GREDI
Groupe de Recherche en Économie
et Développement International

Cahier de recherche / Working Paper
15-08

Macro-Micro Models

John COCKBURN
Luc SAVARD
Luca TIBERTI

UNIVERSITÉ DE
SHERBROOKE

MACRO-MICRO MODELS[1]

John Cockburn
Partnership for Economic Policy (PEP) and Université Laval (john.cockburn@ecn.ulaval.ca)

Luc Savard
GREDI, Universite de Sherbrooke (Luc.Savard@USherbrooke.ca)

Luca Tiberti
Partnership for Economic Policy (PEP) and Université Laval (luca.tiberti@ecn.ulaval.ca)

1.1 INTRODUCTION

Since the late seventies, researchers and policy makers have sought to analyse and simulate the impacts of macro policy reforms on income distribution. Concerns such as the social implications of structural adjustment policies[2], poverty/inequality effects of trade liberalization[3], pro-poor or inclusive growth[4] or the poverty impacts of the global food and, subsequently, financial and economic crisis[5] have driven this research agenda.

This type of analysis requires tools that combine both macro and micro frameworks. The integration of microsimulation techniques within a computable general equilibrium (CGE) model constitutes such a tool. While CGE models focus on the sectoral, macro and price effects of major policy reforms, they generally fail to adequately capture distributive impacts. On the other hand, microsimulation techniques focus on the household- and individual-specific distributive effects, but are generally confined to micro reforms as they are unable to model general equilibrium effects – notably on the prices of factors and products, as well as other macro variables – of macro reforms. Combining these tools allows the analyst to track the impact of a major policy change or external shock on macroeconomic or sectoral variables down to the change in income or welfare at the household level. The flexibility of both tools has allowed inter alia for distributional impact analysis of various policies and programs in the context of the Millennium Development Goals and the Monterrey Consensus[6].

Context

The primary reason for introducing microsimulations into a CGE model is to analyse and exploit the individual heterogeneity in the sampled population in terms of behaviours and factor endowments in evaluating the impacts of a shock with significant general equilibrium effects, whether this be an external shock (e.g. world commodity prices) or an internal policy change. In fact, individuals are affected by, and react to, such shocks differently, notably according to their

[1] This paper appeared as Chapter 9 (pages 251-274) in The Handbook of Microsimulation Modelling, Edited by Cathal O'Donoghue, 2014; Emerald Group Publishing Limited, ISBN: 978-1- 78350-569-2. DOI: 10.1108/S0573-85552014293.
[2] See, for example, Cornia, Jolly and Stewart (1989).
[3] See, for example, Anderson, Cockburn and Martin (2010).
[4] See, for example, Annabi, Cissé, Cockburn and Decaluwé (2008).
[5] See, for example, Wodon and Zaman (2009) and Cockburn, Fofana and Tiberti (2012).
[6] See McGill (2004), Vos et al (2008) and Ortega Diaz (2011).

sources of income and consumption patterns. If such heterogeneity is not fully taken into account, distributive and poverty results may be incorrect.

It should also be stressed that micro analysis plays other roles in CGE-micro simulation approaches. First, it may serve to calibrate some macro data (e.g. labour force by production sectors or by skill category). Second, it can be used to estimate the parameters of key behavioural functions in the CGE model. For example, price and income elasticities can be estimated using data available in a typical household budget survey[7]. Most of the time – and this is a major critique of most CGE models – these parameters are "borrowed" from the literature for nearby (or not) countries and rarely correspond exactly to the product categories, functional forms and year used in the model. Third, in the case of macro shocks that have micro foundations, the micro module can be used to precisely estimate the shock to introduce into the CGE model. This is, for example, the case of tax reforms involving changes in exemptions or deductions, in which case the microsimulation model is useful to estimate changes in effective tax rates, which can then be transmitted into the CGE model (Feltenstein et al., 2013). Finally, the reconciliation of the databases for the micro and CGE analysis can help flag problems in the CGE database.

1.2 Methodological Characteristics and Choices

There are numerous ways that microsimulations have been used in conjunction with a CGE model in the literature[8]. In this section, we classify and present all six principal approaches. In the subsequent section, we present numerous examples of applications of the various approaches for illustrative purposes. In the first two approaches, microsimulations are integrated directly into the CGE modelling framework, whereas the CGE and microsimulation models are separate in the four other approaches. The integrated approaches are distinguished by their use of representative or actual households. The other four approaches are distinguished by the way that the CGE and microsimulation models are linked – CGE results fed down to the microsimulations, or vice versa, or a looping technique – and in the nature of the microsimulation model itself (with and without behavioural responses).

The representative household approach

The oldest approach to conducting "micro" analysis in a CGE framework is the representative household (RH) approach[9]. This approach breaks down households into a number of categories based on socio (e.g. education/sex of household head), economic (e.g. income deciles or activity/skill level of household head) or geographic (i.e. rural/urban, regions, etc.) criteria. This can range from few to many. Although it is not strictly a CGE microsimulation approach, given that there is no modelling of specific individuals/households, it was a step in the direction of

---

[7] According to Peichl (2009, p. 309): "Typical variables and parameters used in this bottom-up linkage include labour supply elasticities, income components, average and marginal tax rates, consumption patterns, income levels and tax revenues."

[8] For previous reviews, see Davies (2009) and Colombo (2010).

[9] Key early contributions include Adelman and Robinson (1977) for South Korea, Taylor and Lysy (1979) for Brazil and Dervis *et al* (1982).

integrating more micro considerations into CGE models and served as a starting point for other developments. This approach has been and continues to be used widely.

When combined with a household-level income-expenditure database, this approach can be used to perform poverty analysis. The change in income of the representative household simulated by the CGE model is applied to the incomes of all corresponding households in the database according to various hypotheses[10]. Some have proposed to apply the percentage variation in income of the RH to all corresponding households[11]. This is a strong assumption that evacuates all the heterogeneity between households within a given category, leaving only inter-category changes[12].

Other authors propose to model the distribution of income with a lognormal function and generate the change in income distribution with the theoretical relationship between the mean and the variance for the lognormal function. This assumes that the change in income of the representative household is equal to the change in the average income of the corresponding households[13]. This is also a strong assumption. The representative household in a CGE model is the sum of incomes of the corresponding households and thus the structure of income and expenditure of the group is overrepresented by the richest households. As a result, the change in aggregate income likely has little correlation with the change in average income of the group.

In the late 1990s, Decaluwé et al (1998) and Decaluwé et al (1999a) reviewed CGE models with poverty analysis. They proposed the use of more flexible functional forms to model income distribution and an endogenous poverty line to capture heterogeneity in consumption. In the following years, a large number of authors followed in this strand of research[14].

In an application to the Philippines, Savard (2005) compares the RH approach with the TD-BU approach presented below and finds that the results of poverty and income distribution analysis can be completely reversed when taking into account within-group distributional effects. According to Bourguignon et al (2005), the RH approach can lead to a significant underestimation of changes in income distribution.

Another drawback of this approach concerns the fact that the modeller is constrained to a single classification of households in the CGE model, and is unable to then explore impacts according to alternative classifications (e.g. female-headed households).

The fully integrated approach (FI)

---

[10] Among the first applications were Adelman and Robinson (1977) for South Korea, de Janvry et al (1991) for Ecuador and Chia, Wahba and Whalley (1994) for Côte d'Ivoire. See

[11] E.g. Decaluwé et al (1999) or Aka (2004)

[12] Numerous studies have shown that these can be as large as or larger than between-group changes, e.g. Huppi and Ravallion (1991), Savard (2005), Cockburn (2006) and Cogneau and Robilliard (2008).

[13] E.g. Adelman and Robinson (1979) for Korea, de Janvry et al. (1991) for Ecuador, Azis et al (2001) for Indonesia, and Colatei and Round (2000) for Ghana.

[14] See Table 1 in the following section for a list.

To solve this problem, the fully integrated (FI) approach consists in incorporating a large number or all of the *individual* households from a household survey directly into the CGE model. Thus, representative household categories are replaced by actual households that can number in the tens of thousands. This approach, which has become possible with improvement in computer processing capacities, thus captures within-group distributional effects, as each household of the survey will be affected according to its specific income structure and expenditure pattern. According to Bourguignon, Bussolo, and Pereira da Silva (2008) it is the most theoretically sound approach to conducting microsimulations in a CGE framework. This approach was first proposed by Decaluwé et al (1999b) and applied *inter alia* by Cogneau and Robilliard (2007), Gørtz *et al* (2000), Cockburn (2006), and Boccanfuso et al (2008 and 2009).

The CGE model structure is identical to the RH approach, but the number of household accounts is much larger. To integrate these households into the CGE model requires that the two databases be perfectly consistent, which is generally not the case without some adjustments. First, one must reclassify and aggregate the micro-data on income sources and consumption goods into the categories used in the CGE model. The next step involves adjusting each household's income to match its total expenditure and savings. Finally, the aggregated household incomes by source and consumption by product must be balanced out with the corresponding income payments and final consumer demand in the CGE database[15].

Compared to the RH approach, the FI approach makes it possible to perform theoretically sound, distributional analysis for different household classifications – capturing intra-group distributional changes – as the individual household results can be organized as desired. Based on this, one might expect widespread use of the approach, which is not the case for a number of reasons.

First, some cite the fact that the data reconciliation procedure can be quite time intensive[16]. However, it could be argued that this reconciliation process is salutary in bringing out inconsistencies and errors in both the micro and CGE databases and disciplining the analyst to make judgments on the necessary adjustments. Second, FI models can quickly become very large as the number of equations increases with the number of households. Indeed, in early stages, models with over 5000 households and more than ten sectors were difficult and slow to solve numerically[17]. However, as computing processors have improved, this is less of a problem.

A third drawback, raised by Savard (2003) and Bourguignon and Savard (2008), concerns the limitations imposed by the CGE model on the behavioural functional forms that can be used. Many analysts are interested in investigating the impact of policies that involve discrete choice or regime switching by individuals or households. For example, following a macro shock an individual may move in or out of employment, or between the formal and informal sectors. These discrete types of behaviour cannot be captured in standard CGE models.

[15] For social accounting matrix (SAM)-based CGE models, Lemelin et al (2013) provide a complete review of balancing techniques such as RAS or cross-entropy approaches.
[16] E.g. Rutherford, Tarr (2007).
[17] See Chen and Ravallion (2004).

It is this concern that has made sequential approaches to integrating microsimulations into a CGE model the most popular, as recommended by authors such as Cogneau and Robillard (2007), Savard (2003) and Bourguignon et al (2005). In the following sub-sections, we explore four such methods. In the first two methods, results from the CGE model are fed down to a separate microsimulation model, which differs simply by whether it integrates behavioural responses or not. In the third method, it is the results from the microsimulation model that are instead fed up to the CGE model, whereas the final method establishes a loop to ensure consistency between the two models.

The top down micro-accounting approach (TD-MA)

The most common method of conducting microsimulations in a CGE framework is the top-down micro-accounting approach (TD-MA)[18]. The approach is formally presented by Chen and Ravallion (2004) and has been extensively applied in recent years[19]. The general idea is to feed product and factor price changes simulated by a CGE model into a micro-simulation household model. In order to do this, categories of product and factor prices in the CGE model must be mapped to prices in the microsimulation model.

Changes in the CGE factor prices are transferred to the microsimulation model, leading to household-specific income changes that vary according to factor endowments (labour, capital and other assets). This income change is combined with changes in consumer prices from the CGE model to compute welfare changes that take into account household-specific consumption patterns. This welfare change can then be used to analyse distributional impacts. This approach allows for rich distributional and poverty analysis based on full household survey data.

It is an accounting approach in that, in the microsimulation model, there are no behavioural responses to these price changes. As such, this approach is particularly useful to analyse the immediate or short-term impacts of a shock, before agents are able to adjust their behaviour.

Besides the lack of a behavioural response, this approach is also criticized for the absence of a micro-feedback effect to the CGE model.[20] This criticism is discussed in more detail in the final paragraph of the following sub-section.

The fact that the approach does not require any reconciliation between the CGE and micro databases can be seen as an advantage or drawback. Where adequate data are not available for full national-level data reconciliation – for example, in the case of a non-nationally

[18] Some refer to this approach as the sequential (Boccanfuso and Savard, 2007 and Lay, 2010), macro-micro layered (Peichl, 2009), non-parametric (Vos and Sanchez, 2010) or arithmetic (Clauss and Schubert, 2009) approach.

[19] Among early applications of this approach are Vos and De Jong (2003) and King and Handa (2003). Other more recent examples are Boccanfuso and Savard (2007) for Mali and Abdelkhalek et al (2009) for Morocco, Ahmed and O'Donoghue for Pakistan.

[20] This issue has been raised in two literature reviews of macro-micro modeling for poverty analysis namely Hertel and Reimer (2005) and Bourguignon and Spadaro (2005), and more recently in Bourguignon and Savard (2008) who provide an alternative to capture this feedback effect. In this last paper, the authors link the two models through consumption and labour supply. The two variables need to converge at the end of the resolution process. The marginal propensity to save is used to balance the budget constraint of the aggregate household in the CGE model. As a robustness check, other variables were used, such as income tax rate, but this did not have an impact on the distributional analysis given the small adjustments to this variable.

representative household survey – this approach can still be applied and give information on household-specific impacts. Where such data are available, some effort to reconcile data to detect any problems is desirable, even if it is not required by the approach.

The top down with behaviour approach (TD-WB)

The TD-WB approach integrates, at the individual/household level, behavioural responses in the microsimulation model to the price changes fed from the CGE model.[21] This approach was first proposed by Bourguignon, Robilliard and Robinson (2005). Its main contribution is to allow for more heterogeneity between households and hence richer income distributional analysis. Behavioural parameters are typically obtained through reduced-form econometric estimates using the household survey data.

Behaviour typically encompasses only consumer choices and labour supply, but could include other decisions involving savings, human capital investments, crop production, etc. This focus can be justified by the fact that labour activities constitute the main source of household income and, especially in developing countries, most income goes to consumption (with marginal saving rate being relatively low). Also, in the immediate and short term, these components are likely to react fastest and most to policy changes or exogenous shocks.

As with the FI and TD-MA approaches, it captures within-group distributional changes, but is richer and more flexible in terms of household behaviour.

One criticism of this approach is the potential inconsistency between the behaviour of the aggregate household(s) in the CGE model and that of the individual households in the micro-simulation model. Boeters and Savard (2013) show how aggregate behaviour can be made to mimic the micro household behaviour as a first approximation. This can be done by running a simulation using the micro-simulation model with endogenous labour supply (for example a 1% increase in wage rates), computing the elasticity of the response based on this simulation and introducing an aggregate labour supply function with this elasticity into the CGE model.

As with the TD-MA approach, this approach is also open to criticism for the lack of feedback effects from the microsimulation model to the CGE model[22]. The importance of the feedback effect will depend on the aggregation error[23]. If the behavioural functions allow for perfect aggregation, the results of the two models will be consistent and there will be no feedback effect. Household functions do not aggregate perfectly if they contain fixed (or exogenous) shares of consumption, savings or taxation that differ between households. Since these shares are generally calibrated to reproduce the average shares in the reference period in micro household models, the aggregation of micro behaviour functions will not scale up to that of the corresponding aggregate household in the CGE model. In addition, when the microsimulation

[21] See Hérault (2010) for a comparison between reweighting and behavioural approaches.

[22] This critique of the top-down approaches is highlighted in two literature reviews of macro-micro modelling for poverty analysis: Hertel and Reimer (2005) and Bourguignon and Spadaro (2006).

[23] For a detailed discussion of the aggregation of micro household behavior to a representative household, consult Deaton and Muellbauer (1980). Bourguignon and Savard (2008) also discuss this issue in a CGE framework.

model includes a discrete regime switching function – such as entry/exit from the labour market – consistency with the CGE model, which cannot include such behaviour, is lost[24].

The bottom up approach (BU)

In contrast to the two preceding top-down approaches, the link goes from the micro-simulation model to the CGE model in the BU approach. Hence, the impacts of a given shock or policy reform are first modeled in the microsimulation model. These changes are then aggregated and fed into the CGE model to analyse the macro/sectoral impacts.

In general, authors apply this approach to analyse policies targeting individual labour supply decisions. For example, a policy could be designed to get individuals off social assistance and into the labour force. As the first run effects are on the labour supply, the econometrically-estimated micro-simulation model is best designed to capture the direct effect on labour supply. The changes in labour supply are then fed into the CGE model as an exogenous shock. However, the approach can also be applied to shocks directly affecting other types of household/individual behaviour such as consumption, savings, etc.

Once again, this approach lacks any feedback effect, in this case back from the CGE model to the microsimulation model. Moreover, to make the link between the two models, it is necessary to be able to aggregate the micro household behaviour. For example, a (nested) multi-nominal logit specification of the individual direct utility function used to model discrete labour choices can be aggregated up to a CES utility function (Peichl, 2009). Savard (2010) also discusses this aggregation issue where an almost ideal demand system (AIDS) is used in a CGE micro-simulation modelling context.

The iterative approach (IA)

To address the lack of feedback effects in the two TD approaches and the BU approach, Savard (2003) proposed an iterative approach[25]. In his application, the TD-WB approach is extended by adding a bidirectional link between the CGE model and the micro-simulation to obtain a top-down/bottom-up (TD/BU) approach. As in the two TD approaches, the downward link from the CGE model to the microsimulations is performed with good and factor prices. The feedback to the CGE model can be performed with one or more variables, typically consumption and labour supply[26]. The new results fed down from the CGE model to the microsimulations are then updated and so on. The iteration process end when the results from the two models are fully consistent. A formal presentation of this approach can be found in Bourguignon and Savard (2008).

[24] For further details, see Bourguignon *et al.* 2005 and Appendix 1 of this chapter.

[25] This approach was subsequently applied by Aaberge et al. (2007), de Souza Ferreira Filho and Horridge (2004), Muller (2004), Savard (2005 and 2010), Rutherford et al. (2007), Arntz et al. (2008), Mussard and Savard (2010 and 2012).

[26] In Savard (2003), the upward link is performed with two types of labour supply and with consumption. In Savard (2005), the link is performed with only one variable, namely consumption.

Whereas the concern in Savard (2003) is to feedback microsimulation results to the CGE model, Tiberti et al. (2013) do just the opposite in what could be termed a bottom-up/top-down (BU/TD) version of the iterative approach. Indeed, where policies are predominantly targeted at modifying micro-economic behaviour – e.g. labour supply, consumption, etc. – and where these adjustments are sufficient in scale to generate general equilibrium spill-over effect, a BU-TD approach is recommended. Tiberti et al simulate the economy-wide effects of different possible reforms of the existing *Child Support Grant* for South African children. The microsimulation module is first used to estimate impacts on adult labour supply and consumption, which are fed (as exogenous shocks, together with the total cost of the reforms estimated with the micro data) into the CGE model to study the general equilibrium effects of the cash grant and resulting increase in public spending, as in a standard BU approach. However, the CGE results (changes in consumer prices, wages, profits and employment) are then fed back to the microsimulation model to estimate the new real consumption (including the cash grant) to run poverty and distributive analyses. Thus household real income is affected not only by the direct change in the transfer but also by the general equilibrium effects generated by the social protection reform.

In the same vein, Debowicz and Golan (2014) study the direct and indirect (or spill-over) effects on child labour supply induced by the Mexican *Oportunidades* program. Through the BU-TD iterative approach, they capture two main transmission channels: occupation and wage effects. The first effect is captured by the microsimulations, whereas the second is captured by the CGE model after the employment effect is transferred (as an exogenous shock) to the macro model. The authors find that the distributive effects of the program are substantially greater than under partial equilibrium analysis.

Like all of the non-RH approaches (FI, TD-MA, TD-WB and BU), the IA captures within-group income distributional changes. It also includes feedback effects, a characteristic that is shared only with the FI. However, the IA – like the other sequential approaches – offers much more flexibility in the micro behaviour than the FI approach. For example, one can include discrete choice behavioural functions in the micro-simulation model to enrich the distributional analysis and integrate more heterogeneity at the household or individual level. In this regard, the IA requires more consistency between household behaviours in the CGE and microsimulation models than the other sequential approaches, given the constraint to obtain a converging solution.

The main shortcoming of this technique is that convergence is not guaranteed and must be verified for each simulation. An illustration of difficulties in obtaining a converging solution can be found in Savard (2010), where use of an AIDS function with identical parameters in the CGE and microsimulations models led to an infeasible solution.

Choice of approach

Faced with the multitude of approaches, it can be a challenge to select the appropriate approach to conducting microsimulations in a CGE framework. While the RHM approach is the least attractive due to its failure to capture intra-group distributional effects, the choice between the other approaches depends on a variety of factors.

A first factor to consider is data availability. The sequential approaches require a rich micro database in order to econometrically estimate the microsimulation model. The FI approach requires internal consistency in the micro data (i.e. income equal to expenditure plus savings), as well as consistency between the CGE and micro databases. While some adjustments are inevitable, if these become too significant, the credibility of the resulting model is put into question.

The second important criterion is the research question at hand. If one is to analyse a policy in which regime switching behaviour – such as entry/exit from employment – figures prominently, a sequential approach is required. Where micro behaviour is less complex, the FI approach may be preferable.

A third factor is the time frame available. The TD-MA approach is less time-consuming to implement and more appropriate if there is a tight time constraint. Another factor is the human resources available for the project. The TD-WB and IA approaches require expertise both in CGE modelling and econometric analysis. Generally, a full research team including experts in both these areas is required for these approaches.

While computer or software limitations are increasingly irrelevant, they may apply in very sophisticated models or in cases where powerful computers are not available.

To the best of our knowledge, the only example of validation of CGE microsimulation models is Ferreira et al. (2008), who compare predicted changes in occupations, earnings and incomes due to macroeconomic shocks with actual changes between 1998 and 1999 in Brazil[27]. They find that the CGE microsimulation model (a TD-WB) correctly predicts the observed direction and broad pattern of incidence, whereas a CGE with RH sometimes even fails to predict the "true" direction of changes. The difference between simulated and actual changes can be attributed solely to sampling errors, which is not the case for the CGE-RH.

This said, CGE-microsimulation models are generally used not to provide forecasts, but rather to produce "what if" scenarios. This is achieved by comparing simulation results with a baseline scenario. Naturally, we would expect that differences with actual results would increase with the length of simulation period and unexpected shocks that are not included in the baseline and simulation scenarios.

Data considerations

For all approaches, the normal database for constructing and calibrating a CGE model are required, typically an up-to-date SAM. In addition estimates of key external parameters – e.g. price and income elasticities – must be available for the country, borrowed from a similar

[27] Dixon and Rimmer (2013) provide an overview of validation issues in the wider CGE (without microsimulations) literature.

country (based on similar product categories and functional forms to the CGE model) or estimated directly from household survey data. Household survey with detailed income/expenditure data is required to carry out distributive analysis in the RH approach and to implement all other approaches. Additional specialized micro data may also be required for specific research issues, such as the impact of labour market policies.

For all approaches, the CGE and micro databases must be mapped. For example, all the individual products identified in the household expenditure data must be linked to a specific product category in the CGE model. The same is true of labour and capital categories and other income sources (e.g. types of transfers). In this way, simulated changes in variables from the CGE model can be applied to their counterparts in the microsimulations, or vice versa in the case of the BU approach.

In the TD linkage, changes in consumer prices, wages, returns from capital and per worker revenues from self-employment activities are the most common variations fed into the microsimulation model. When labour supply behaviour is introduced (as in the TD-WB approach), changes in the employment levels of the different types of workers are also transmitted. For consistency reasons, these changes should be fed into the microsimulation model in a way that average variations predicted by the CGE model are verified also in the microsimulation model.

As discussed particularly for the FI approach, the integration of microsimulations into a CGE framework requires or incites reflection on the consistency of the CGE and micro databases. For example, the CGE database may be developed from various sources including national accounts, labour market surveys, producer surveys, government financial accounts, household surveys and a fair amount of adjustments and judgment. Nothing guarantees that total final consumption, for example, will match with its value estimated from the household survey, but in general at least the socio-economic structure of the economy (e.g. household consumption shares and employment shares of different type of workers) should be fairly consistent in the two data sets. The same is true for total factor incomes, transfers, savings, etc. The confrontation of these two databases can be demanding but, if conducted systematically, should lead to an improvement of the quality of both.

The case of recursive dynamic CGE models poses additional challenges. The growth in factor endowments (capital/assets and labour) in the CGE model need to be transmitted to the microsimulation model to perform credible distributional analysis. This can be done in various ways such as introducing capital accumulation and labour endowment functions[28], and reweighting the household sample to replicate the demographic evolution of the population, as done in Robichaud, Tiberti and Maisonnave (2013).

1.3 USES AND APPLICATIONS

[28] See Boeters and Savard 2013 for a discussion on the challenges of introducing dynamics with endogenous labor supply in a microsimulation model linked to a CGE model.

CGE microsimulations are used to examine a wide variety of research issues involving both macro and micro components. Typically, they are used to explore distributive and other micro impacts of major shocks with economy-wide (macro) scope. However, in some cases – especially the BU approach – they can be used to explore the macro/sectoral effects of major shock/policy reforms that act primarily at the micro level (e.g. labour market and social protection policies/programs). The choice of CGE microsimulation technique has, to some degree, been linked to the research issues addressed. Table 1 provides a broad overview of examples of the types of issues addressed in CGE microsimulation models. Let us now look in more detail at the key types of analyses conducted using CGE microsimulations.

Structural adjustment programs: One of the earliest studies on the distributive impacts of structural adjustment programs was a RH model developed by Bourguignon *et al* (1983) for Venezuela. Later, in the early 1990s, the OCDE sponsored further RH work by Thorbecke (1991), de Janvry, *et al* (1991), Bourguignon, de Melo and Suwa (1991) and Morrisson (1991) to analyse the impact of structural adjustment programs on income distribution in a variety of contexts. The first study to extend this analysis to poverty impacts was de Janvry *et al* (1991) with an RH application to Ecuador using Foster-Greer-Thorbecke (FGT, 1984) indices.

Trade liberalization: One of the first applications of the FI approach to an actual country examined the distributive impacts of trade liberalization in Nepal (Cockburn, 2006). He finds that urban poverty falls and rural poverty increases, as initial tariffs were highest for agricultural imports. Impacts increase with income level, resulting in rising income inequality.

Chitiga et al (2007) and Cororaton and Cockburn (2007) used the same approach to analyse trade liberalization in South Africa and the Philippines, respectively. Chitiga et al (2007) find that the complete removal of tariffs reduces poverty while inequality hardly changes, but results differ between rural and urban areas. As for Cororaton and Cockburn (2007), their results indicate that the tariff cuts implemented between 1994 and 2000 were generally poverty-reducing but increased inequality.

We can also cite applications of the TD-MA approach to analyse trade reforms. In South Africa and Zimbabwe, Hérault (2007) and Chitiga and Magubu (2005), respectively, conclude that trade liberalization reduces poverty. Chitiga and Magubu also find that it increases inequality. In another early application of the TD-MA approach to analyse trade liberalization, Vos et de Jong (2003) find mild aggregate welfare gains, but rising income inequality and virtually no poverty-reducing effect in Ecuador.

Poverty-reduction policies: Rising inequality and impatience with the promised trickle-down effects of growth has motored increased policy concern with the poverty impacts of macro policies and shocks since the early 1990s. Policy manifestations included the adoption of poverty reduction as the first millennium development goal and the adoption by the Bretton-Woods institutions of conditional debt relief (HIPC program) linked to country poverty reduction strategy programs (PRSP). The major changes in the development policy debate pushed researchers to find more appropriate tools to link policy reforms (macro and micro economic policy reforms) to changes in income distribution.

Chia *et al* (1994) analyse poverty targeting programs using a RH model in Côte d'Ivoire. Cury et al (2010) adopt a BU model to analyse the distributive impacts of cash transfer programs in Brazil. Tiberti et al (2013) use an IA model to study child cash grants in South Africa. They conclude that the poverty and distributive effects do not differ substantially from a partial equilibrium analysis, as the cash grants outweigh all general equilibrium effects in determining income of the poor.

Table 1.1 Applications of CGE microsimulation techniques

Authors	Title	approach
Agriculture		
Chitiga and Mabugu (2008)	Evaluating the impact of land redistribution: A CGE microsimulation application to Zimbabwe	TD-MA
Boccanfuso and Savard (2008)	Groundnut Sector Liberalization in Senegal: A Multi-household CGE Analysis	FI
Boccanfuso and Savard (2007)	Impacts Analysis of Cotton Subsidies on Poverty: A CGE Macro-Accounting Approach	TD-MA
Arndt, Benfica, Tarp, Thurlow and Uaiene (2010)	Biofuels, poverty, and growth: A computable general equilibrium analysis of Mozambique	TD-MA
Fiscal policy		
Llambí, Laens, Perera and Ferrando (2010)	Assessing the impact of the global financial and economic crisis in developing countries: The case of Uruguay	TD-MA
Cury, Coelho and Pedrozo (2010)	The Impacts of Income Transfer Programs on Income Distribution and Poverty in Brazil: An Integrated Microsimulation and Computable General Equilibrium Analysis	IA (BU-TD)
de Souza Ferreira Filho, dos Santos and do Prado Lima (2012)	Tax reform, income distribution and poverty in Brazil: an applied general equilibrium analysis	IA (TD-BU)
Trade liberalization		
Chitiga and Mabugu (2005)	The Impact of Tariff Reduction on Poverty in Zimbabwe: A CGE Top-Down Approach	TD-MA
Hérault (2007)	Trade Liberalization, Poverty and Inequality in South Africa: A Computable General Equilibrium-Microsimulation Analysis	TD-MA
Vos and De Jong (2003)	Trade Liberalization and Poverty in Ecuador: a CGE Macro-Microsimulation Analysis	TD-MA
Chitiga, Mabugu and Kandiero (2007)	Trade Policy and poverty: Results from a CGE Micro-Simulation Analysis	FI
Cororaton and Cockburn (2007)	Trade Reform and Poverty – Lessons from the Philippines: A CGE Microsimulation Analysis	FI
Cockburn et al, 2010	Impacts of Trade Liberalisation in Senegal	FI
Environment		
Boccanfuso, Savard and Estache (2013)	The Distributional Impact of Developed Countries' Climate Change Policies on Senegal: A Macro-Micro CGE Application	FI
Buddelmeyer, Hérault, Kalb and van Zijll de Jon (2012)	Linking a Microsimulation Model to a Dynamic CGE Model: Climate Change Mitigation Policies and Income Distribution in Australia	TD-MA
Araar, Dissou and Duclos (2011)	Household Incidence of Pollution Control Policies: a Robust Welfare Analysis Using General Equilibrium Effects	TD-MA
Vandyck (2013)	Efficiency and Equity Aspects of Energy Taxation	TD-MA
Labour market		
Boeters and Feil (2009)	Heterogeneous labour markets in a microsimulation AGE model: application to welfare reform in Germany	IA (TD-BU)
Cury, Coelho and Pedrozo (2010)	The Impacts of Income Transfer Programs on Income Distribution and Poverty in Brazil: An Integrated Microsimulation and Computable General Equilibrium Analysis	IA (BU-TD)
Peichl (2009)	The benefits and problems of linking micro and macro models: evidence from a flat tax analysis	IA (TD-BU)
Boeters, Feil, Gürtzgen (2005)	Discrete Working Time Choice in an Applied General Equilibrium Model	BU

Fiscal reform: The BU approach is used by de Souza Ferreira Filho et al (2010) to study cuts in food taxes and a reduction in taxes on agricultural inputs in Brazil. They show that the former is more poverty-reducing, whereas the latter is more inequality-reducing. Using a TD-MA approach, Llambì et al (2010) conclude that the 2007 tax reform in Uruguay reduces the incidence, gap and severity of poverty, as well as inequality. With the same approach, Cury et al (2011) study the PIS-COFINS tax reform in Brazil and discover substantial deterioration in poverty indicators following the implementation of this reform.

Agricultural policies: Boccanfuso and Savard (2007) study the impacts of cotton subsidies in Mali with a TD-MA approach and find that removing cotton subsidies produce a reduction in poverty and contribute to easing inequality in Mali. Arndt et al (2010) analyse the development of biofuels in Mozambique with the same approach. Overall, they find that the biofuel investment trajectory analysed increases economic growth by 0.6 percentage points and reduces the incidence of poverty by about 6 percentage points over a 12-year phase-in period.

Boccanfuso and Savard (2008) evaluate the distributional impact of liberalizing the groundnut sector in Senegal with the FI approach. They find that reducing the special import tax on edible oils reduces poverty and that the reduction of world groundnut prices has relatively strong negative effects on poor households if farmers are not protected via a fixed price scheme.

Labour market policies: The BU approach is most commonly adopted for the analysis of labour market policies. Three examples applied to Germany include Boeters et al., 2005 (labour market stimulation through social assistance cuts), Fuest et al., 2008 (a flat tax rate program); Peichl, 2009 (a wage tax). Boeters et al report a broad range of macro and labour supply effects for different subsets of households. Fuest et al. find that a low flat rate tax with a low basic allowance yields positive static welfare effects but increases income inequality. Peichl also analyses a flat tax system and finds weak efficiency gains with increasing inequality.

Boeters and Feil (2009) use an IA (TD/BU) approach to simulate a reform of the German transfer system that stimulates labour supply at the lower end of the wage distribution. This program produce an increase in GDP but produce tax revenue losses because of the shift in functional income distribution.

Environmental Policies: CGE microsimulation approaches have gained popularity for the distributional impact of environmental and climate change policies. Among these, we found application of the TD-MA approach by Araar et al (2011), Buddelmeyer et al (2012) and Vandyck (2013). Araar et al analyse three pollution control policies in Canada and conclude that they have a positive impact on poverty, with a small increase in inequality. Buddelmeyer et al (2012) use the same approach to assess the effects of climate-change mitigation policies in Australia and find that these policies are likely to have positive distributional effects despite a slightly negative effect on average real income. Finally, Vandyck (2013) analyse the distributional effects of increased oil excise taxes in Belgium. His results suggest that distributional effects of the environmental tax reform depend strongly on changes in factor prices and welfare payments.

Boccanfuso et al (2013) adopt the FI approach and find that international climate change (CC) policies produce a slight increase in poverty in Senegal, jointly with a loss of land productivity.

1.4 Summary and Future Directions

Behavioural content: A first area where there is considerable scope to extend and improve CGE microsimulations is in enriching the behavioural content of the microsimulation component. As discussed earlier, most of the TD-WB and IA studies reviewed in this chapter focus efforts on capturing individual/household labour supply and, less often, consumption behaviour. However, as attention is increasingly directed to inclusive growth policies and the medium-to-longer term effects of other macro shocks and policies, dynamic behaviour, notably linked to human capital accumulation, marriage and demography become increasingly important.

As the other chapters of this book illustrate, there have been huge strides in microsimulation techniques, many of which could be gainfully integrated into a CGE framework. One example is the modelling of agricultural household behaviour, as outlined in chapter 17 (Farms-Hennessy/Richardson). Kimhi (1996) proposes an on- and off-farm labour choice model with a regime-switching mechanism that could be integrated into a BU or IA (TD-BU) approach. Newman and Gertler (1994) propose a model to estimate family labour supply and consumption decisions for developing countries, again with regime-switching behaviour, that could also integrate well into an IA (TD-BU) application.

Social dimensions of well-being: Linked to this enrichment of the behavioural content of CGE microsimulations is the need to broaden the dimensions of well-being analysed beyond monetary poverty and inequality measures. Indeed, human capital accumulation and demographic effects, along with health and nutritional effects, are of interest in themselves.

One important attempt to widen the scope of CGE-microsimulation analyses is the Maquette for MDG Simulations (MAMS) [29], developed to explore the fiscal and financing requirements to attain the Millennium Development Goals (MDGs) and to provide guidance on related decisions concerning public spending allocation, fiscal and aid policies. A sequential dynamic TD-WB approach is adopted. Education, health and

[29] For more details, see Löfgren, Cicowiez and Diaz-Bonilla (2013)

environmental indicators - and their interaction – are captured in the CGE component of MAMS, whereas the microsimulation component is relatively standard and focuses on monetary poverty impacts. This exposes this approach to the same critiques as the RH approach, where the individual heterogeneity and transmission channels linked to these variables are not captured.

Education: Robichaud et al. (2013) adapt and extend the MAMS education module in a sequential dynamic TD/WB approach to study the growth and distributive impacts of different scenarios of public spending on primary and secondary education in Uganda. Like MAMS, the CGE module models school entry, dropout/repetition/promotion for each grade, and graduation for each cycle (primary and secondary/tertiary) corresponding to the categories of workers based on their skills. Unlike MAMS, the authors also included microsimulations of all the above-mentioned education behaviours, based on econometric (binary) models with error terms calibrated to reflect initial observed choices[30]. Individuals are followed year by year from the beginning of schooling through to their entry into the labour market. Individual schooling statuses are updated to match CGE results using individual probabilities and a queuing approach. Drop-outs and graduates are fed into the supply of skilled/unskilled labour. In this way, the heterogeneous long-term effects of education spending reforms on individual human capital accumulation and, consequently, labour productivity are captured. Of course, all this can also have important effects on monetary poverty and inequality which, in turn, affect education in the following year[31].

A drawback of this and the MAMS models is that education behaviour lacks an explicit optimization framework. Instead, individuals decide based on ad hoc demand functions with estimated elasticities of demand. Cloutier and Cockburn (2008) develop a static RH model where individuals maximize welfare by equalizing total (direct and opportunity) costs of education with the expected benefits from the skilled wage premium. The inclusion of a microsimulation component and a dynamic modelling structure would allow much more realistic analysis of the micro impacts on the distribution of human capital and the resulting monetary poverty/inequality effects.

In a more comprehensive approach, in addition to the effects on the labour market, human capital accumulation could affect, for example, fertility, child/adult nutrition and mortality, which could, in turn, feed back into education decisions.

Health: As for education, an interesting extension to CGE microsimulation techniques would be to allow individual health status to have long-term effects on human capital (see chapter 14: Health; Schofield/Edwards). MAMS includes some links between health

[30] For the estimation of errors terms in binary models, see Gourieroux et al. (1987).

[31] The Global Income Distribution Dynamics (GIDD) proposes a wider framework than in Robichaud, Tiberti and Maisonnave (2013) but uses a simpler, non-parametric (i.e. non-behavioral) approach to introduce changes in the skills composition and the demographic structure (Bourguignon and Bussolo, 2013). This is done by reweighting the original sampling weights in a way that the projected aggregate population and education figures are replicated.

and education modules – children's health status (proxied by under-five mortality rate) affects educational behaviour and performances – but the lack of a microsimulation components means that it fails to capture important individual effects.

Brown et al's (2007) evaluation of a diabetes prevention campaign in Australia represents an interesting example of how individual health behaviour can be modeled in the microsimulations and then passed onto the CGE model to estimate general equilibrium effects. The authors estimate the effect of diabetes on individual labour supply and the likely impact of a prevention campaign on aggregate labour supply. The change in the aggregate labour supply is then fed into the CGE model as an exogenous shock and used to estimate different economy-wide effects of the campaign through the change in labour supply[32].

Demographics: In Robichaud, Tiberti and Maisonnave (2013) a simple static ageing approach is adopted where sample weights are calibrated so that the total population in the micro data corresponds to population projections in each year[33]. If fertility and mortality modules are introduced, a so-called dynamic ageing procedure can be applied. The next steps should be the development of a CGE microsimulation model of all key individual life events – fertility, marriage, separation, migration, mortality – along the lines of chapter 10 (demographics, Paul Mason). However, in all cases, as stated by Bourguignon and Bussolo (2013, pp. 1432), "[e]mpirical models cannot do better than theory, and a full dynamic theory that would permit us to include a full representation of lifetime individual behaviour and its heterogeneity in the population within a dynamic and stochastic general equilibrium framework is simply not available at this stage".

Rehabilitating the fully integrated approach: Despite its theoretical superiority and the automatic accounting for feedback effects, the fully integrated approach has been rarely used. The key reason for this is the rigidity of behavioural specifications currently possible within a CGE framework, notably with regards to discrete choices. With recent improvements in software used for CGE modelling (GAMS, GEMPACK, etc.) and the development of new models, possibly outside the CGE framework, with this software, it would certainly be worthwhile to systematically explore the extent to which it is possible to repatriate some of the behaviour specifications in the behavioural sequential approaches into the FI framework.

---

[32] As noted in Bourguignon and Bussolo (2013), the approach is restrictive as the authors do not take into account the feedback effects of the macro model on the microeconomic behavior.

[33] To do that, one can use the algorithm developed by Deville and Särndal (1992).

1.5 REFERENCES

Aaberge, R., U. Colombino, E. Holmøy, B. Strøm and T. Wennemo (2007): "Population Aging and Fiscal Sustainability: Integrating Detailed Labour Supply Models with CGE Models". In A. Harding and A. Gupta (Eds.): Modelling our Future: Population Ageing, Social Security and Taxation, Elsevier, Amsterdam, Volume 15, 259-290, 2007.

Abdelkhalek, T., D. Boccanfuso, and L. Savard (2009), "Politiques économiques, pauvreté et inégalités au Maroc : Analyse en équilibre général micro simulé", Mondes en Développement 37(4): 99-118.

Adelman I. and S. Robinson (1979), "Income distribution policy: A computable general equilibrium model of South Korea" in Irma Adelman. (ed.), The selected essays of Irma Adelman. Volume 1. Dynamics and Income Distribution, UK: Economists of the Twentieth Century Series, Aldershot, 1979, p. 256-289.

Ahmed, V., & O'Donoghue, C. (2010). Global economic crisis and poverty in Pakistan. *International Journal of Microsimulation*, *3*(1), 127o129.

Aka, F. B. (2004), "Poverty, Inequality and Welfare Effects of Trade Liberalisation: A CGE model for Côte d'Ivoire". Research Paper, No. RP-160, AERC, Nairobi, October 2006

Anderson, K., Cockburn, J., & Martin, W. (Eds.). (2010). Agricultural price distortions, inequality, and poverty. World Bank Publications, Washington DC.

Annabi, N., F. Cissé, J. Cockburn and B. Decaluwé (2008), "Trade liberalisation, Growth and Poverty in Senegal: A Dynamic Microsimulation CGE Model Analysis", Économie et Prévision 186(5): 117-131.

Araar, A. Y. Dissou and J-Y. Duclos, (2011), "Household Incidence of Pollution Control Policies: a Robust Welfare Analysis Using General Equilibrium Effects", Journal of Environmental Economics and Management 61(2): 227-243.

Arndt, C, R. Benfica, F. Tarp, J. Thurlow and R. Uaiene (2010), "Biofuels, poverty, and growth: A computable general equilibrium analysis of Mozambique", Environment and Development Economics 15(1): 81-105.

Arntz, M., S. Boeters, N. Gürtzgen, and S. Schubert (2008), "Analysing welfare reform in a microsimulation-AGE model: The value of disaggregation", Economic Modelling 25(3): 422–439.

Azis, I., E. Azis and E. Thorbecke, (2001), "Modelling the Socio-Economic Impact of the Financial Crisis : The Case of Indonesia", Final Report prepared for IFPRI and the World Bank, Washington.

Boccanfuso, D. and L. Savard (2007) “Impacts Analysis of Cotton Subsidies on Poverty: A CGE Macro-Accounting Approach”, Journal of African Economies 16(4): 629-659.

Boccanfuso, D. and L. Savard, (2008) “Groundnut Sector Liberalization in Senegal: A Multi-household CGE Analysis”, Oxford Development Studies 36(2): 159– 186.

Boccanfuso, D. A. Estache and L. Savard, (2009) “Impact Analysis of Electricity reforms in Senegal: A macro-micro analysis”, Journal of Development Studies 45(3): 351-375.

Boccanfuso, D. L. Savard, and A. Estache, (2013), “The Distributional Impact of Developed Countries’ Climate Change Policies on Senegal: A Macro-Micro CGE Application”, Sustainability 5(6): 2727-2750.

Boeters, S., Feil, M., Gürtzgen, N. (2005). “Discrete working time choice in an applied general equilibrium model”. Computational Economics. 26(3-4): 1-29.

Boeters, S., and M. Feil, M., (2009), “Heterogeneous labour markets in a microsimulation AGE model: application to welfare reform in Germany”, Computational Economics. 33(4): 305-335.

Boeters, S. and L.Savard, (2013). “The Labour Market in Computable General Equilibrium Models” in Dixon, P.B., Jorgenson, D.W. (Eds.), Handbook of Computable General Equilibrium Modelling. North Holland, Elsevier B.V., pp. 1645–1718.

Bourguignon, F. and M. Bussolo (2013) "Income distribution in Computable General Equilibrium Modelling” in Dixon, P.B., Jorgenson, D.W. (Eds.), Handbook of Computable General Equilibrium Modelling. North Holland, Elsevier B.V., pp. 1383–1437.

Bourguignon F., J. de Melo Jaime, A. Suwa (1991). "Modelling the effects of adjustment programs on income distribution”. World Development 19(11): 1527-1544.

Bourguignon, F., A.S. Robilliard and S. Robinson, (2005), “Representative Versus Real Households in the Macroeconomic Modelling of Inequality ”, in T. J. Kehoe, T.N. Srinivasan and J. Whalley (eds.) “Frontiers in applied general equilibrium modelling”, Cambridge, Cambridge University Press.

Bourguignon, F., and A. Spadaro (2006) “Microsimulation as a Tool for Evaluating Redistribution Policies”, Journal of Economic Inequality, 4(1): 77-106.

Bourguignon, F. and L. Savard (2008). “A CGE Integrated Multi-Household Model with Segmented Labour Markets and unemployment” in Bourguignon, F., L.A. Pereira Da Silva and M. Bussolo (eds.), The Impact of Macroeconomic Policies on Poverty and Income Distribution: Macro-Micro Evaluation Techniques and Tools, Palgrave-Macmillan Publishers Limited, Houndmills, England.

Bourguignon F., G. Michel and D. Miqueu (1983), "Short-run rigidities and long run adjustments in a computable general equilibrium model of income distribution and development". Journal of Development Economics 13(1-2): 21-43.

Bourguignon, F., M. Bussolo, and L.A. Pereira Da Silva (2008) "Introduction: Evaluating the Impact of Macroeconomic Policies on Poverty and Income Distribution" in Bourguignon, F., M. Bussolo, and L.A. Pereira Da Silva (eds.), The Impact of Macroeconomic Policies on Poverty and Income Distribution: Macro-Micro Evaluation Techniques and Tools, Palgrave-Macmillan Publishers Limited, Houndmills, England.

Brown, L., A. Harris, M. Picton, L. Thurecht, M. Yap, A. Harding, P. Dixon, J. Richardson (2007) "Linking Microsimulation and Macro-Economic Models to Estimate the Economic Impact of Chronic Disease Prevention", in Asghar Zaidi, Ann Harding and Paul Williamson (Eds.), New Frontiers in Microsimulation Modelling, Chapter 20, Ashgate, Vienna.

Buddelmeyer, H. N. Hérault, G. Kalb, M. van Zijll de Jon, (2012), "Linking a Microsimulation Model to a Dynamic CGE Model: Climate Change Mitigation Policies and Income Distribution in Australia", International Journal of Microsimulation, 5(2): 40-58.

Chen, S. and M. Ravallion. (2004), "Welfare impacts of China's accession to the world trade organization". The World Bank Economic Review 18(1): 29-57.

Chia, N.-C., S. Wahba and J. Whalley (1994), "Poverty-reduction targeting programmes: A general equilibrium approach". Journal of African Economies 3(2): 309-338.

Chitiga, M., R. Mabugu, (2005), "The Impact of Tariff Reduction on Poverty in Zimbabwe: A CGE Top-Down Approach", South African Journal of Economics and Management Sciences 8(1): 102-116.

Chitiga, M. R. Mabugu and T. Kandiero (2007), "Trade Policy and poverty: Results from a CGE Micro-Simulation Analysis", Journal of Development Studies 43(6): 1105-1125.

Chitiga, M., R. Mabugu, (2008), "Evaluating the impact of land redistribution: A CGE microsimulation application to Zimbabwe", Journal of African Economies 17(4): 527-549.

Clauss, M., S. Schubert, (2009), The ZEW combined microsimulation-CGE model: innovative tool for applied policy analysis, ZEW Discussion Papers, No. 09-062, ZEW - Zentrum für Europäische Wirtschaftsforschung / Center for European Economic Research

Cloutier, M.H., J. Cockburn and B. Decaluwé (2008), “Education and Poverty in Vietnam: A Computable General Equilibrium Analysis”, CIRPÉE Working Paper 08-04, Université Laval, Québec, Canada.

Cockburn, J. (2006), "Trade Liberalisation and Poverty in Nepal: A Computable General Equilibrium Micro Simulation Analysis", in M. Bussolo et J. Round (eds.), Globalization and Poverty: Channels and Policies, Routledge, London.

Cockburn, J., Corong, E., Decaluwé, B., Fofana, I., & Robichaud, V. (2010). The Growth and Poverty Impacts of Trade Liberalization in Senegal. *International Journal of Microsimulation*, *3*(1).

Cockburn, J., I. Fofana and L. Tiberti (2012), “Simulating the Impact of the Global Economic Crisis and Policy Responses on Children in West and Central Africa”, in Caroline Harper, Nicola Jones, Ronald U. Mendoza, David Stewart and Erika Strand (eds.), Children in Crisis : Seeking Child-Sensitive Policy Responses, Palgrave MacMillan, New York, United States.

Cogneau, D. Robillard, A.S. (2007). "Growth, distribution and poverty in Madagascar: learning from a microsimulation model in a general equilibrium framework” in A. Spedaro (ed.), Microsimulation as a tool for the evaluation of public policies: methods and applications, Fundacion BBVA, Madrid, pp. 73-111.

Cogneau D. and A.-S. Robilliard, 2008. “Simulating Targeted Policies with Macro Impacts: Poverty Alleviation Policies in Madagascar”, in Bourguignon F., L. A. Pereira da Silva and M. Bussolo (eds), The Impact of Macroeconomic Policies on Poverty and Income Distribution : Macro-Micro Evaluation Techniques and Tools, Washington DC & New-York NY: World Bank & Palgrave McMillan.

Colatei, D., and J. I. Round (2000). ‘Poverty and Policy: Experiments with a SAM-based CGE Model for Ghana’. Paper presented at the XIII International Conference on Input-Output Techniques, 21-25 August. Macerato, Italy.

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

Cornia, G. A., Jolly, R., & Stewart, F. (1989). Adjustment with a human face: Protecting the vulnerable and promoting growth: A study by UNICEF, Oxford University Press.

Cororaton, C. and J. Cockburn (2007), "Trade Reform and Poverty – Lessons from the Philippines: A CGE Microsimulation Analysis", Journal of Policy Modelling 20(1): 141-163.

Cury, S., Coelho, A. M. and Pedrozo E. (2010). "The Impacts of Income Transfer Programs on Income Distribution and Poverty in Brazil: An Integrated Microsimulation and Computable General Equilibrium Analysis", MPIA working paper 2010-20, Partnership for Economic Policy, Dakar, Senegal.

Cury, S., A. Mori Coelho, E. Pedrozo, (2011) Economic analysis of PIS-COFINS tax reform: integrating a microsimulation model with a computable general equilibrium model, PEP-NET MPIA11086.

Davies, J. B, (2009), "Combining Microsimulation with CGE and Macro Modelling for Distributional Analysis in Developing and Transition Countries", International Journal of Microsimulation 2(1): 49-65.

Deaton, A. and J. Muellbauer (1980) Economic and consumer behaviour. Cambridge: Cambridge University Press, 450 p.

Debowicz, D. and Golan J. (2014) "The Impact of Oportunidades on Human Capital and Income Distribution. A Top-Down/Bottom-up Approach", Journal of Policy Modelling 36(1): 24-42.

Decaluwé B., Patry, A and L. Savard (1998). "Income Distribution, Poverty Measures and Trade Shocks: A Computable General Equilibrium Model of an Archetype Developing Country", Working paper 98-14, CREFA, Université Laval.

Decaluwé B., Patry, A. Savard, L. and E. Thorbecke (1999a), "Poverty analysis within a general equilibrium framework". Working paper, African economic research consortium, n° 99-09, Nairobi.

Decaluwé B., Dumont J.-C. and L. Savard. (1999b), "How to measure poverty and inequality in general equilibrium framework". Cahier de recherche, CREFA, Université Laval, n°99-20, Québec.

de Janvry A., E. Sadoulet and A. Fargeix (1991), Adjustment and equity in Ecuador, Paris: Centre de Développement de l'OCDE.

Dervis, K., J. de Melo and S. Robinson. (1982), General equilibrium models for development policy. London: Cambridge University Press, 526 p.

de Souza Ferreira Filho, J.B., C. V. dos Santos and S. M. do Prado (2010), "Tax reform, income distribution and poverty in Brazil: an applied general equilibrium analysis", International Journal of Microsimulation 3(1): 114-117.

de Souza Ferreira Filho, J. B. and M. Horridge (2004). "Economic Integration, Poverty and Regional Inequality in Brazil", Monash University, COPS/IMPACT Working Paper G-149

Deville, J.C., and C.E. Särndal (1992) "Calibration Estimators in Survey Sampling", Journal of the American Statistical Association, 87(418): 376-382.

Dixon, Peter B., and Maureen T. Rimmer (2013). "Validation in computable general equilibrium modelling." in P. Dixon and D. Jorgenson (eds). Handbook of Computable General Equilibrium Modelling 1: 1271-1330.

Feltenstein, A., L. Lopes, J. Porras-Mendoza, S. Wallace (2013) "The Impact of Micro-simulation and CGE modelling on Tax Reform and Tax Advice in Developing Countries: A survey of Alternative Approaches and an Application to Pakistan", International Center for Public Policy Working Paper 13-09.

Ferreira, F.H.G., P. Leite, L.A. Pereira da Silva and P. Picchetti (2008) "Can the distributional impacts of macroeconomic shocks be predicted? A comparison of Top-Down Macro-Micro models with historical data for Brazil", in Bourguignon, F., L.A. Pereira Da Silva and M. Bussolo (eds.), The Impact of Macroeconomic Policies on Poverty and Income Distribution: Macro-Micro Evaluation Techniques and Tools, Palgrave-Macmillan Publishers Limited, Houndmills, England.

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

Foster J., J. Greer and E. Thorbecke E. (1984). "A class of decomposable poverty measures", Econometrica 52(3): 761-766.

Gorman W., (1953), "Community preference fields". *Econometrica,* 21(1): 63-80.

Gortz, M., Harrison, G. Neilsen, C. and T. Rutherford (2000), Welfare gains of extending opening hours in Denmark. Economic working paper B-00-03, University of South Carolina, Darla Moore School of Business, Columbia, South Carolina.

Gourieroux, C., A. Monfort, E. Renault and A. Trognon (1987). "Generalised residuals," Journal of Econometrics, Elsevier, 34(1-2): 5-32.

Heckman J., L. Lochner, C. Taber (1998), "Explaining rising wage inequality: Explorations with a dynamic general equilibrium model of labour earnings with heterogeneous agents". Review of Economic Dynamics 1: 1-58.

Hérault, N., (2007). "Trade liberalization, poverty and inequality in South Africa: a computable general equilibrium-microsimulation analysis", Economic Record 83(262): 317-328.

Hérault, N. (2010). Sequential Linking of Computable General Equilibrium and Mi% crosimulation Models: A Comparison of Behavioural and Reweighting Techniques. *International Journal of Microsimulation*, *3*(1), 35o42.

Hertel, T. and J. Reimer (2005) “Predicting the poverty impacts of trade reform”, Journal of International Trade & Economic Development, 14(4): 377-405.

Huppi M. and M. Ravallion (1991), “The sectoral structure of poverty during an adjustment period: Evidence for Indonesia in the mid-1980s”, World Development 19(12): 1653-1678.

Kimhi, A. (1996), “Off-Farm Work Participation of Israel Farm Couples: The Importance of Farm Work Participation Status”, Canadian Journal of Agricultural Economics 44(4):481-490

King D. and S. Handa (2003), “The welfare effects of balance of payments reforms: A macro-micro simulation of the cost of rent-seeking”, The Journal of Development Studies 39(3): 101-128.

Lay, J. (2010), “Sequential Macro-Micro Modelling with Behavioural Microsimulations”, International Journal of Microsimulation 3(1): 24-34.

Lemelin, A., I. Fofana and J. Cockburn (2013), “Balancing a Social Accounting Matrix: Theory and Application”, mimeo, Partnership for Economic Policy, www.pep-net.org/programs/mpia-development-policy-modelling/pep-standard-cge-models/sambal-gpcema/.

Llambí, C. S. Laens, M. Perera, M. Ferrando, (2010), “Assessing the impact of the global financial and economic crisis in developing countries: The case of Uruguay”, MPIA working paper 2011-16, Partnership for Economic Policy (PEP).

Löfgren, H., M. Cicowiez and C. Diaz-Bonilla (2013). “MAMS – A Computable General Equilibrium Model for Developing Country Strategy Analysis” in Dixon, P.B., Jorgenson, D.W. (Eds.), Handbook of Computable General Equilibrium Modelling. North Holland, Elsevier B.V., pp. 159–276.

McGill, E. (2004) “Poverty and Social Analysis of Trade Agreements: A More Coherent Approach”, Boston College International and Comparative Law Review 27(2): 371-427.

Morrisson, C. (1991), «Adjustment Incomes and Poverty in Morocco». World Development 19(11): 1633-1651.

Muller, T. (2004). Evaluating the economic effects of income security reforms in Switzerland : an integrated microsimulation – computable general equilibrium approach, mimeo, University of Geneva.

Mussard, S. and L. Savard, (2010), “Macro/Micro modelling and Gini Multi-decomposition: An application to the Philippines”, Journal of Income Distribution 19(2): 51-78.

Mussard, S. and L. Savard, (2012), "The Gini Multi-decomposition and the Role of Gini's Transvariation: Application to Partial Trade Liberalization", Philippines Applied Economics, 44(10); pp. 1235-1249.

Newman, J.L. and P.J. Gertler (1994), "Farm Productivity, Labour Supply, and Welfare in a Low Income Country", The Journal of Human Resources 29(4): 989-1026.

Ortega Diaz, A. (2011), "Microsimulations for Poverty and Inequality in Mexico Using Parameters From a CGE Model", Social Science Computer Review February 29(1): 37-51.

Peichl, A. (2009), "The benefits and problems of linking micro and macro models: evidence from a flat tax analysis", Journal of Applied Economics 12(2): 301-329.

Preston, M. H. (1959), "A view of the aggregation problem", The review of economic studies 27(1): 58-64

Robichaud, V., L. Tiberti and H. Maisonnave (2013) "Impact of Increased Public Education Spending on Growth and Poverty in Uganda: A Combined Micro-Macro Approach", PEP-MPIA Working-Paper 2014-01, Partnership for Economic Policy

Rutherford T., and D. Tarr (2007), "Poverty effects of Russia's WTO accession: modelling 'real' household and endogenous productivity effects". Journal of International Economics, 75(1): 131-150.

Savard L. (2003) "Poverty and Income Distribution in A CGE-Household Micro-simulation Model: Top-Down/Bottom-Up Approach", CIRPEE, Working Papers 03-43, Université Laval.

Savard, L. (2005), "Poverty and inequality analysis within a CGE Framework: a comparative analysis of the representative agent and microsimulation approaches‟, Development Policy Review, 23(3), 313-332.

Savard, L. (2010) "Scaling up Infrastructure Spending in the Philippines : A top-down bottom up micro-simulation approach", *International Journal of Microsimulation* 3(1): 43-59.

Taylor L. and F. Lysy (1979), "Vanishing income redistributions: Keynesian clues about model surprises in the short-run". Journal of Development Economics 6(1):11-29.

Thorbecke E. (1991). "Adjustment growth and income distribution and equity in Indonesia", World Development 19(11): 1595-1614.

Tiberti, L., H. Maisonnave, M. Chitiga, R. Mabugu, V. Robichaud and S. Ngandu (2013), "The economy-wide impact of the South African Child Support Grant: a Micro-Simulation-Computable General Equilibrium Analysis", Cahiers de recherche CIRPÉE 13-03, Université Laval, Québec, Canada.

Vandyck, T. (2013), Efficiency and Equity Aspects of Energy Taxation, EUROMOD Working Paper No. EM 12/13.

Vos R., De Jong Niek (2003), "Trade liberalization and poverty in Ecuador: a CGE macro-microsimulation analysis", Economic System Research 15(2): 211-232.

Vos, R., M. V. Sánchez and C. Kaldewei, (2008), "Latin America and the Caribbean's Challenge to Reach the MDGs: Financing Options and Trade-offs**,** United Nations, DESA Working Paper No. 68.

Vos, R., and M. Sanchez (2010), A Non-Parametric Microsimulation Approach to Assess Changes in Inequality and Poverty, DESA Working Paper No. 94, UNDP.

Wodon, Q. and H. Zaman (2009): "Rising food prices in sub-Saharan Africa: Poverty impact and policy responses", World Bank Research Observer, 25 (1), 157-176.

1.6 Appendix 1 The Aggregation Problem

According to Deaton and Muellbauer (1980), the aggregation problem is defined as the passage from the microeconomic behaviour of consumers (or workers) to the aggregate demand (labour supply) analysis. Or, as Preston (1959) states, the aggregation problem is tied to the link between micro and macro theory and therefore differences that can occur between large models (micro-simulation models) and smaller models (macro models) relying on aggregated variables and parameters. This is exactly the problem at hand with linking CGE models with microsimulation models. To respond to this problem, a few decades back Gorman (1953) demonstrated that using or assuming the same marginal consumption and saving propensities was sufficient to solve this problem and obtain perfect linear aggregation. According to Deaton and Muellbauer (1980), this solution is extremely restrictive since it imposes linear and identical Engle curves for all households in a microsimulation model. Moreover, this assumption is incompatible with empirical analysis of household consumption behaviour. The second problem is linked to the household specific labour supply. Deaton and Muellbauer (1980) present the conditions for aggregation of labour supply with the following cost function:

$$c(u,w,p) = wT + \mu = Y$$

Where u is the utility level, w, the wage, p, the price level of goods, T, time endowment for work, μ, the non-work income or transfer from other agents and Y, the income of the worker. In this context, leisure is treated as a good with price w. Perfect linear aggregation is possible if the cost function has the following form:

$$c_h(u_h,w,p) = \alpha_h(w,p) + u_h b(w,p)$$

Average leisure must be a function of average income ($\bar{Y}$), wage (w) and prices (p). We can see that the problem is tied to the demand for goods. Indeed, it is plausible that prices are the same for all consumers, yet w varies between households given specific characteristics such that the function b(w,p) will be specific to each household. Therefore, the marginal consumption share will be household specific for good i, logb/logpi. In this case, perfect aggregation is impossible. To obtain perfect aggregation, the derivative of the labour income with respect to non-labour income, μ and the derivative between labour income and time endowment must be identical for all workers. According to Heckman et al. (1998), worker-specific labour supply is one of the most important factors in explaining the differential distributional impact of policy reform.