteristics. In the present work we have instead the income declared by self-employed as labour income, and we do not need an additional equation to compute the income deriving from self-employment activity.

The *second equation* represents the "choice" of labour status made by household members. Each individual at working age has to "choose" among three alternatives: being a wage worker, being self-employed or being inactive. We estimate the selection model using a multinomial logit specification, which assigns each individual to the alternative with the highest associated probability. In our model we have arbitrarily set to zero the utility of being inactive. Vector Z_{mi} of explanatory variables includes some personal characteristics of individual i of household m. The equation is defined only for individuals at working age, and it is estimated separately for different demographic groups, defined for household heads, spouses and other members. The index function $g(mi)$ assigns each individual to a specific demographic group.
The *third equation* is an accounting identity that defines total household net income, Y_m, as the sum of the labour income of its members YL_{mi} (NC_m is the number of members at working age in household m) and of the exogenous income YE_m, net of taxes. The variable W_{mi} is a dummy variable taking value one if individual i of household m is a wage worker, and zero otherwise. Taxes on income are computed according to "Ley de equidad fiscal", which was introduced in 2003.
Real net income in equation *(5)* is computed dividing nominal household income by a household specific consumer price index, as computed in equation *(4)*, where η_{ms} are consumption shares for different goods and P_s is the price of good s.
We have grouped the various commodities into 10 consumption goods.

Estimation

The aim of the first equation in the model is to obtain efficient estimates for labour incomes and incomes deriving from self-employment activity, but only for those individuals that are observed to be inactive in the survey. These estimates are used in the case that, after a policy reform, one or more of them will change their labour market status and become wage workers or go into self-employment activity. In this case, using these estimates, we will be able to assign a wage or a labour income to individuals that have changed their labour market status after the simulation run.

For all the other individuals that are observed to receive a wage or to earn a positive income from their activity, we use instead the observed wage and income levels and not the estimated ones.

Equation (1) is estimated separately for each labour market segment, which is defined according to occupation, gender and skill level. An individual is considered high-skilled when his/her education attainment is more than primary school, and unskilled otherwise. We estimated the equation using a Heckman two-step procedure to correct for the selection bias[7]. Vector X_{mi} includes some regional dummies, the logarithm of age, and the number of school years attended. In the selection equation we used a dummy indicating the presence or not of children under six, a dummy variable indicating the racial group (distinguished in white and non-white), and the number of adults living in the household to correct for the selection bias. The estimation results for the labour market segments low-skilled wage workers, women, and high-skilled self-employed, men, are reported in Tables 1 and 2.

[7] Inactive people are divided only according to gender and skill level.

Table 1 - Estimation results, Heckman selection model for labour income (low-skilled wage workers, women)

Heckman selection model, two-step estimates				
			Number of obs.	3126
			Censored obs.	2396
			Uncensored obs.	730
			Wald chi2 (10)	151.74
			Prob > chi2	0.0000
Dependent variable: logarithm of yearly wage				
	Coefficient	*Std. Error*	*z*	*P>|z|*
constant	6.120207	1.318075	4.64	0.000
ln(age)	0.221083	0.169068	1.31	0.191
arur	-0.997838	0.442870	-2.25	0.024
r1	-0.146869	0.253803	-0.58	0.563
r2	-0.850731	0.271074	-3.14	0.002
r3	-0.885224	0.377423	-2.35	0.019
lambda	1.939433	1.187985	1.63	0.103
Selection equation				
constant	-0.172367	0.269785	-0.64	0.523
ln(age)	-0.049158	0.060533	-0.81	0.417
arur	-0.452511	0.054082	-8.37	0.000
r1	0.144866	0.092596	1.56	0.118
r2	-0.146336	0.094710	-1.55	0.122
r3	-0.292587	0.103431	-2.83	0.005
gr	0.085156	0.129487	0.66	0.511
ch6	-0.012388	0.054211	-0.23	0.819
nad	-0.036539	0.013463	-2.71	0.007
rho	0.878940			
sigma	2.206558			

arur: urban/rural area (0 urban, 1 rural); r1, r2, r3: regional dummies for the four regions, Managua, Pacific, Central and Atlantic regions (reference region Managua); gr: racial group (0 white, 1 non-white); ch6 = presence or not of children under 6 (0 no children under 6, 1 one or more children under 6); nad: number of adults living in the household; lambda: inverse mills ratio.

Table 2 - Estimation results, Heckman selection model for labour income (high-skilled self-employed, men)

Heckman selection model, two-step estimates				
			Number of obs.	958
			Censored obs.	488
			Uncensored obs.	470
			Wald chi2 (10)	270.65
			Prob > chi2	0.0000
Dependent variable: logarithm of yearly labour income				
	Coefficient	*Std. Error*	*z*	*P>|z|*
constant	8.314737	2.186083	3.80	0.000
ln(age)	0.497086	0.566287	0.88	0.380
arur	-0.319998	0.247125	-1.29	0.195
r1	-0.428120	0.242832	-1.76	0.078
r2	-0.406418	0.262587	-1.55	0.122
r3	-0.148755	0.328582	-0.45	0.651
years of school	0.134023	0.062750	2.14	0.033
lambda	-1.695824	0.471557	-3.60	0.000
Selection equation				
constant	-5.800225	0.488066	-11.88	0.000
ln(age)	2.016758	0.128209	15.73	0.000
arur	0.007804	0.132835	0.06	0.953
r1	0.042955	0.126017	0.34	0.733
r2	0.174041	0.137928	1.26	0.207
r3	0.230188	0.175659	1.31	0.190
years of school	-0.044537	0.033413	-1.33	0.183
gr	-0.224695	0.229871	-0.98	0.328
ch6	0.384146	0.097169	3.95	0.000
nad	-0.126610	0.024663	-5.13	0.000
rho	-0.815810			
sigma	2.078696			

See legend for Table 1.

Equation (2) represents the "choice" of the labour status made by individuals. Each individual can "choose" among three alternatives: being inactive, being a wage worker or being self-employed. The utility of being inactive is arbitrarily set to zero. Parameters of this equation were obtained through the estimation of a multinomial logit model, assuming that the residual terms ε_i are distributed according to the Extreme Value Distribution – Type I[8]. The estimation was conducted on sub-samples of individuals at working age, differentiated according to their demographic group (household heads, spouses, and other members). The explanatory variables include some regional dummies, sex, logarithm of age, skill level, illiteracy and racial group, the number of household members and that of children under six. For spouses and other members we also used labour market status, skill level and illiteracy of the household head. The model is estimated by Maximum Likelihood. The estimation results are reported in Tables 3 to 5.

Following the procedure described in Duncan and Weeks (1998), we drew a set of error terms ε_i for each individual from the extreme value distribution, in order to obtain for each individual an estimate that is consistent with his/her observed activity or inactivity status. From these drawn values, we selected 100 error terms for each individual, in such a way that, when adding it to the deterministic part of the model, it perfectly predicts the activity status that is observed in the survey.

After a policy change, only the deterministic part of the model is recomputed. Then, by adding the random error terms previously drawn to the recomputed deterministic component, a probability distribution over the three alternatives (being a wage worker, being self-employed or being inactive) is generated for each individual. This implies that the model does not assign every individual from the sample to one particular alternative, but it gives the individual probabilities of being in one condition rather than in the other. This way, the model does not identify a particular labour market status for each

[8] The Extreme Value distribution (Type I) is also known as Gumbel (from the name of the statistician who first studied it) or double exponential distribution, and it is a special case of the Fisher-Tippett distribution. It can take two forms: one is based on the smallest extreme and the other on the largest. We will focus on the latter, which is the one of interest for us. The standard Gumbel distribution function (maximum) has the following probability and cumulative density functions, respectively:

pdf: $f(x) = \exp\left(-x - e^{-x}\right)$

CDF: $F(x) = \exp\left(-e^{-x}\right)$.

individual after the policy change, but it generates a probability distribution over the different alternatives[9].

Table 3 - Estimation results, multinomial model, household heads (RRR)

Multinomial logistic regression (labour market status = inactivity is the base outcome)				
			Number of obs.	3590
			LR chi2 (22)	797. 50
			Prob > chi2	0.0000
			Pseudo R2	0.1103
			Log likelihood	-3217.29
Labour market status: Wage worker				
	RRR	*Std. Error*	*z*	*P>|z|*
arur	0.856107	0.113767	-1.17	0.242
r1	1.204847	0.203082	1.11	0.269
r2	0.919470	0.163786	-0.47	0.637
r3	1.140500	0.236109	0.64	0.525
sex	0.164213	0.019620	-15.12	0.000
ln(age)	0.101116	0.022915	-10.11	0.000
qual	1.668111	0.241817	3.53	0.000
alfa	0.904310	0.125660	-0.72	0.469
gr	1.005275	0.283091	0.02	0.985
lnc	0.999180	0.125738	-0.01	0.995
nch6	0.875273	0.059414	-1.96	0.050
Labour market status: Self-employed				
arur	1.365137	0.170192	2.50	0.013
r1	1.287282	0.218066	1.49	0.136
r2	1.510400	0.264805	2.35	0.019
r3	1.902738	0.384524	3.18	0.001
sex	0.184854	0.020611	-15.14	0.000
ln(age)	0.397288	0.087407	-4.20	0.000
qual	0.880234	0.128972	-0.87	0.384
alfa	0.935067	0.119069	-0.53	0.598
gr	0.782463	0.206958	-0.93	0.354
lnc	1.191989	0.142684	1.47	0.142
nch6	0.877780	0.055559	-2.06	0.039

arur: urban/rural area (0 urban, 1 rural); r1, r2, r3: regional dummies for the four regions, Managua, Pacific, Central and Atlantic regions (reference region Managua); sex: gender dummy (0 man, 1 woman); qual: skill level (0 primary school or less, 1 more than primary school); alfa: dummy variable for illiteracy (0 literate, 1 illiterate or semi-literate); gr: racial group (0 white, 1 non-white); lnc: logarithm of number of household members; nch6: number of children under 6.

[9] This procedure is also described in Creedy and Kalb (2005). See also Creedy *et al.* (2002b).

Table 4 - Estimation results, multinomial model, spouses (RRR)

Multinomial logistic regression (labour market status = inactivity is the base outcome)				
			Number of obs.	2572
			LR chi2 (30)	1324.38
			Prob > chi2	0.0000
			Pseudo R2	0.2344
			Log likelihood	-2163.44
Labour market status: Wage worker				
	RRR	*Std. Error*	*z*	*P>|z|*
arur	0.441348	0.067240	-5.37	0.000
r1	1.236323	0.228341	1.15	0.251
r2	0.972160	0.189136	-0.15	0.885
r3	0.830216	0.188088	-0.82	0.411
sex	0.033707	0.010730	-10.65	0.000
lage	1.675376	0.236386	3.66	0.000
qual	2.658774	0.421025	6.18	0.000
alfa	0.688802	0.129472	-1.98	0.047
gr	1.351889	0.421050	0.97	0.333
lnc	1.136499	0.201381	0.72	0.470
ch6	0.788947	0.106655	-1.75	0.080
sh1	1.017216	0.217309	0.08	0.936
sh2	0.695049	0.153931	-1.64	0.100
qual_hhh	1.096629	0.171393	0.59	0.555
alfa_hhh	0.633085	0.124560	-2.32	0.020
Labour market status: Self-employed				
arur	0.550564	0.062605	-5.25	0.000
r1	1.625452	0.278943	2.83	0.005
r2	0.868100	0.155040	-0.79	0.428
r3	0.998334	0.195205	-0.01	0.993
sex	0.110186	0.034215	-7.10	0.000
lage	1.710129	0.196716	4.66	0.000
qual	0.904985	0.129851	-0.70	0.487
alfa	0.612875	0.078585	-3.82	0.000
gr	0.741322	0.158286	-1.40	0.161
lnc	1.300308	0.180817	1.89	0.059
ch6	0.765705	0.085410	-2.39	0.017
sh1	0.485880	0.088480	-3.96	0.000
sh2	0.997432	0.176471	-0.01	0.988
qual_hhh	1.215565	0.169844	1.40	0.162
alfa_hhh	0.894089	0.115555	-0.87	0.386

See legend for Table 3. ch6: presence or not of children under 6 (0 no children under 6, 1 one or more children under 6); sh1, sh2: dummy variables for the occupational status of the household head (inactive, wage worker or self-employed, reference category inactivity); alfa_hhh: dummy variable for literacy of the household head (0 literate, 1 illiterate or semi-literate).

Table 5 - Estimation results, multinomial model, other members (RRR)

Multinomial logistic regression (labour market status = inactivity is the base outcome)				
			Number of obs.	4992
			LR chi2 (32)	1721.62
			Prob > chi2	0.0000
			Pseudo R2	0.1634
			Log likelihood	-4408.04
Labour market status: Wage worker				
	RRR	*Std. Error*	*z*	*P>|z|*
arur	0.824444	0.072712	-2.19	0.029
r1	0.979827	0.107931	-0.19	0.853
r2	0.918551	0.107773	-0.72	0.469
r3	0.711421	0.097806	-2.48	0.013
sex	0.204095	0.015428	-21.02	0.000
lage	6.759236	0.881377	14.65	0.000
qual	0.957752	0.084746	-0.49	0.626
alfa	0.699411	0.080142	-3.12	0.002
gr	0.880421	0.170281	-0.66	0.510
lnc	0.887087	0.100894	-1.05	0.292
ch	1.205024	0.148301	1.52	0.130
ch6	1.430704	0.130579	3.92	0.000
sh1	0.977419	0.096661	-0.23	0.817
sh2	0.787106	0.074041	-2.54	0.011
qual_hhh	0.724914	0.073728	-3.16	0.002
alfa_hhh	1.385381	0.123121	3.67	0.000
Labour market status: Self-employed				
arur	1.276138	0.123260	2.52	0.012
r1	1.344980	0.214562	1.86	0.063
r2	2.176651	0.349789	4.84	0.000
r3	1.921958	0.337287	3.72	0.000
sex	0.150325	0.013125	-21.7	0.000
lage	2.516042	0.383694	6.05	0.000
qual	0.710553	0.072736	-3.34	0.001
alfa	0.914365	0.104452	-0.78	0.433
gr	1.328942	0.301983	1.25	0.211
lnc	1.100904	0.144585	0.73	0.464
ch	1.304911	0.183973	1.89	0.059
ch6	0.947604	0.096573	-0.53	0.597
sh1	0.651611	0.091971	-3.03	0.002
sh2	2.897396	0.328958	9.37	0.000
qual_hhh	0.700602	0.090371	-2.76	0.006
alfa_hhh	1.030809	0.097232	0.32	0.748

See legend for Table 4. ch: dummy variable for presence of children under 15 (0 no children, 1 one or more children).

2.2. The CGE Model

The main characteristics of the CGE model are the following.

There are two representative households, divided according to their residence in urban or rural areas. Both maximize utility according to a Linear Expenditure System (LES) system. They obtain income from their supply of labour and capital, and they also receive transfers from the government and remittances from abroad.

Domestic production is carried on by 38 production sectors, which are producing 38 commodities following a Leontief technology in the aggregation of value added (capital and aggregate labour) and the intermediate aggregate. The aggregation of intermediate inputs is done according to a Leontief technology, while capital and labour are aggregated into value added according to a Constant Elasticity of Substitution (CES) function.

Labour demand is divided into eight different labour types, distinguished according to sex, qualification level and occupation (wage workers or self-employed) of the workers. These labour types are then aggregated to form a "labour aggregate" according to a CES function. The price of each labour type is set at the level of its marginal productivity.

Investments in the economy are savings-driven.

The public sector consumes goods, saves, and raises taxes on households' income, on firms' output and sells, on consumption of certain goods and tariffs on imports. It also pays subsidies to exports, and transfers to firms and households. The equilibrium of public budget constraint is reached through the change in public savings.

For the foreign sector the Armington assumption holds, and domestic production and imports are aggregated through a CES function. Domestic production is divided into supply of exports and supply of domestically produced good for the internal market following a Constant Elasticity of Transformation (CET) function.

A stylized scheme of the production structure and of the foreign sector design is reported in Appendix B.

Calibration

The calibration of the model is done on the Social Accounting Matrix (SAM) for Nicaragua for the year 2000 (see Sánchez and Vos, 2005 for details).

Some parameter values were taken from the existing literature. Sánchez and Vos (2005) is the source for the values of the substitution elasticities in the production function, in the Armington function (aggregation of the composite good sold on the internal market), and in the CET function (aggregation of internal production intended to the internal market and exports)[10]. Sánchez and Vos (2005) also estimated the values of income elasticity of consumption demand using the data of the EMNV 2001. The values for the Frisch parameter were taken from Lluch, Powell and Williams (1977).

For what concerns the elasticity of substitution among the eight different labour types, we implemented a sensitivity analysis, using different values of elasticity. We report the results of the simulation for the different values considered in this sensitivity analysis (see Tables 7 to 18).

2.3. Linking the Two Models

The basic difficulty of the Top-Down approach is to ensure consistency between the micro and macro levels of analysis. Thus, it is necessary to introduce a system of equations to ensure the achievement of consistency between the two models[11]. In practice, this consists in imposing the macro results obtained with the CGE model onto the microeconomic level of analysis. In particular, the changes in the commodity prices, P_q, must be equal to those resulting from the CGE model; the changes in average earnings with respect to the benchmark in the micro-simulation module must be equal to the changes in the wage rate obtained with the CGE model, as well as the change in the

[10] Sánchez and Vos (2005) used the values estimated in Sánchez (2004) for a similar model for Costa Rica, carrying on a sensitivity analysis for some parameter values.

[11] This way, what happens in the MS module can be made consistent with the CGE modelling by adjusting parameters in the MS model, but, from a theoretical point of view, it would be more satisfying to obtain consistency by modelling behaviour identically in the two models.

return to capital in the micro-simulation module must be equal to the one observed after the simulation run in the CGE model. In addition, the changes in the number of wage workers in the micro-simulation model must match those observed in the CGE model.

In our model, these consistency conditions translate into the following set of constraints, which can be called "linking" equations:

Household specific consumer price index:	$PCI_m = \sum_{s=1}^{NG} \eta_{ms} \cdot P_{ms} \cdot \left(1 + \Delta P_s^{CGE}\right)$	*(L.1)*
Logarithm of wage earnings:	$Log\left(YL_{mi}\right) = Log\left[\hat{YL}_{mi} \cdot \left(1 + \Delta PL^{CGE}\right)\right]$	*(L.2)*
Capital income:	$YK_m = KS_m \cdot \left(1 + \Delta PK^{CGE}\right)$	*(L.3)*
Employment level:	$\Delta EMP_l^{MS} = \Delta EMP_l^{CGE}$	*(L.4)*

The variables with no superscripts are those coming from the microsimulation module; those with the ^ notation correspond to the ones that have been estimated: in particular, $Log(\hat{YL}_{mi})$ is the wage level resulting from the regression model for individual *i*, member of household *m*, while $\hat{W}_{mi}$ is the labour market status of individual *i* of household *m* deriving from the estimation of the multinomial model.

ΔP_s^{CGE}, ΔPL^{CGE} and ΔPK^{CGE} indicate, respectively, the change in the prices of goods, the change in the wage rate and in the return to capital deriving from the simulation run of the CGE model, while ΔEMP_l^{CGE} and ΔEMP_l^{MS} are the employment level percentage changes for the CGE model and the microsimulation model for labour type *l*.

From equation *(L.4)*, the number of newly employed (or inactive) of labour type *l* resulting from the MS model must be equal to the change in the employment level of labour type *l* observed after the CGE run. This implies that the CGE model determines the employment level of the economy after the simulation, and that the MS model selects which individuals among the inactive persons have the highest probability of becoming employed (if the employment level is increased from the CGE simulation result), or either who, among the wage workers or self-employed, has the lowest probability of being employed after the policy change (if the employment level is decreased)[12].

[12] And, in this case, his/her new wage level will be determined by the regression model of wage earnings.

One possible way of imposing the equality between the two sets of parameters of system of equations *(L)* is through a change in the parameters of the selection and regression models. Following Bourguignon *et al.* (2003b), we restrict this change in the parameters to a change in the intercepts of functions *(1)* and *(2)*. The justification for this choice is that it implies a *neutrality* of the changes, that is, changing the intercepts a of equation *(1)* just shifts proportionally the estimated labour income of all individuals, without causing any change in the ranking between one individual and the other. The same applies for the labour market status selection equation: we choose to change the intercept α of equation *(2)*, and this will shift proportionally all the individual probabilities of each alternative, without changing their relative positions in the probability distribution, only to let some more individuals become employed (or some less if the employment rate of the CGE model is decreased), irrespectively of their personal characteristics. This change in the intercept will be of the amount that is necessary to reach the number of wage workers or self-employed resulting from the CGE model. Thus, this choice preserves the ranking of individuals according to their *ex-ante* probability of being employed, which was previously determined by the estimation of the multinomial model. For this reason the change in the intercept parameter satisfies this neutrality property.

3. SIMULATION AND RESULTS

The simulation of the introduction of DR-CAFTA into the Nicaraguan economy consists of a reduction of tariff rates on imports from the US.

As we are working with a static model, we cannot model the scheduled gradual change in the tariff rates, which is planned to be distributed along the ten years following the introduction of the Trade Agreement. As our model does not have any dynamic characteristic, it will be able capture the effects of the Treaty in the short-medium run, say about five years. Thus, the simulation we implemented will take into account the reduction in the tariff rates which is intended to take place after the first five years of effectiveness of the Treaty. This choice is expected to have no big influence on the results of the model, as the main tariff reduction for most of the commodities will take place in the first year after the introduction of the Agreement.

As our model is only a one-country study, we are not going to model the changes in the regime adopted in USA with respect to goods and commodities imported from Nicaragua. So, for instance, we are not going to take into account the access quotas imposed on these imports from Nicaragua to USA. These quotas are represented by limits to the importable quantities of some goods (in particular, beef, peanuts, cheese and sugar), but they are planned to reach an unlimited amount for beef and peanuts after the fifteenth year of enforcement of the Treaty, while for cheese they will be more than doubled after sixteen years. The unique quota which is expected to remain quite low is the one imposed on sugar, which will reach an amount 30% superior than the one imposed in the first year of enforcement of the Agreement.

The general reduction in the first five years after the introduction of the Treaty is about thirty percent of the previously adopted tariffs. The reductions adopted for the specific commodities and services are reported in Table 6.

Table 6 - Tariff change in the first five years after the introduction of DR-CAFTA

Commodity or service group	Percentage change
Coffee	-0.536
Other agricultural products	-0.543
Animals and animal products	-0.667
Forestry and wood extraction	-0.308
Fish and other fishing products	-0.956
Mining	-
Meat and fish	-0.180
Sugar*	0.178
Milk products	-0.050
Other industrial food products	-0.407
Beverages and tobacco	-0.231
Textiles, clothes, shoes and leather products	-0.221
Textiles, clothes, shoes and leather products (Zona Franca)	-0.221
Wood products and furniture	-0.191
Pulp, paper and paper products, printing	-0.380
Refined petrol, chemical products, rubber and plastic products	-0.147
Glass and other non metallic products	-0.123
Common metals and their products	-0.320
Machinery and transport equipment	-0.129
Motor vehicles trade and repair	-0.846
Average reduction	-0.314

* The raise in the tariff of this good is due to the fact that the quota imposed on the quantity of sugar was transformed in tariff in the first year.

As the supporters of the agreement with US expected an increase in the capital investments from USA in Nicaragua, we also considered an exogenous change in the initial capital endowment of different amounts (2, 5 and 10 %, respectively).

The percentage changes resulting from the simulation for a selected set of variables are reported in Tables 7 to 18.

A sensitivity analysis was also conducted to take into account different possible values for the elasticity of substitution of labour demand at the stage of aggregation of the eight different types of labour, which are divided according to sex, qualification level and occupation (wage workers or self-employed) of the workers, as explained in the description of the CGE model.

Table 7 - Simulation results, macroeconomic variables, elasticity of substitution for labour inputs 0.3 (percentage deviations from benchmark values)

	Sim1	Sim2	Sim3	Sim4
Wage rate	-0.269	-0.211	-0.278	1.594
Real wage rate	-0.026	-0.018	0.054	2.126
Capital return	-0.211	-0.073	-0.346	-4.066
Consumer price index	-0.243	-0.193	-0.332	-0.521
Capital endowment	0.000	2.000	5.000	10.000
Public savings	-1.161	7.879	20.087	28.818
Tax revenues	-0.754	1.855	5.062	8.221
Public expenditure	-0.360	-0.160	-0.141	0.562
Aggregate employment	0.000	0.000	0.000	0.000
Imports	0.136	-0.532	-0.239	0.280
Exports	0.277	0.451	3.382	8.331
Sales on the domestic market	-0.232	-0.149	-0.247	1.015
Domestic production	-0.274	-0.212	-0.279	1.592
Investment	0.005	-0.021	-0.141	-2.159
High-skilled workers employment level	0.004	-0.046	-0.051	-0.027
Low-skilled workers employment level	-0.004	0.046	0.051	0.027
Male workers employment level	-0.005	-0.029	-0.029	0.049
Female workers employment level	0.005	0.029	0.029	-0.049
Wage workers employment level	0.157	0.038	-0.009	0.141
Self-employed workers employment level	-0.157	-0.038	0.009	-0.141
Wage rate high-skilled	-0.278	-0.121	-0.181	1.672
Wage rate low-skilled	-0.260	-0.301	-0.376	1.516

Sim1: reduction of tariff rates on imports from USA (see Table 6).
Sim2: reduction of tariff rates on imports from USA and 2% reduction of initial capital endowment.
Sim3: reduction of tariff rates on imports from USA and 5% reduction of initial capital endowment.
Sim4: reduction of tariff rates on imports from USA and 10% reduction of initial capital endowment.

Table 8 - Simulation results, sectoral changes (elasticity of substitution for labour inputs 0.3)
(percentage deviations from benchmark values)

	Sim1	Sim2	Sim3	Sim4
Agricultural sectors				
Domestic production	2.774	-1.157	-3.697	-4.109
Sales on the domestic market	3.280	-1.180	-4.198	-5.128
Exports to USA	6.320	-0.876	-0.232	2.005
Exports to other countries	-2.082	-1.702	0.297	2.648
Imports from USA	-1.968	-0.145	1.574	2.623
Imports from other countries	7.438	-5.087	0.075	1.004
Industrial sectors				
Domestic production	-3.504	-0.064	0.764	5.107
Sales on the domestic market	-1.630	-0.017	0.514	3.046
Exports to USA	-6.198	3.289	9.818	20.038
Exports to other countries	-5.090	-0.250	2.592	7.932
Imports from USA	0.887	-2.833	-14.811	-17.900
Imports from other countries	0.110	0.064	3.235	4.643
Textile sectors				
Domestic production	0.986	-5.519	-11.585	-15.303
Sales on the domestic market	1.537	-4.381	-9.337	-14.614
Exports to USA	0.841	-8.619	-18.890	-21.642
Exports to other countries	0.649	-7.383	-15.803	-18.609
Imports from USA	1.996	-6.155	-14.148	-19.597
Imports from other countries	1.653	-6.498	-14.497	-19.936
Exporting sectors				
Domestic production	8.721	3.073	7.421	9.877
Sales on the domestic market	10.724	10.247	23.936	28.422
Exports to USA	5.380	4.846	12.002	16.662
Exports to other countries	7.682	0.077	0.569	2.397
Exports (all)	6.657	2.200	5.659	8.748
Imports from USA	2.133	-7.048	-16.243	-21.763
Imports from other countries	8.985	7.975	18.933	22.996
Imports (all)	8.276	6.421	15.294	18.366

- Agricultural sectors: coffee, sugar cane, corn, other agricultural products, animals and animal products, products of the forest and wood extraction, fishing.
- Industrial sectors: mining, energy, water, meat and fish, sugar, milk products, other food, beverages, tobacco, textiles (local and Zona Franca), wood products, paper, refined oil products, chemical and plastic products, glass, metal, machinery and equipment, construction.
- Textile sectors: textiles (local and Zona Franca).
- Exporting sectors: all sectors with initial ratio exports/production greater than 50% (coffee, tobacco, textiles -only Zona Franca, transport services).

Table 9 - Simulation results, employment and wage rate changes, household income and consumption levels, elasticity of substitution for labour inputs 0.3 (percentage deviations from benchmark values)

	Sim1		**Sim2**		**Sim3**		**Sim4**	
	Wage rate	**Empl. level**	**Wage rate**	**Empl. level**	**Wage rate**	**Empl. level**	**Wage rate**	**Empl. level**
High-skilled wage workers, men	-1.049	0.784	-0.321	0.109	-0.070	-0.209	1.313	0.276
High-skilled wage workers, women	-0.414	0.141	-0.459	0.248	-0.546	0.269	1.586	0.006
High-skilled self-employed, men	1.007	-1.268	0.527	-0.735	0.029	-0.307	2.242	-0.636
High-skilled self-employed, women	1.628	-1.872	0.422	-0.632	-0.304	0.025	2.159	-0.554
Low-skilled wage workers, men	0.017	-0.290	-0.039	-0.173	-0.290	0.011	0.902	0.684
Low-skilled wage workers, women	-0.247	-0.027	-0.280	0.068	-0.311	0.032	1.954	-0.354
Low-skilled self-employed, men	-0.347	0.074	-0.497	0.286	-0.533	0.256	1.722	-0.128
Low-skilled self-employed, women	-0.517	0.245	-0.253	0.041	-0.171	-0.108	1.864	-0.267
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
Households' nominal income	-0.209	-0.249	-0.125	-0.262	-0.231	-0.324	-0.076	1.420
Households' real income	0.036	-0.004	0.064	-0.049	0.096	0.032	0.485	1.825
Households' disposable income	-0.209	-0.249	-0.125	-0.262	-0.231	-0.324	-0.076	1.420
Households' consumption expenditure	-0.222	-0.249	-0.133	-0.262	-0.246	-0.324	-0.081	1.420
Households' savings	-0.209	-0.249	-0.125	-0.262	-0.231	-0.324	-0.076	1.420
Household specific price index	-0.245	-0.245	-0.189	-0.213	-0.327	-0.356	-0.558	-0.397
Households' consumption level	0.023	-0.011	0.058	-0.056	0.082	0.028	0.469	1.847
Households' utility level	0.023	-0.009	0.059	-0.059	0.084	0.032	0.483	1.989

Sim1: reduction of tariff rates on imports from USA (see Table 6).
Sim2: reduction of tariff rates on imports from USA and 2% reduction of initial capital endowment.
Sim3: reduction of tariff rates on imports from USA and 5% reduction of initial capital endowment.
Sim4: reduction of tariff rates on imports from USA and 10% reduction of initial capital endowment.

Table 10 - Simulation results, macroeconomic changes (elasticity of substitution for labour inputs 0.7) (percentage deviations from benchmark values)

	Sim1	Sim2	Sim3	Sim4
Wage rate	0.057	0.092	0.649	1.561
Real wage rate	0.070	0.497	0.818	2.936
Capital return	-0.042	-1.035	-1.301	-6.444
Consumer price index	-0.013	-0.403	-0.168	-1.335
Capital endowment	0.000	2.000	5.000	10.000
Public savings	0.432	6.386	23.009	44.283
Tax revenues	-0.003	1.807	6.374	11.644
Public expenditure	-0.093	0.113	0.298	0.075
Aggregate employment	0.000	0.000	0.000	0.000
Imports	0.134	0.806	-0.364	3.039
Exports	0.272	3.210	3.124	14.019
Sales on the domestic market	0.088	-0.073	0.346	1.189
Domestic production	0.048	0.090	0.647	1.537
Investment	0.078	-0.177	0.199	0.620
High-skilled workers employment level	-0.002	-0.157	-0.038	0.337
Low-skilled workers employment level	0.002	0.157	0.038	-0.337
Male workers employment level	-0.049	0.109	-0.154	0.318
Female workers employment level	0.049	-0.109	0.154	-0.318
Wage workers employment level	0.060	-0.066	-0.046	0.389
Self-employed workers employment level	-0.060	0.066	0.046	-0.389
Wage rate high-skilled	0.067	0.407	0.734	0.901
Wage rate low-skilled	0.047	-0.223	0.564	2.222

Sim1: reduction of tariff rates on imports from USA (see Table 6).
Sim2: reduction of tariff rates on imports from USA and 2% reduction of initial capital endowment.
Sim3: reduction of tariff rates on imports from USA and 5% reduction of initial capital endowment.
Sim4: reduction of tariff rates on imports from USA and 10% reduction of initial capital endowment.

Table 11 - Simulation results, sectoral changes (elasticity of substitution for labour inputs 0.7) (percentage deviations from benchmark values)

	Sim1	**Sim2**	**Sim3**	**Sim4**
Agricultural sectors				
Domestic production	1.602	-3.424	-4.130	-3.045
Sales on the domestic market	2.260	-4.090	-3.930	-6.140
Exports to USA	-15.866	4.579	-1.032	17.177
Exports to other countries	-5.222	-0.128	-3.670	5.739
Imports from USA	-23.624	-0.489	-0.566	-14.752
Imports from other countries	-5.402	4.078	4.475	6.586
Industrial sectors				
Domestic production	-1.534	1.479	3.121	0.501
Sales on the domestic market	-1.107	0.791	1.548	1.021
Exports to USA	5.808	5.196	8.520	17.506
Exports to other countries	2.212	5.354	5.983	1.145
Imports from USA	-2.775	-23.814	-26.493	-13.117
Imports from other countries	1.647	6.864	5.777	3.969
Textile sectors				
Domestic production	5.713	-5.089	-2.465	-26.377
Sales on the domestic market	5.185	-6.468	-1.311	-27.392
Exports to USA	8.359	0.282	-8.791	-24.329
Exports to other countries	7.111	-2.227	-5.820	-25.371
Imports from USA	7.476	-2.380	-5.900	-26.145
Imports from other countries	7.131	-2.669	-6.280	-26.384
Exporting sectors				
Domestic production	1.274	6.660	5.905	34.624
Sales on the domestic market	8.076	14.503	20.272	61.429
Exports to USA	3.693	9.964	11.441	37.070
Exports to other countries	-1.463	3.318	0.161	23.162
Exports (all)	0.833	6.277	5.183	29.354
Imports from USA	9.225	1.657	-8.694	-21.648
Imports from other countries	9.463	13.159	17.851	50.293
Imports (all)	9.439	11.969	15.105	42.851

- Agricultural sectors: coffee, sugar cane, corn, other agricultural products, animals and animal products, products of the forest and wood extraction, fishing.
- Industrial sectors: mining, energy, water, meat and fish, sugar, milk products, other food, beverages, tobacco, textiles (local and Zona Franca), wood products, paper, refined oil products, chemical and plastic products, glass, metal, machinery and equipment, construction.
- Textile sectors: textiles (local and Zona Franca).
- Exporting sectors: all sectors with initial ratio exports/production greater than 50% (coffee, tobacco, textiles - only Zona Franca, transport services).

Table 12 - Simulation results, employment and wage rate changes, household income and consumption levels, elasticity of substitution for labour inputs 0.7 (percentage deviations from benchmark values)

	Sim1		Sim2		Sim3		Sim4	
	Wage rate	**Empl. level**	**Wage rate**	**Empl. level**	**Wage rate**	**Empl. level**	**Wage rate**	**Empl. level**
High-skilled wage workers, men	-0.038	0.086	0.376	-0.285	0.911	-0.262	-0.296	1.838
High-skilled wage workers, women	-0.999	1.058	0.982	-0.884	0.430	0.216	3.272	-1.683
High-skilled self-employed, men	0.602	-0.551	-0.112	0.202	0.911	-0.262	0.705	0.826
High-skilled self-employed, women	5.535	-5.199	0.032	0.058	-0.833	1.492	-0.421	1.965
Low-skilled wage workers, men	0.870	-0.815	-0.730	0.825	0.662	-0.016	0.500	1.031
Low-skilled wage workers, women	-0.186	0.234	0.013	0.077	0.911	-0.262	0.512	1.019
Low-skilled self-employed, men	-0.462	0.513	-0.068	0.158	0.911	-0.262	3.166	-1.578
Low-skilled self-employed, women	0.178	-0.130	0.043	0.046	-0.660	1.315	3.725	-2.109
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
Households' nominal income	0.035	-0.001	-0.164	-0.087	0.050	0.608	-0.796	1.843
Households' real income	0.045	0.024	0.234	0.332	0.229	0.749	0.625	2.999
Households' disposable income	0.035	-0.001	-0.164	-0.087	0.050	0.608	-0.796	1.843
Households' consumption expenditure	0.037	-0.001	-0.174	-0.087	0.054	0.608	-0.847	1.843
Households' savings	0.035	-0.001	-0.164	-0.087	0.050	0.608	-0.796	1.843
Household specific price index	-0.010	-0.025	-0.396	-0.417	-0.178	-0.141	-1.413	-1.122
Households' consumption level	0.050	0.013	0.226	0.337	0.230	0.744	0.542	3.043
Households' utility level	0.050	0.016	0.230	0.364	0.236	0.805	0.563	3.276

Sim1: reduction of tariff rates on imports from USA (see Table 6).
Sim2: reduction of tariff rates on imports from USA and 2% reduction of initial capital endowment.
Sim3: reduction of tariff rates on imports from USA and 5% reduction of initial capital endowment.
Sim4: reduction of tariff rates on imports from USA and 10% reduction of initial capital endowment.

Table 13 - Simulation results, macroeconomic variables,
elasticity of substitution for labour inputs equal to value added aggregation sectoral elasticities
(percentage deviations from benchmark values)

	Sim1	**Sim2**	**Sim3**	**Sim4**
Wage rate	0.197	0.172	0.399	0.813
Real wage rate	0.173	0.483	0.406	1.236
Capital return	-0.082	-0.900	-0.386	-2.106
Consumer price index	0.024	-0.309	-0.007	-0.417
Capital endowment	0.000	2.000	5.000	10.000
Public savings	0.759	9.952	23.589	30.675
Tax revenues	0.305	2.748	6.666	8.967
Public expenditure	0.085	0.122	0.410	0.771
Aggregate employment	0.000	0.000	0.000	0.000
Imports	0.288	1.313	0.728	0.068
Exports	0.591	4.254	5.376	7.894
Sales on the domestic market	0.223	0.047	0.357	0.597
Domestic production	0.188	0.169	0.390	0.797
Investment	0.081	0.277	0.157	-1.990
High-skilled workers employment level	-0.027	-0.146	-0.148	-0.354
Low-skilled workers employment level	0.027	0.146	0.148	0.354
Male workers employment level	-0.021	-0.115	-0.128	0.143
Female workers employment level	0.021	0.115	0.128	-0.143
Wage workers employment level	-0.072	-0.127	-0.179	-0.375
Self-employed workers employment level	0.072	0.127	0.179	0.375
Wage rate high-skilled	0.254	0.468	0.706	1.532
Wage rate low-skilled	0.139	-0.123	0.092	0.094

Sim1: reduction of tariff rates on imports from USA (see Table 6).
Sim2: reduction of tariff rates on imports from USA and 2% reduction of initial capital endowment.
Sim3: reduction of tariff rates on imports from USA and 5% reduction of initial capital endowment.
Sim4: reduction of tariff rates on imports from USA and 10% reduction of initial capital endowment.

Table 14 - Simulation results, sectoral changes,
elasticity of substitution for labour inputs equal to value added aggregation sectoral elasticities
(percentage deviations from benchmark values)

	Sim1	Sim2	Sim3	Sim4
Agricultural sectors				
Domestic production	3.613	-6.414	-6.367	-7.150
Sales on the domestic market	4.681	-5.978	-0.927	-1.100
Exports to USA	-20.053	-8.085	-37.486	-42.262
Exports to other countries	-7.365	-4.892	-22.812	-24.609
Imports from USA	-33.527	1.091	2.940	4.747
Imports from other countries	-4.675	-0.614	-1.355	-0.622
Industrial sectors				
Domestic production	-1.623	2.460	3.030	5.484
Sales on the domestic market	-1.162	1.266	0.704	1.923
Exports to USA	8.536	10.957	26.881	36.899
Exports to other countries	3.041	8.609	15.385	19.393
Imports from USA	-2.395	-25.514	-34.416	-40.961
Imports from other countries	2.085	8.054	9.342	9.996
Textile sectors				
Domestic production	9.145	1.516	-1.092	-10.006
Sales on the domestic market	7.794	1.394	-1.261	-8.856
Exports to USA	13.848	2.192	-1.298	-17.184
Exports to other countries	11.799	1.777	-1.104	-13.775
Imports from USA	11.399	2.155	-1.262	-14.233
Imports from other countries	11.054	1.812	-1.606	-14.595
Exporting sectors				
Domestic production	2.149	5.895	6.392	9.272
Sales on the domestic market	11.256	17.710	37.849	52.240
Exports to USA	5.917	10.246	16.334	22.094
Exports to other countries	-1.497	1.024	-6.356	-8.347
Exports (all)	1.804	5.130	3.746	5.206
Imports from USA	14.188	3.553	0.937	-15.084
Imports from other countries	13.587	16.982	36.799	47.538
Imports (all)	13.649	15.593	33.090	41.060

- Agricultural sectors: coffee, sugar cane, corn, other agricultural products, animals and animal products, products of the forest and wood extraction, fishing.
- Industrial sectors: mining, energy, water, meat and fish, sugar, milk products, other food, beverages, tobacco, textiles (local and Zona Franca), wood products, paper, refined oil products, chemical and plastic products, glass, metal, machinery and equipment, construction.
- Textile sectors: textiles (local and Zona Franca).
- Exporting sectors: all sectors with initial ratio exports/production greater than 50% (coffee, tobacco, textiles - only Zona Franca, transport services).

Table 15 - Simulation results, employment and wage rate changes, household income and consumption levels, elasticity of substitution for labour inputs equal to value added aggregation sectoral elasticities

(percentage deviations from benchmark values)

	Sim1		Sim2		Sim3		Sim4	
	Wage rate	**Empl. level**	**Wage rate**	**Empl. level**	**Wage rate**	**Empl. level**	**Wage rate**	**Empl. level**
High-skilled wage workers. men	0.052	0.136	0.983	-0.807	1.770	-1.356	2.223	-1.394
High-skilled wage workers. women	-0.328	0.518	-0.469	0.641	-0.668	1.065	1.117	-0.316
High-skilled self-employed. men	0.538	-0.349	0.598	-0.427	0.194	0.196	0.632	0.165
High-skilled self-employed. women	5.093	-4.667	-0.288	0.457	0.622	-0.231	1.510	-0.703
Low-skilled wage workers. men	1.627	-1.416	0.517	-0.347	0.753	-0.360	0.998	-0.199
Low-skilled wage workers. women	-0.289	0.478	-0.260	0.429	-0.445	0.839	0.502	0.294
Low-skilled self-employed. men	-0.650	0.843	-0.602	0.775	-0.543	0.938	-1.287	2.111
Low-skilled self-employed. women	0.039	0.148	0.159	0.010	0.996	-0.599	2.033	-1.211
	Urban	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**	**Urban**	**Rural**
Households' nominal income	0.120	0.074	-0.075	-0.047	0.192	0.135	0.087	0.168
Households' real income	0.087	0.076	0.234	0.277	0.191	0.167	0.490	0.619
Households' disposable income	0.120	0.074	-0.075	-0.047	0.192	0.135	0.087	0.168
Households' consumption expenditure	0.127	0.074	-0.079	-0.047	0.204	0.135	0.093	0.168
Households' savings	0.120	0.074	-0.075	-0.047	0.192	0.135	0.087	0.168
Household specific price index	0.033	-0.002	-0.308	-0.324	0.001	-0.033	-0.401	-0.448
Households' consumption level	0.100	0.065	0.229	0.278	0.207	0.161	0.501	0.639
Households' utility level	0.100	0.071	0.236	0.299	0.211	0.173	0.513	0.683

Sim1: reduction of tariff rates on imports from USA (see Table 6).
Sim2: reduction of tariff rates on imports from USA and 2% reduction of initial capital endowment.
Sim3: reduction of tariff rates on imports from USA and 5% reduction of initial capital endowment.
Sim4: reduction of tariff rates on imports from USA and 10% reduction of initial capital endowment.

		Benchmark	Sim1	Sim2	Sim3	Sim4
Gini index		60.66	0.12%	-0.12%	-0.09%	0.04%
Theil index		79.60	0.27%	-0.17%	-0.17%	0.09%
P_0	General	58.18	-0.08%	-0.04%	0.12%	-1.15%
	Extreme	35.35	0.14%	-0.27%	-0.14%	-1.49%
P_1	General	32.34	-0.06%	-0.34%	-0.09%	-1.44%
	Extreme	18.23	-0.21%	-0.48%	-0.26%	-1.61%
P_2	General	22.62	-0.15%	-0.45%	-0.20%	-1.53%
	Extreme	12.78	-0.39%	-0.70%	-0.44%	-1.56%

		Benchmark Urban	Benchmark Rural	Sim1 Urban	Sim1 Rural	Sim2 Urban	Sim2 Rural	Sim3 Urban	Sim3 Rural	Sim4 Urban	Sim4 Rural
Gini index		57.66	55.32	2.31%	1.68%	1.96%	1.75%	2.02%	1.72%	2.09%	1.86%
Theil index		72.25	58.72	0.22%	-0.18%	-0.29%	-0.08%	-0.27%	-0.09%	-0.17%	0.25%
P_0	General	43.45	77.00	-0.20%	0.00%	-0.20%	0.07%	0.10%	0.14%	-2.06%	-0.49%
	Extreme	20.89	53.83	0.20%	0.10%	-1.02%	0.10%	-0.61%	0.10%	-2.85%	-0.81%

Sim1: reduction of tariff rates on imports from USA (see Table 6).
Sim2: reduction of tariff rates on imports from USA and 2% reduction of initial capital endowment.
Sim3: reduction of tariff rates on imports from USA and 5% reduction of initial capital endowment.
Sim4: reduction of tariff rates on imports from USA and 10% reduction of initial capital endowment.
All the indices are computed on per-capita gross income.
The poverty line for the general poverty rate is fixed at a level of 5157 $C per year, while the extreme poverty line is 2691 $C.
P_0 is the "headcount ratio": it measures the incidence of poverty as the proportion of total population lying below the poverty line.
P_1 is the "poverty gap ratio", which measures the intensity of poverty. as it reflects how far the poor are from the poverty line.
P_2 is also called "severity of poverty index" as it gives an indication of the degree of inequality among the poor.

Table 17 - Microeconomic results, income distribution and poverty changes

(elasticity of substitution for labour inputs 0.7)

		Benchmark	Sim1	Sim2	Sim3	Sim4
Gini index		60.66	0.02%	-0.04%	-0.11%	-0.18%
Theil index		79.60	0.00%	-0.07%	-0.30%	-0.78%
P_0	General	58.18	-0.66%	0.04%	-0.29%	-1.40%
	Extreme	35.35	-1.08%	-0.34%	-0.61%	-2.36%
P_1	General	32.34	-1.11%	-0.26%	-0.67%	-2.07%
	Extreme	18.23	-1.00%	-0.31%	-1.11%	-2.15%
P_2	General	22.62	-1.05%	-0.30%	-0.90%	-2.12%
	Extreme	12.78	-0.73%	-0.26%	-1.38%	-1.88%

		Benchmark		Sim1		Sim2		Sim3		Sim4	
		Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
Gini index		57.66	55.32	1.91%	1.74%	-1.63%	1.80%	2.07%	1.59%	1.71%	1.73%
Theil index		72.25	58.72	-0.57%	-0.07%	-0.30%	0.13%	-0.33%	-0.31%	-1.42%	-0.03%
P_0	General	43.45	77.00	-1.96%	-0.28%	-0.10%	0.14%	-0.59%	-0.07%	-3.04%	-0.21%
	Extreme	20.89	53.83	-2.44%	-0.40%	-1.63%	0.30%	-0.61%	-0.61%	-4.28%	-1.41%

Sim1: reduction of tariff rates on imports from USA (see Table 6).
Sim2: reduction of tariff rates on imports from USA and 2% reduction of initial capital endowment.
Sim3: reduction of tariff rates on imports from USA and 5% reduction of initial capital endowment.
Sim4: reduction of tariff rates on imports from USA and 10% reduction of initial capital endowment.
All the indices are computed on per-capita gross income.
The poverty line for the general poverty rate is fixed at a level of 5157 $C per year, while the extreme poverty line is 2691 $C.
P_0 is the "headcount ratio": it measures the incidence of poverty as the proportion of total population lying below the poverty line.
P_1 is the "poverty gap ratio", which measures the intensity of poverty. as it reflects how far the poor are from the poverty line.
P_2 is also called "severity of poverty index" as it gives an indication of the degree of inequality among the poor.

Table 18 - Microeconomic results, income distribution and poverty changes

(elasticity of substitution for labour inputs equal to value added aggregation sectoral elasticities)

		Benchmark	Sim1	Sim2	Sim3	Sim4
Gini index		60.66	0.05%	-0.14%	-0.14%	-0.14%
Theil index		79.60	0.14%	-0.31%	-0.30%	-0.26%
P_0	General	58.18	-0.45%	-0.33%	-0.41%	-0.78%
	Extreme	35.35	-0.47%	-0.74%	-0.81%	-1.08%
P_1	General	32.34	-0.56%	-0.58%	-0.81%	-1.20%
	Extreme	18.23	-0.35%	-0.56%	-0.75%	-1.32%
P_2	General	22.62	-0.49%	-0.62%	-0.85%	-1.28%
	Extreme	12.78	-0.36%	-0.50%	-0.62%	-1.27%

		Benchmark Urban	Benchmark Rural	Sim1 Urban	Sim1 Rural	Sim2 Urban	Sim2 Rural	Sim3 Urban	Sim3 Rural	Sim4 Urban	Sim4 Rural
Gini index		57.66	55.32	-0.12%	0.17%	-0.35%	0.01%	-0.37%	0.05%	-0.41%	0.04%
Theil index		72.25	58.72	-0.16%	0.21%	-0.62%	0.02%	-0.65%	0.10%	-0.68%	0.00%
P_0	General	43.45	77.00	-1.08%	0.00%	-0.98%	0.14%	-1.08%	0.07%	-1.67%	-0.14%
	Extreme	20.89	53.83	-1.43%	0.00%	-2.24%	0.00%	-2.44%	0.00%	-3.26%	0.00%

Sim1: reduction of tariff rates on imports from USA (see Table 6).
Sim2: reduction of tariff rates on imports from USA and 2% reduction of initial capital endowment.
Sim3: reduction of tariff rates on imports from USA and 5% reduction of initial capital endowment.
Sim4: reduction of tariff rates on imports from USA and 10% reduction of initial capital endowment.
All the indices are computed on per-capita gross income.
The poverty line for the general poverty rate is fixed at a level of 5157 $C per year, while the extreme poverty line is 2691 $C.
P_0 is the "headcount ratio": it measures the incidence of poverty as the proportion of total population lying below the poverty line.
P_1 is the "poverty gap ratio", which measures the intensity of poverty. as it reflects how far the poor are from the poverty line.
P_2 is also called "severity of poverty index" as it gives an indication of the degree of inequality among the poor.

The results show a very little answer of the economy to the tariff change. This outcome is not completely surprising, because the tariff levels which were in force previous the introduction of the DR-CAFTA were already quite low. Moreover, other studies found not only for Nicaragua but also for other countries in the region the same small answer to trade liberalization[13].

The sole reduction of tariffs on imports will cause a very small increase in total domestic production which in the best hypothesis will be of 0.2%. However, if we consider a small value for the elasticity of substitution among different labour inputs (elasticity fixed at 0.3), the change in domestic output is even negative. The negative response of output in this case is alleviated when considering a positive shock in the initial capital endowment, but this shock has to be of significant amount to cause a positive change in output (10% change in capital endowment).

However, if we try to have a closer look to the sectoral effects of the reform (see Tables 8, 11 and 14), and considering only the tariff reduction, we can observe that traditional sectors such as the agricultural and textile sectors are increasing their production, while the capital intensive (industrial sectors) sectors lose. On the contrary, when we take into account also the capital shock (simulations 2, 3 and 4), the direction of these results is inverted, so that we have the capital intensive sectors gaining and the traditional sectors (agricultural and textile sectors) that decrease their production level.

In all cases, however, the overall increase in production seems to be driven by the growth of the exporting sectors, which are gaining in all the simulations.

Anyway, the reduction of the tariff rates on imports does not generate significant losses for the government, as tax revenues do not decrease of high amounts. When the elasticity of substitution for labour is considered at the same level of the one used for value added aggregation, tax revenues even increase, due to the higher production and consumption levels in the economy. This increase becomes even bigger when we introduce a positive shock to capital endowment.

Taking into consideration the positive shock to capital endowment, the changes considered are in general of a higher amount, but anyway in the best hypothesis of a 10%

[13] See for instance Sánchez (2005), Vos *et al.* (2004), and the book edited by Ganuza et al. (2004), which contains sixteen country-studies on different countries in Latin and Central America on the consequences of the trade liberalization carried on during the last decades in this region.

change in the capital stock, the resulting change in domestic production will be around 1.5%.
In the first scenario (reduction of tariff rates on imports only), the change in labour demand apparently favours unskilled workers, and women in particular, except for the case with a low elasticity of substitution, where a small increase in the demand for qualified workers is experienced. The change in the employment levels of wage workers and self-employed depends similarly on the adopted value of the elasticity of substitution. Anyway, all the changes occurring in the employment levels of the different labour inputs are very small.
When the elasticity of substitution is sufficiently high (higher than 0.3), real wage is observed to increase, as well as real income does, thus increasing consumption levels for both rural and urban households.

For what concerns the microeconomic results, that is the changes in income distribution and poverty, we can observe in general very small changes in the underlying indices.
Taking into account only the reduction in tariffs on imports, poverty rates at a national level decrease in all the counterfactuals. On the contrary, income inequality is rising (even if of a very little amount), especially when we consider separated indices for urban and rural areas. Poverty seems to decrease more in urban than in rural areas.
This result of an increasing income inequality in both urban and rural areas confirms what was already found by Vos *et al.* (2004) for most of Latin and Central American countries in the case of trade liberalization.
When we take into account the positive shock on capital, then income inequality is observed to decrease. Anyway, the negative changes resulting in both income inequality and poverty indices remain very small (and in some cases they are even positive, such as in the case with constant elasticity of substitution in labour inputs equal to the elasticities used in value added aggregation), and especially in rural areas, where poverty is observed to have its greatest incidence.

4. CONCLUSION

The small positive results deriving from our analysis show that the introduction of the Free Trade Agreement with US in Nicaragua cannot be seen as the unique solution to the high poverty rates and the unequal income distribution of the country. In the best hypothesis the consequent increment in production would be of around 1.5%. This result is not surprising, as the tariff levels in force before the introduction of the DR-CAFTA were already quite low, after the process of trade liberalization carried on during the 1990s in all Central and Latin America's countries.

The main impact of the Treaty is to be found in the increase of exports, which, according to the supporters of the Agreement, are expected to be the leading engine of future development and economic growth in the country. Anyway, this increment in the amount of exported good is able to increase domestic production of only 1.5 percentage points in the best scenario.

It is true however that in our model we did not take into account the possible improvement in productivity generated by the new investments in advanced technology coming from the US, which could have given a major boost to the economy. Anyway, the dynamic model developed by Sánchez and Vos (2006), which includes also a positive shock on factor productivity, finds again small responses of the economy to trade liberalization, and to the Trade Agreement with the USA in particular.

The DR-CAFTA alone seems to be unable to bring about big changes in the structure of the economy, and especially for what concerns poverty and inequality reduction. It should at least be accompanied by other policies supporting lower incomes, especially in rural areas. One possible future implementation of the model presented here could be the design and the analysis of such a policy.

CONCLUSION

In this thesis we analyse and investigate the method of linking Computable General Equilibrium (CGE) models to Microsimulation (MS) models which has recently developed in the literature that studies developing countries.

CGE models are useful instruments for the study of a reform or a shock that has economy-wide effects, and in particular of those reforms/shocks that can produce structural and sectoral changes on the whole economy. Anyway, one of the limits of CGE models is that, as they generally follow the representative household approach, they are often unable to capture within-group distribution and some specific individual agents' behaviour. This is however of particular importance when we want to carry out income inequality and poverty analysis.

On the other hand, microsimulation (MS) models are accurate instruments in the representation of the tax-benefit system, and in the analysis of individual behaviour (such as labour supply or consumption) in response to a change of the tax-benefit system. In this respect, microsimulation models are very helpful and precise in the study of income distribution and poverty issues, as they work at a very detailed level, that is at the level of the individual or of the single household. The main drawback of these models is that they carry out only partial equilibrium analyses, thus not being able to capture the general equilibrium impact of a reform of the tax-benefit system. Moreover, if we want to analyse the distributional and poverty effects of a reform which takes place at the macroeconomic level (as it could be for instance a reform of the trading system), this is simply not doable with a microsimulation model. However, this kind of studies can be very important for poverty and inequality issues, especially in the case of developing countries where structural shocks and macroeconomic reforms are more likely to take place.

Linking CGE and MS models allows to overcome simultaneously the limits of both models and to obtain a more comprehensive instrument for the analysis of the effects of policy reforms and structural shocks on poverty and inequality. The modelling tool resulting from the link of the two models is indeed able to account for full agents' heterogeneity and microeconomic behaviour at the individual or household level, structural changes of the economy and general equilibrium effects of economic policies at the same time.

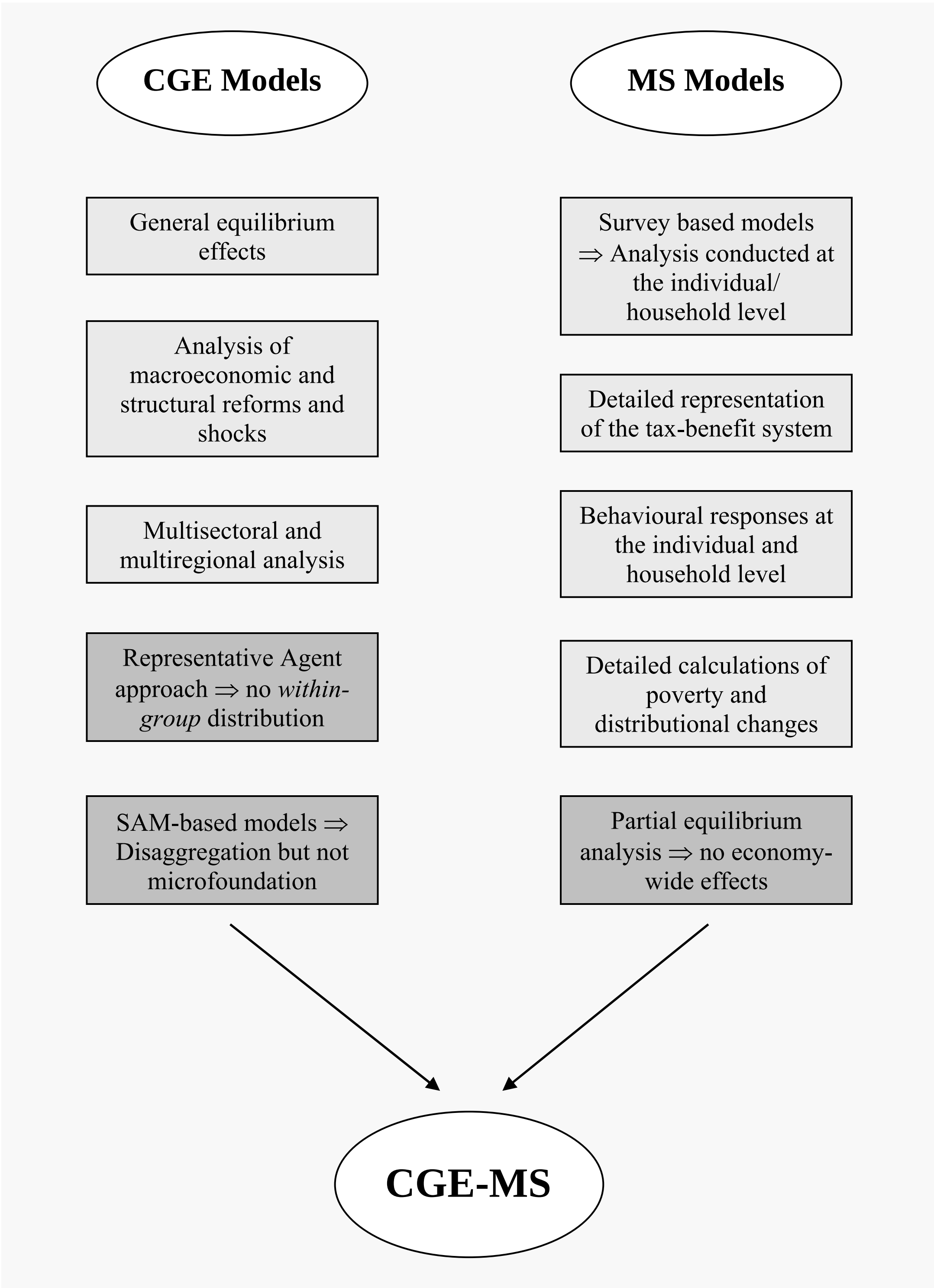

Figure 1 – CGE and Microsimulation Models

In the **first chapter** of the thesis we have tried to give an assessment of the recent developments observed in methods that link together CGE and microsimulation models, with a special concern for the different linking approaches existing in the literature for developing countries. There are three main approaches that are currently used in the literature: the integrated approach, which integrates the household survey into the CGE model, and the layered approach (Top-Down and TD/BU approaches), which instead develops the two models separately.

In the **second chapter** we have made a comparison of these three approaches. To do this we have built three models for the same economy and we investigate the different results coming out from the three different approaches. We have seen that most of the differences in the results coming out from the three main approaches arise when working with layered models (Top-Down and TD/BU approaches) rather than with integrated models.

We have observed that an integrated approach can be deficient on the aspect of the microeconomic specification and behavioural responses by individual agents. This is mainly due to the fact that the introduction of microeconometric behavioural equations into a CGE model looks of hard application and cumbersome for computational aspects.

On the other side, a Top-Down approach completely disregards the possible feedback effects coming from the microeconomic side of the economy, which could in principle affect also the macroeconomic variables.

In our opinion the TD/BU modelling seems to be the most complete approach, as on one side it can include all the possible microeconometric estimates to account for behavioural responses by individual agents, and on the other side it also takes into account the feedback effects from the micro to the macro level of analysis. However, two main problems arise when using this approach. First of all, the way in which these feedback effects are reported into the CGE model can affect results in a fundamental way. In particular, the fact of using shares or parameters instead of absolute levels of endogenous variables, when possible, seems to lead to more consistent results. Secondly, eventual data inconsistencies between the micro and the macro datasets can also affect results seriously. This can be overcome only by adjusting either one or the other dataset, thus going back to the problem of data reconciliation encountered with the integrated model.

However, while with an integrated model we encounter this problem when building the model, when we run a TD/BU model without previously adjusting the data, we have the problem of data inconsistencies that enters the results and we are not able to distinguish which is the part of the change that is due to feedback effects and which is the part due to data inconsistencies.

Bourguignon *et al.* (2001) and Bourguignon *et al.* (2003b) also provide strong arguments for working with layered rather than integrated models. These arguments are most persuasive when, as in their work for Indonesia, it is regarded as very important to simulate realistically variation in labour supply and occupational choice responses to changing prices, wages and employment conditions.

A reasonable conclusion may be that integrated models are best for some purposes and layered models for others. The integrated models, indeed, appear cleaner and more transparent, and they show a better reliability under the point of view of the theoretical consistency between the two levels of analysis. They may have the drawback of not being able to fully capture even the direction and the relative magnitude of distributional and of other effects in terms of a full microeconomic analysis.

Layered models, in contrast, perhaps have an advantage when the concern is about short-term distributional impacts in a setting where realism is at a premium and theoretical niceties are not so important.

In general, however, when building such models one has also to take into account the practical advantages and drawbacks of the various approaches (see Figure 2): for instance, the layered approach requires time and effort in the building of the entire model, as one has to go through two different modelling techniques and two different databases. On the other side, one of the main advantages of the integrated approach is its simplicity and easiness of implementation. Its simplicity allows what is instead still missing in the framework of a layered approach: dynamics. Indeed, while with integrated models recursive dynamics is already introduced in a few examples, such as the model by Annabi *et al.* (2005) for Senegal, one of the main things still missing up to now in a layered framework is a dynamic featuring, which in the future will need further effort.

This is of course of difficult implementation, both on the side of modelling (both models should be dynamic) and on that of data requirements. In particular, either panel survey data or a good database to compute transition probabilities (see in more detail Chapter 1, Section 2.2, page 39 on dynamic microsimulation techniques) are required for the building up of a dynamic microsimulation model. But this is not all. How the linking should be made is also an open question which until now did not receive a precise and detailed answer yet. A first attempt in this direction was made by Bibi and Chatti (2006) with their dynamic layered model for Tunisia.

In our applied analysis (**Chapter 3**), we develop a CGE-MS model for Nicaragua using a Top-Down approach. The model is used to simulate the effects of the Free Trade Agreement with the United States on income distribution and poverty in Nicaragua.
The main reason why we opted for a layered approach is that we wanted to estimate behavioural labour supply responses at the level of individuals. We did this through the estimation of a discrete choice labour supply model. This kind of switching regime equation is of cumbersome implementation into a CGE model, and in any case this would have implied the introduction of thousands of additional agents into the model, as in our survey there are 12645 individuals at working age.
The fact that we did not take into account the feedback effects from the micro into the macro level of analysis with a TD/BU approach is justified from the fact that the reform we simulate produces very small changes in the microeconomic structure of the country. We believe that these small changes are not sufficient to produce a significant adjustment in the macroeconomic structure of the economy.
Our analysis confirms the importance of using microsimulation techniques and survey data within the framework of a general equilibrium model. This way, indeed, it is possible to have a detailed insight into the distribution of incomes. In our applied study, for instance, we observe a small response of inequality at a national level, but if we disaggregate this result further, we can see that there is a systematic decrease of inequality in the urban areas, while in the rural areas inequality generally increases. The advantage of having such a model is that this process of disaggregation of the results has in principle no limits, until we reach the individual household level, so that we can study the effects of the reform on poverty and inequality in a very detailed way.

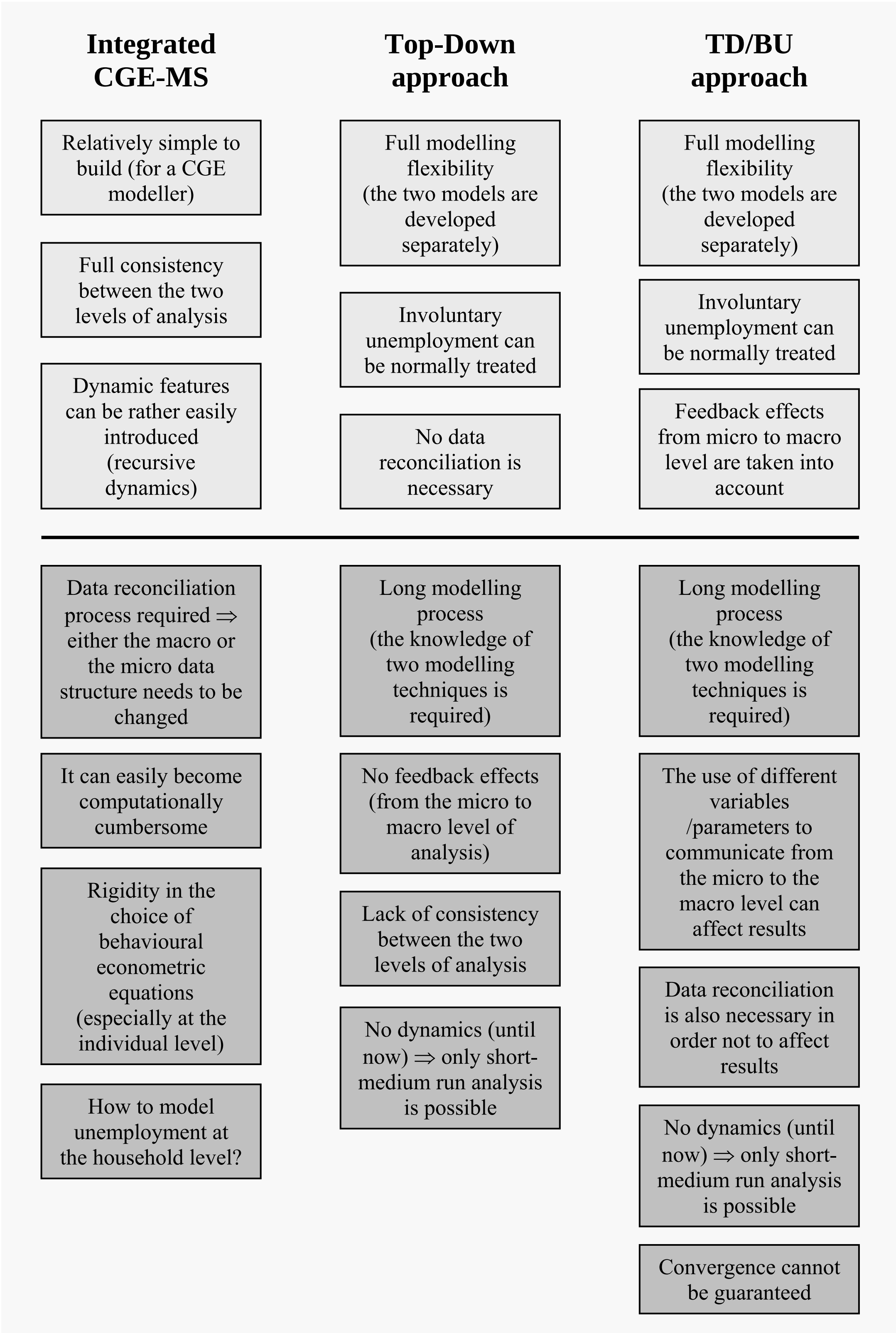

Figure 2 – Linking CGE and MS Models: Three Different Approaches

The main impact of the Treaty is to be found in the increase of exports, which, according to the supporters of the Agreement, are expected to be the leading engine of future development and economic growth in the country. Anyway, this increment in the amount of exported good is able to increase domestic production of only 1.5 percentage points in the best scenario. A small positive response of the economy to trade liberalization is also found in other studies, and especially in the work done by Sánchez and Vos (2006), who developed a dynamic CGE model for Nicaragua which also includes a positive shock on factor productivity that could be generated by the new investments in advanced technology coming from USA.

However, the results deriving from our analysis show that the introduction of the Free Trade Agreement with USA in Nicaragua cannot be seen as the unique solution to the high poverty rates and the unequal income distribution of the country. Indeed, even if we observe a systematic decrease of inequality in the urban regions, in the rural areas inequality generally increases.

Thus, the DR-CAFTA alone seems to be unable to bring about big changes in the structure of the economy, and especially for what concerns poverty and inequality reduction. It should at least be accompanied by other policies supporting lower incomes, especially in rural areas.

APPENDIX

APPENDIX A – Some Inequality and Poverty Indices

Here, we will give details of some inequality and poverty measures we have used during the analysis.

Gini index

The Gini coefficient is one of the most commonly used indicators of income inequality. It is defined as:

$$G = \frac{1}{2\mu N^2} \sum_i \sum_j \left| y_j - y_i \right|$$

where μ is the arithmetical mean of the incomes, N is the size of the population, and y_i and y_j are the incomes of agents i and j, respectively. Thus, the second factor at the right hand side represents the sum of the differences (in modulus) computed over all pairs of incomes. In the literature, however, we can also find different (although equivalent) definitions. In particular, it can be derived from the Lorenz curve, which plots the cumulative share of total income earned by households ranked from bottom to top (see below), in the following way:

$$G = 1 - 2\int_0^1 L(p)dp\,, \qquad (A.1)$$

where $L(p)$ is the Lorenz curve. The previous formula thus measures the area that is laying between the curve and the diagonal as a fraction of the total area under the 45° line. In terms of Figure A.1 below, this means:

$$G = \frac{A}{A+B} = \frac{\frac{1}{2} - B}{\frac{1}{2}} = 1 - 2B\,.$$

If the Lorenz curve coincides with the 45° line, which represents the situation of perfect equality, then the integral in equation *(A.1)* will take the value of ½, and the Gini index will equal zero.

The Gini index can thus take values between zero (perfect equality) and one (maximum level of inequality, that is, when all the income in the economy is owned by only one individual: $y_{\max} = \mu N$). Thus, the smaller is the index, the smaller is the inequality in the economy. The Gini index is very useful because it allows the ordering of different income distributions according to their level of inequality.

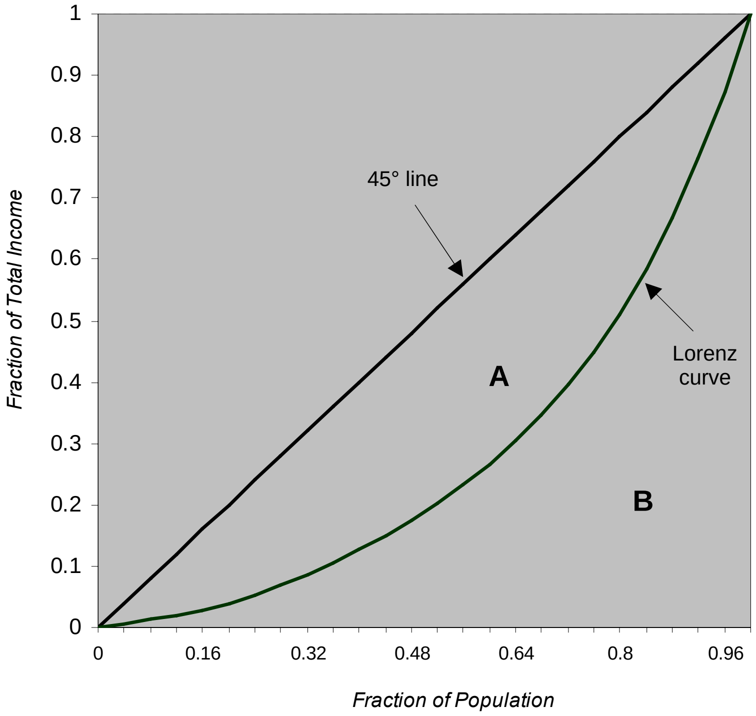

Figure A.1 – Lorenz Curve and Gini Coefficient

Lorenz curve

The Lorenz curve is defined according to the following expression:

$$L(p) = L(j/N) = \frac{\sum_{i=1}^{j} y_i}{\sum_{i=1}^{N} y_i}, \qquad \text{for } j = \{1, 2, \ldots, N\}.$$

In the continuous the expression becomes:

$$p = F(y) \Rightarrow L(p) = \int_0^y \frac{x \cdot f(x)}{\mu} dx,$$

where y is the income in the point we want to compute the curve, p is the cumulated probability of income, and μ is mean income.

This curve therefore shows the relationship between a particular percentage of the population, say $j = h/N$, and the proportion of total income that it perceives. Based on an analysis of the stochastic dominance of Lorenz curves, one could eventually infer, among different economies, which one has a more equitable distribution.

Atkinson's index

Atkinson's index is one of the few inequality measures that explicitly incorporate normative judgments about social welfare (Atkinson, 1970). The index is derived by calculating the so-called equity-sensitive average income (y_e), which is defined as that level of per capita income which if enjoyed by everybody would make total welfare exactly equal to the total welfare generated by the actual income distribution. It is sometimes also called equally distributed equivalent income. It is given by:

$$y_e = \left[\frac{1}{N} \cdot \sum_{i=1}^{N} \left(\frac{y_i}{\mu}\right)^{(1-e)}\right]^{1/(1-e)},$$

where y_i is the proportion of total income received by individual i, and e is the so-called inequality aversion parameter, which measures the degree of society's inequality aversion. It indeed reflects the strength of society's preference for equality, and can take values ranging from zero to infinity. When $e > 0$, there is a social preference for equality (or an aversion to inequality). As e rises, society attaches more weight to income transfers at the lower end of the distribution and less weight to transfers at the top. $e \rightarrow 0$ implies neutrality with respect to inequality, so that inequality is not perceived as a problem. Suppose instead that $e \rightarrow \infty$, then it means that there are Rawlsian preferences in the society, that is, that individuals have a preference for perfect equality. Typically, in the literature the most common values that are used for e include 0.5 and 2.

The Atkinson index (I_e) is then given by:

$$I_e = 1 - \frac{y_e}{\mu},$$

where μ is the actual mean income. The more equal the income distribution, the closer y_e will be to μ, and the lower the value of the Atkinson index. For any income distribution, the value of I_e lies between 0 and 1.

Coefficient of variation

The coefficient of variation is a measure of the dispersion of data around the mean. It is defined as the ratio of the standard deviation to the mean, that is:

$$CV = \frac{\sigma}{\mu}.$$

The coefficient of variation is a dimensionless number that allows comparison of the variation of populations that have significantly different mean values. It is often reported as a percentage (%) by multiplying the above calculation by 100.

Generalized Entropy coefficients

The family of Generalized Entropy indices satisfies a desirable property for inequality indices, that is, all the indices belonging to this family can be decomposed into a within-group and a between group contribution. The formulas for the indices are:

Generalized entropy index: $$I(c) = \frac{1}{Nc} \cdot \frac{1}{(c-1)} \sum_{i=1}^{N} \left[\left(\frac{y_i}{\mu} \right)^c - 1 \right]$$ for $c \neq 0,1$

Mean Logarithmic Deviation: $$I(0) = \frac{1}{N} \sum_{i=1}^{N} \ln \left(\frac{\mu}{y_i} \right)$$ for $c = 0$

Theil coefficient: $$I(1) = \frac{1}{N} \sum_{i=1}^{N} \frac{y_i}{\mu} \cdot \ln \left(\frac{y_i}{\mu} \right)$$ for $c = 1$

Parameter c reflects different perceptions of inequality, with lower values indicating a higher degree of inequality aversion. A value of c greater than one means that differences at the high end of the welfare distribution are assigned more importance than those at the low end.

For the second index, known as Mean Logarithmic Deviation, a value of zero represents perfect equality and higher values denote increasing levels of inequality, within a given administrative unit. The parameter value 0 means that differences at the low end of the welfare distribution are assigned more importance than those at the high end.

Finally, Theil coefficient (or "information theory" measure) has a potential range from zero to infinity, with higher values (greater entropy) indicating more unequal distribution of income. If instead everyone has the same (i.e., mean) income, then the index equals 0. If one person has all the income, then the index is equal to ln(*N*). The parameter value 1 means that differences are equivalently treated at all points in the welfare distribution.

The Theil index has the advantage of being additive across different subgroups or regions in the country. Indeed, it is the weighted sum of inequality within subgroups. For example, inequality within the United States is the sum of each state's inequality weighted by the state's income relative to the entire country.

If the population is divided into *m* certain subgroups and s_k is the income share of group *k*, T_k is the Theil index for that subgroup, and μ_k is the average income in group *k*, then the Theil index of the population is:

$$T = \sum_{k=1}^{m} s_k \cdot T_k + \sum_{k=1}^{m} s_k \cdot \ln \frac{\mu_k}{\mu}$$

Therefore, one can say that a certain group "contributes" a certain amount of inequality to the whole.

<u>Poverty indices</u>

We will give details of the poverty indices we have used during the analysis.

Foster, Greer and Thorbecke (1984) have suggested a useful class of poverty indices that takes the following form:

$$P_\alpha = \frac{1}{N} \cdot \sum_{i=1}^{q} \left[\frac{(Z_p - Y_i)}{Z_p} \right]^\alpha \quad ,$$

where Z_p denotes the poverty line, Y_i the expenditure or income of the *i*-th poor household (or individual), *N* the total number of households and *q* the number of households whose expenditures or incomes are below the poverty line. Of course, the choice of the poverty line is of great importance in the determination of the index, and it may reflect different judgements about the researcher's choice for an appropriate level of welfare.

From the general formula above, one can compute different kinds of poverty measures by simply varying the value of α:

- If $\alpha = 0 \Rightarrow P_0 = \frac{q}{N}$

P_0 is also called "Headcount ratio", as it measures the incidence of poverty as the proportion of total population lying below the poverty line.

- If $\alpha = 1 \Rightarrow P_1 = \frac{1}{N} \cdot \sum_{i=1}^{q} \frac{(Z_p - Y_i)}{Z_p} = IP_0$

This index gives a good measure of the intensity of poverty, as it reflects how far the poor are from the poverty line. Indeed, it quantifies the extent to which the income of the poor lies below the poverty line. Hence the reason why it is also called "Income or Poverty gap ratio".

- If $\alpha = 2 \Rightarrow P_2 = \frac{1}{N} \cdot \sum_{i=1}^{q} \left[\frac{(Z_p - Y_i)}{Z_p} \right]^2$

This measure is also known as "Poverty Severity Index", as it gives an indication of the degree of inequality among the poor. The greater is the inequality of distribution among the poor and thus the severity of poverty, the higher is P_2.

APPENDIX B – Structure of Production and Foreign Sector

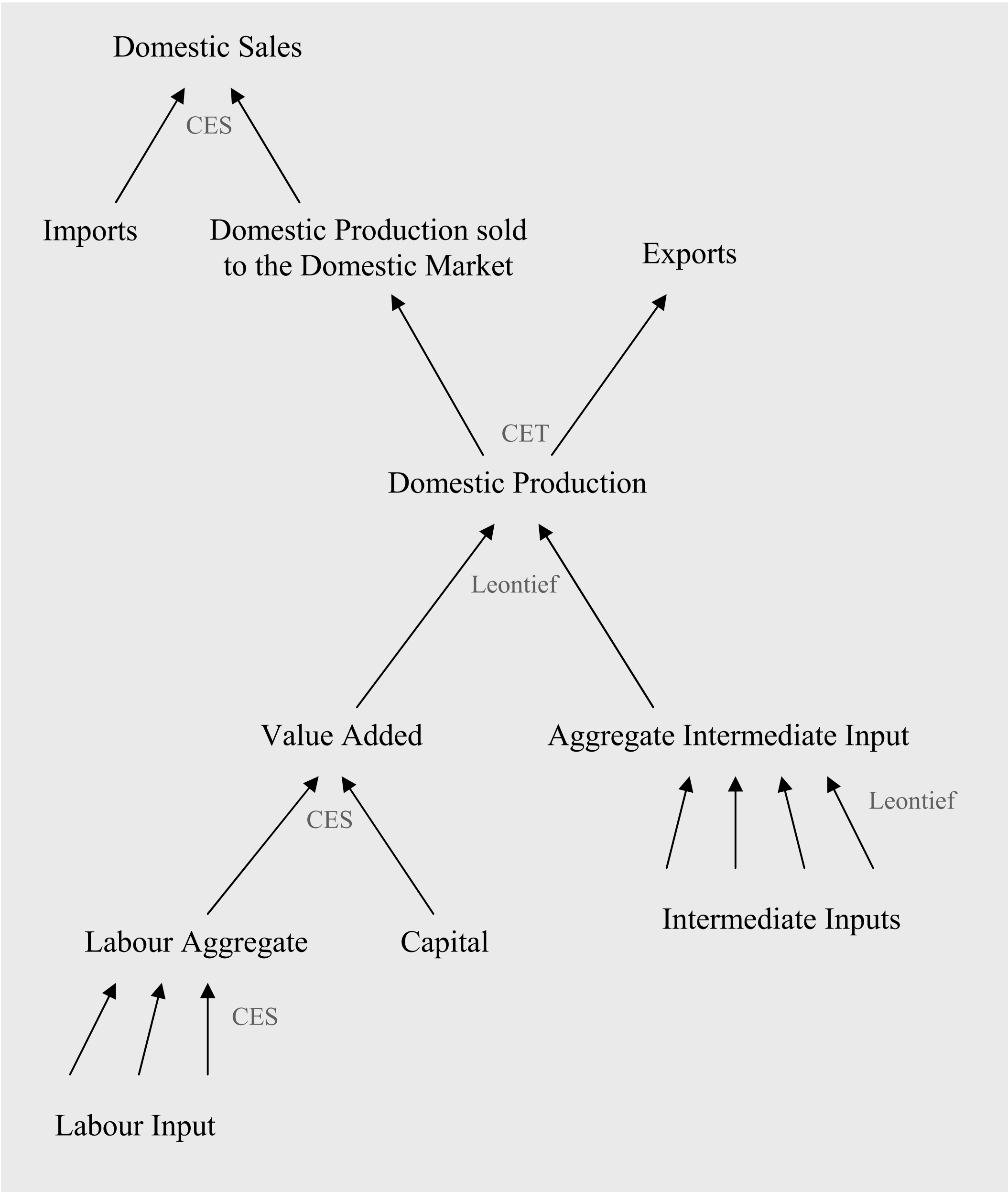

Figure B.1 – The Structure of Production and the Foreign Sector

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