University of Verona

Doctorate in Economics and Finance

XXI Cycle

A GLOBAL CGE MODEL AT THE NUTS 1 LEVEL FOR TRADE POLICY EVALUATION

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2010 March

To my family

Acknowledgements

I would like to express my sincere gratitude to Prof. Federico Perali, director of my thesis, for sharing his scientific expertise while guiding me with his invaluable help and suggestions.

A heartfelt thanks to my friends at CEPII, particularly Riccardo Magnani, whose collaboration was essential for bringing this work to completion.

Special thanks to Prof. Pieroni for his constant availability and the many kindnesses shown.

Last but not least, I want to thank my father, Alvaro, my mother, Idola and my sisters, Barbara and Elisabetta for their loving support and presence throughout these years of academic study and personal growth.

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Chapter 3

A global CGE trade model at the NUTS 1 level with imperfect competition

Introduction

In recent years the development of the *World Trade Organization* (WTO) has generated a great demand for estimates of potential consequences of trade policy. The Uruguay round and Doha round negotiations are typical examples. The *policy maker* could be interested in having information about the effects of trade liberalization on income, production and other relevant macroeconomic variables. It could also be useful for her/him to know the distribution of these effects across families, countries or sectors to evaluate who are the winners and who are the losers. *Computable General Equilibrium* (CGE) models are an important tool for meeting this need because they allow a lot of trade information to be elaborated in a coherent economic structure where agents maximise their utility and firms maximise their profits. Today many governments and international institutions, e.g. the WTO, the *European Commission* (EC) and the *World Bank* (WB), use CGE models to assess the impact of global trade reform.

While these models are widely used in policy analysis in different areas (international trade, tax policy, income distribution), they were funded and developed in the context of academic research. 'The central ideal is to convert the Walrasian general equilibrium structure (formalized in the 1950s by Kenneth Arrow, Gerard Debreu, and others) from an abstract representation of an economy into realistic models of actual economies' (Shoven and Walley, 1992, p. 1). The models are solved numerically. In 1967 Scarf found the first algorithm that guaranteed a convergence toward an equilibrium solution. Today specific software, such as GAMS or GEMPACK, makes the computation easy and allows thousands of equations and variables to be solved.

Over the years, the CGE models have evolved by incorporating elements that do not belong to Walrasian framework. The so-called Structuralist CGE models incorporate elements of short-run macro models, including "demand driven" Keynesian equilibria where money is not neutral.

In this work my attention is directed toward large-scale global CGE trade models, such as GTAP, MEGABARE and MIRAGE, used by international organizations (e.g. the WB, the WTO, the EC) for their analysis of trade liberalization.[1] I have chosen this kind of model because I had the opportunity to work with MIRAGE at CEPII.

This type of models maintains a strong Walrasian spirit. Factors are fully employed, money does not explicitly figure into the model and a solution is made possible through relative prices. Nevertheless, some important non-Walrasian assumptions, such as imperfect competition and others, are introduced or can be introduced; these will be explained in the first chapter.

A global approach has the unquestionable advantage of taking into account within the same theoretical structure the trade relationships of all countries or groups of countries in the world, such as the EU, the USA, China, India and Africa. With respect to this, it is very important to have a consistent economic global database that covers all parts of the world. GTAP, based in the Agricultural Economics Department at Purdue University (West Lafayette, Indiana), has been created to satisfy this need; It is a global network of researchers who conduct quantitative analysis of international economic policy issues, especially trade policy. The latest version of the GTAP database, GTAP 7.0 (Narayanan and Walmsley, 2008), is a large *social account matrix* (SAM). It contains complete bilateral trade information as well as transport and protection linkages among 113 countries or groups of countries and 57 sectors for the base year 2004. GTAP is the most widely used dataset for global CGE trade models. It is very rich and practical, however it only allows analysis at the national level.

CGE trade models exist at a sub-national level but they only consider a single region or a handful of regions. As will be shown in section 1.4, the CAPRI-GTAP (Jansson, Kuiper and Adenäuer, 2009), MONASH-MRF (Peter *et al.*, 1996) and MIRAGE-DREAM (Jean and Laborde, 2004) models are examples of large-scale

[1] GTAP is the acronyms for *Global Trade Analysis Project*. The MEGABARE model has been developed by ABARE (*Australian Bureau of Agricultural and Resources Economics*). MIRAGE stands for *Modelling International Relationships in Applied General Equilibrium*, it has been developed by CEPII (*Centre d'Etudes Prospectives et d'Informations Internationales*).

global CGE trade models which also include many regions.[2] MONASH-MRF refers to the Australian regions, CAPRI-GTAP is specific to the agriculture sector of the EU and MIRAGE-DREAM considers the NUTS (*Nomenclature d'Unités Statistiques*) regions of the 25 members of the EU (Romania and Bulgaria did not belong to the EU in 2004).[3]

There are so few models because there is a lack of well-suited regional data concerning foreign trade. For instance, in the EU there is no complete dataset on foreign trade that is available for the NUTS regions. Concerning foreign trade, some information is available for some countries at the regional level, but this is not systematically the case. Thus, simplifying assumptions must be made to make the models manageable. In addition, this kind of model is very demanding both in terms of data and computational resources. Research teams, supported by public institutions, work on these models which are highly disaggregated at the geographical level.

The objective of this thesis is to build a global CGE trade model at the NUTS 1 level for the 68 regions within the first 15 member states of the European Union. The aim is not to exactly reproduce the models mentioned above but, taking advantage of my work experience at CEPII, the aim is to build a simple parsimonious CGE model. Data on value added, skilled labour and unskilled labour are available at the NUTS 1 level while simplifying assumptions arise for the remaining variables. Therefore a CGE trade model is built in which only the production is specified at the NUTS 1 level.

This type of model should allow the consequences of trade policy in Europe to be investigated at a disaggregated geographical level while maintaining a global approach. This is of interest at both the theoretical and empirical levels.

[2] CAPRI is an acronym for *Common Agricultural Policy Regional Impact Analysis*. MONASH-MRF model has been developed at Monash university, MRF stands for *Multi-Regional Forecasting*. DREAM stands for *Deep Regional Economic Analysis Model*.

[3] The *Nomenclature d'Unités Statistiques* is a sub-national geocode standard developed by the European Union for referencing the subdivisions of European countries for statistical purposes. There are three level of aggregation: level 1 (more aggregated), level 2 (medium aggregated) and level 3 (less aggregated).

It is of theoretical interest because it helps one to understand how this kind of model works from an economic point of view. Its relative simplicity allows the results to be interpreted.

It is of empirical interest because the knowledge gained about the geographical disaggregated effects could be useful information for the *policy maker*. In fact, trade liberalization implies strong distributional effects not only across people but also across the regions of a given country. Just as there can be winner and loser countries, there can also be winner and loser regions and the *policy maker* could be interested in compensating loser regions for equity.

The model is used to analyse the output reallocation across sectors in each region after a trade shock and this source of information could be useful for a *policy maker* in order to implement, for example, the right outplacement policy.

The EU economy is very diversified and world trade agreements do not take into account the disparities existing at regional level. This geographical heterogeneity in the EU should be considered in WTO negotiations. In addition, it is of interest to assess how European workers respond to trade shock. Will they migrate to another European region?

All of this calls for an assessment of the possible impact of trade policy at the regional NUTS level. The evaluation could help in making suitable policy choices given that cohesion policy is an important competence of European Union.

The thesis is organized as follows.

In the first chapter, I set out the global CGE trade models.[4] In section 1 some relevant theoretical assumptions are laid out from the most traditional ones, such as the Armington hypothesis (1969) to the most recent ones, such as the firm heterogeneity (Melitz, 2003). Section 2 is devoted to a crucial issue concerning CGE approach, i.e. the sensitivity of simulation results to key hypotheses such as assumptions about Armington elasticity, firm conduct and the labour market. In section 3, I describe three main global CGE trade models used by international institutions: the GTEM, GTAP and MIRAGE models. Special attention is given to

[4] I neglect short-run analysis and the link between real variables and financial variables. These aspects are the focus of Structuralist-Keynesian CGE models.

the MIRAGE model, which I used at CEPII. At the end of Chapter 1 in section 4 some global CGE trade models at the sub-national level are presented: MONASH-MRF, CAPRI-GTAP and MIRAGE-DREAM. This section serves as an introduction to Chapter 2 and Chapter 3.

In Chapter 2 I set out a global CGE trade model at the NUTS level with perfect competition in the goods market. This kind of model is built by starting from MIRAGE but is original, in that the basic structure was greatly modified with respect to MIRAGE. It is applied to all NUTS 1 regions within the EU15. In section 1, I introduce the model. In section 2, I illustrate the data, especially describing the procedure used to match the two datasets, the national and sub-national ones. In section 3, sectoral and geographical aggregations are displayed. There is a set of 4 sectors. Two geographical levels define the model: one for the groups of countries in the world and the other one is for the NUTS 1 regions in the EU15. In section 4, the theoretical structure is laid out: the demand side, the supply side, factor markets and macroeconomic closure. The calibration strategy is presented in section 5 where I explain the simplifying assumptions that I use to determine some parameters and variables at the sub-national level. The trade policy experiment, presented in section 6, is conducted on the 68 NUTS 1 regions in the EU15. The trade shock is a world liberalization in agriculture.[5] Even if the model is used to assess tariff liberalization in agriculture, it is can applied to other sectors according to the special interest of the researcher. In section 7, the results are shown such as the production reallocation across sectors in each region. In addition, sensitivity analysis on production reallocation is conducted by the introduction of skilled/unskilled labour mobility within the EU15. Further interesting results are presented such as the variation in regional value added, the unskilled/skilled migration within the EU15 and the welfare change. A major limitation of the CGE models is that they are difficult to interpret because of many variables and equations, which make them a “black box” (Panagariya and Duttagupta, 2001). Thus, in section 8, I build a stylised model in order to find a strategy for interpreting the results.

[5] Agriculture is the most protected sector in the world.

In Chapter 3, I set out a global CGE trade model at the NUTS 1 level with imperfect competition in the goods market. In section 1, I introduce it. The database basically does not change nor does the sectoral and geographical aggregations. In section 2, I describe the theoretical structure: the demand side, the supply side, factor markets and macroeconomic closure. The introduction of the Cournot-Nash scheme in firm conduct modifies substantially the demand side. In section 3, I show the calibration strategy used to determine the three parameters of imperfect competition: the elasticity of substitution between firm-specific varieties, the mark-up and the number of firms. In section 4, I present the results and compare them with the perfect competition version of the model. In section 5, an interpretation of the results is laid out for the case of imperfect competition.

Appendices A1, A2, A3 and A4, respectively, display notation, list of variables, the parameters and the equations of the model with both perfect and imperfect competition.

At the end of thesis, the main findings are illustrated and possible extensions for further research are discussed.

Chapter 1

Global CGE trade models

1.1 Relevant theoretical assumptions

In this first section, I describe some important theoretical assumptions which are introduced or can be introduced into global CGE trade models, where global means that all of the countries or groups of countries in the world (e.g. Asia, the EU or Africa) are considered simultaneously in the same model.[1]

Global CGE trade models, basically, have a Walrasian structure. Money is neutral, factors are fully employed and the Walras law is respected.[2] In addition, macro-economic closure is neoclassical as investments are driven by savings. Trade balance is determined endogenously.

However, some relevant non-Walrasian hypotheses can be made. I identify four main features that depart from the classical Walrasian framework and Heckscher-Ohlin trade theory (1991): geographical product differentiation, horizontal product differentiation in the goods market, dynamic set-up and firm heterogeneity. The sequence is not random but follows the "historical" evolution in modelling theoretical assumptions of CGE trade models.

1.1.1 Geographical product differentiation: the Armington hypothesis

The Armington hypothesis (1969) considers the imported good to be an imperfect substitute of the domestic good. This is the first violation of the Walras and

[1] Clearly, the geographical and sectoral aggregations are chosen to be consistent with the special objective of the researcher.

[2] The Walras law asserts that if *n-1* markets are in equilibrium in an economy, then the remaining market is also in equilibrium, what implies a redundant equation in the general equilibrium system of equations.

Hechscher-Ohlin scheme where the imported good and the domestic good are perfect substitutes. This geographical product differentiation is introduced into CGE trade models to give a greater realism to the simulation results. The Heckscher-Ohlin model fails to replicate the *cross-hauling* flows that are observed in the trade data.[3] Furthermore, in this type of model a small trade shock is sufficient to cause an unrealistic specialization phenomenon with enormous variations in the sectoral production of a country.

The idea that imported and domestic goods are imperfect substitutes implies that they have different prices. This can be achieved through a CES (*Constant Elasticity of Substitution*) or a Cobb-Douglas function which model the demand for the country.

In the case of a CES function with C countries, the Armigntom assumption for the general country c and sector i can be written in two stages. The first concerns the degree of substitution between the domestic and imported good. It is given by:

$$\min PDTOT_{i,c} DTOT_{i,c} = PD_{i,c} D_{i,c} + PM_{i,c} M_{i,c} \tag{1.1}$$

$$s.t. \quad DTOT_{i,c}^{1-1/\sigma_{ARM_i}} = D_{i,c}^{1-1/\sigma_{ARM_i}} + M_{i,c}^{1-1/\sigma_{ARM_i}} \tag{1.2}$$

where $DTOT_{i,c}$, $D_{i,c}$ and $M_{i,c}$ are, respectively, total, domestic and aggregated import demand in country c and sector i, $PDTOT_{i,c}$, $PD_{i,c}$ and $PM_{i,c}$ are, respectively, the price of total, domestic and import demand in country c and sector i and σ_{ARM_i} parameter is the elasticity of substitution in sector i between the imported and domestic goods (so-called Armington elasticity).

The second stage concerns the degree of substitution across imports of country c in sector i. It is the following:

$$\min PM_{i,c} M_{i,c} = \sum_{c^* \neq c} PDEM_{i,c^*,c} DEM_{i,c^*,c} \tag{1.3}$$

[3] A country can export and import the same good.

$$s.t. \quad M_{i,c}^{1-1/\sigma_{IMP_i}} = \sum_{c^* \neq c} \alpha IMP_{i,c^*,c} DEM_{i,c^*,c}^{1-1/\sigma_{IMP_i}} \tag{1.4}$$

where $DEM_{i,c^*,c}$ is the good which is exported from country c^* to country c in sector i, $PDEM_{i,c^*,c}$ is the associated price, σ_{IMP_i} parameter is the elasticity of substitution across the imports of country c and αIMP is a parameter of the CES function.

The Armington assumption is now a standard hypothesis for modelling trade in CGE models. The Armington and import elasticities (σ_{ARMi} and σ_{IMPi}) cannot be directly calibrated in the CES function; they must be estimated econometrically or derived from trade literature. With the CES function, Brown (1987) shows that greater substitutability across imports (greater σ_{IMPi}) implies reduced trade effects in the countries which experience the tariff change. On the other hand, greater substitutability across domestic and imported goods (greater σ_{ARMi}) implies increased trade effects in the country which experiences the tariff change.

A main criticism of the Armington assumption concerns the source of product differentiation. Taylor and Von Armin (2006, p.14) note that 'national product differentiation ignores the fact that companies, not countries, increasingly determine the characteristics of products. In other words, much international trade is intra-company, which make the Armington set-up irrelevant'.

Other sources of product differentiation can be introduced; horizontal product differentiation is an important example. The next subsection will examine this aspect in more detail.

1.1.2 Horizontal product differentiation

The introduction of horizontal product differentiation into CGE models stems from the Krugman theoretical model (1979). Krugman applies the "love of variety" approach, introduced by Dixit and Stiglitz (1977), to international trade theory. To summarize, his model contains two predictions concerning the impact of trade on the productivity of firms: the *scale effect* as surviving firms expand their outputs, and the *selection effect*, as some firms are forced to exit from the market; however, aggregate productivity does not change and all the firms are symmetric.

In his pioneering work, Harris (1984) incorporates elements of new trade theory, such as strategic price-setting behaviour and increasing returns to scale, into a standard *computable general equilibrium* model for the Canadian economy.

Since Harris, imperfect competitive CGE models have been widely used to assess trade liberalization issues, particularly in the *North American Free Trade Agreement* (NAFTA), the European single market program and the Uruguay and Doha negotiations. For example, Harrison *et al.* (1997) build a global CGE trade model to quantify the Uruguay Round. Increasing returns to scale are introduced and firms compete in a quantity adjusting oligopoly framework.

Norman (1990) explains the need to consider economies of scale and imperfect competition to analyse the consequences of trade liberalization. By using simplified models, he finds that imperfect competition makes a significant quantitative difference (compared to the standard, perfectly competitive theory) to the effects of trade liberalization on inter-industry trade patterns. In addition, the Armington assumption is not a good approximation of product differentiation and oligopolistic interaction.

Horizontal differentiation in the goods market can be modelled in different ways. Following Willenbockel (2004), I identify four types of imperfect competition schemes used in CGE trade models. In Bertrand oligopoly, each firm conjectures that the supply prices of the rivals in the goods market do not respond to changes in its own supply price. In oligopoly with conjectural price variations, each firm conjectures that the supply prices of the rivals in the goods market respond to changes in its own price through a certain non-zero price reaction as in Delorme and van der Mensbrugghe (1990). In Cournot oligopoly, each firm conjectures that the supply quantities of the rivals in the goods market do not respond to changes in its own supply quantity; this approach is used by Harrison *et al.* (1996), Willenbockel (1994), Burniaux and Waelbroeck (1992) and Capros *et al*. (1998). In oligopoly with conjectural output variations, each firm conjectures that the supply quantities of the rivals in the goods market respond to changes in its own supply quantity according to a certain output response.

Problems can arise if imperfect competition is introduced into CGE trade models. Mercenier (1995) shows that in a CGE model for the European integration program with economies of scale and imperfect competition, the equilibrium solution is not unique. He finds that the trade experiment, consisting of forcing individual firms to switch from their initial segmented-market pricing strategy to an integrated market pricing strategy, causes two different equilibria. The non-uniqueness of solution in CGE models with imperfect competition is often ignored from model builders and users. Nevertheless it can be a serious matter in the interpretation of trade policy experiments.

Another issue is the dependency of imperfect competition equilibrium on the choice of numeraire. Gabszewicz and Vial (1972) present this property of theoretical general equilibrium models with imperfect competition. Ginsburgh (1994) gives numerical examples for CGE models. However, the normalisation problem can be avoided in CGE models by “reasonable” restrictions on the information set of the oligopolistic firm (Willenbockel, 2003). For example, when firms rule out the possibility that their production decision influences the aggregate income via factor prices and profit feedback effects (the so-called Ford effect), the numeraire matter can be neglected.

1.1.3 From a static to dynamic model

Theoretical growth literature has shown that trade liberalization may affect capital stock accumulation or human capital accumulation and technology. These processes are intrinsically dynamic. Thus, the impact of trade liberalization on output and welfare could be misleading if only the static effect, that is linked to the efficient allocation of factors, is considered.

Concerning capital stock accumulation, the Baldwin theoretical model (1989) shows that trade policy may change income or the endogenous saving rate, that, in turn, influences the stock of capital. In addition, François *et al.* (1995) and Baldwin (1989, 1992) argue that the magnitude of the trade policy effect could be greater than in the static model.[4] With respect to the second aspect, human capital accumulation and technology, Baldwin and Forslid (1999) find analogous results when technological externality is introduced. Empirical studies do not give a definitive answer about the existence of such growth effects (see e.g. Fontagné and Guérin, 1997, for a survey of this literature). Thus, no clear and robust conclusion is possible.

The simplest way to interpret the effects of trade policy liberalization in global CGE models is through comparative static. Basically, a parameter, such as a barrier tariff, is modified. The new equilibrium solution is compared with the equilibrium solution in the baseline model. The consequent changes can be considered long-term or short-term effects according to the assumption about factor mobility, in particular, the capital factor. Harrison *et al.* (1997) and François *et al.* (1995) use this approach. They allow the rental rate of capital to vary within each country, while holding constant the aggregate stock of capital in order to assess short-term effects of trade policy liberalization. In contrast, they allow aggregate stock capital to vary, holding the rental rate of capital constant in order to assess the long-term or steady state impact of the shock. They find that long-term welfare gains are two to four times higher than the short-run estimates.[5]

Even if this type of model distinguishes between long-term and short-term effects, essentially, they are still a comparison between two equilibria and do not capture the trade impact on human and capital accumulation. For this reason, the latest generation of global CGE models incorporate time into their general structure.

[4] For example, “the additional dynamic gain on welfare is positive if liberalization raises the return to capital; if the liberalization lowers the return to capital, the dynamic welfare effects tend to offset the static gains from trade” (Baldwin, 1992, p. 166).

[5] Nevertheless, it should be emphasized that the long-term effects of this type of model do not consider that in a fully dynamic framework, consumption decreases to achieve the higher capital stock. Thus, Harrison *et al* (1996, 1997) and Rodrik (1997) highlight that these models tend to overestimate the overall welfare gain.

For example, MIRAGE, GTAP and GTEM all have a dynamic version but It is very rough because no intertemporal dynamic optimisation is taken into account. Basically, the model is solved recursively. In each period, investment is endogenously determined and is added to the depreciated capital in the next period. The growth rate of factors, with the exception of capital, is set exogenously. The time span can be freely chosen, usually 15 to 20 years. These assumptions imply temporal inconsistency in the behaviour of economic agents.

1.1.4 Firm heterogeneity: the Melitz model

In recent years, there has been a growing development of a new generation of theoretical trade models based on the assumption of heterogeneous firms. The "New trade theory" associated with Krugman (1979) and others introduced Dixit-Stiglitz monopolistic competition and scale economies to allow for intra-industry trade across countries observed in the data[6], thereby overcoming a limitation of traditional Heckscher-Ohlin model. However, it did not explain why some firms in the same sector export while others do not.

For this reason, in 2003 Melitz built one of the first models that had heterogeneous firms and sunk costs of exporting. These hypotheses are fundamental in order to explain the difference between exporting and non-exporting firms within the same industry.

Other works followed that of Melitz, in particular Helpman *et al.* (2004) and Bernard, Redding and Schott (2007). The Bernard-Redding-Schott model inserts the traditional endowment-based comparative advantages into the new theoretical framework of heterogeneous firms.

The Melitz model is a dynamic single industry model with heterogeneous firms. It considers a Krugman structure with monopolistic competition and increasing returns while adding productivity heterogeneity across firms. The productivity distribution

[6] As shown in subsection 1.1.1, *computable general equilibrium* approach solves *cross-hauling* problem through the introduction of the Armington hypothesis.

can belong to one of the several common distribution families: lognormal, exponential, gamma, Weibul, truncation on (0, +∞) of the normal, logistic, extreme value, Laplace and Pareto distributions.

The productivity heterogeneity is crucial in order to show the gain in the level of aggregate productivity or welfare obtained in the transition from autarky to free trade, or in response to a more liberalised environment. In fact, these processes determine a selection effect and a reallocation of market shares because the less productive firms are replaced by the more productive foreign firms.

A curious effect is the anti-variety Krugman effect that occurs in the Melitz model when the export costs are high and foreign firms replace a larger number of domestic firms in the transition from autarky to free trade. However the overall effect on welfare remains positive because of the increased productivity.

As Kehoe points out (2005), a main weak link in CGE approach is that models do not allow trade policy to influence aggregate productivity and induce trade growth along the extensive margin, i.e. the number of exporting firms and traded goods. On the contrary, the *policy maker* is often interested in assessing the aggregate productivity gain of trade policy. Inserting the Melitz assumption into the *computable general equilibrium* framework could satisfy this need.

Global CGE trade models, such as GTAP, GTEM and MIRAGE, do not incorporate Melitz hypothesis about firm heterogeneity because it is too recent. However, two applications of the Melitz assumption to CGE trade models exist: Balistreri, Hillberry and Rutherford (2007) and Zhai (2008).

Zhai builds a global CGE trade model with twelve macro-areas, fourteen sectors and five production factors. Within the fourteen sectors, the agriculture and energy sectors produce homogenous products.[7] In each of these two sectors, there is a representative firm operating under constant returns to scale technology. The other manufacturing and service sectors produce differentiated products. In these sectors, the production and trade structures of the CGE model closely follow the Melitz model. Different from Melitz, the Zhai CGE model is not characterised by a steady

[7] The agriculture and energy sectors are assumed to be perfectly competitive, also in the Mirage model (see subsection 1.3.3).

state equilibrium, but rather a static equilibrium. A Pareto distribution is used to model the productivity heterogeneity.

The results of trade policy simulation, a 50% global manufacturing tariff cut, are compared with the results of a standard Armington CGE model with constant returns to scale and representative firm. The model predicts a global welfare gain of $91.6 billion, measured in equivalent variation (EV), more than double of the estimated gain in the standard Armington CGE model. In addition, as predicted by the theoretical model, trade policy simulation increases the number of exporting firms, decreases the number of domestic firms and increases the aggregate manufacture productivity. However, it should be emphasized that the shape parameter in Pareto productivity distribution plays an important role in determining the impact of trade barriers on trade flows.

Balistreri, Hillberry and Rutherford use an original approach to insert the Melitz assumptions in their model which is, indeed, a mix of a numerical general equilibrium (GE) and partial equilibrium (PE) model. Two steps are needed to solve the model. In the first step, a PE model is solved for each commodity in order to obtain the industrial organization of heterogeneous firms (i.e. the number of firms operating within and across borders). The PE model takes aggregate income levels and resources supply schedules as given. The second module is a GE model of global trade in all products. The GE model takes industrial structure as given and determine relative prices, comparative advantages and terms of trade. Then, they iterate between these two models in policy simulation as long as the PE and GE models are mutually consistent. They find that in the case of a 50% tariff reduction in trade manufactured goods, the global welfare gains are four times greater than in the standard Armington CGE models. As in the Zhai application, trade policy increases the number of exporting firms, decreases the number of domestic firms and increases the aggregate manufacture productivity.

Both the Zhai and Balistreri, Hillberry and Rutherford models are calibrated on the GTAP database. Zhai sets exogenously the relevant parameters of firm heterogeneity, e.g. shape parameter of the Pareto distribution. Balistreri, Hillberry and Rutherford develop an original procedure to calibrate these parameters.

1.2 Sensitivity of the simulation results to key hypotheses

A crucial issue in the *computable general equilibrium* approach is the sensitivity of the simulation results to key hypotheses. Parameters are generally calibrated by using available data, where it is possible, or are set exogenously from econometric estimates. Sometimes econometric estimates are not available or robust. This lack of econometric foundation makes the CGE effects of trade policy simulations vulnerable to key assumptions about the parameter value. CGE models are sensitive not only with respect to the value of parameters but also to the hypotheses of the model, i.e. the type of equation which defines the equilibrium in the factor or goods market or the functional form chosen to model the substitutability across products or factors (see McKitrick, 1998).

In this section I consider three main elements that may affect trade policy results in global CGE models: Armington elasticity, firm conduct and labour market.

1.2.1 Armington elasticity

CGE modellers typically draw the elasticity value from econometric studies that use time series price variations to identify an elasticity of substitution between domestic goods and composite imports (Alaouze, 1977; Alaouze *et al.*, 1977; Stern *et al.*, 1976; Gallaway *et al.*, 2003). This method has three drawbacks: the use of point estimate as true, a downward bias in the point estimates created by problems in estimation technique and an inconsistency between the data sample of an econometric estimate and the trade policy experiment. Hertel *et al.* (2007) try to overcome these limits by using cross-section price variations in place of time series price variations for the econometric estimate. In addition, they take into account the uncertainty regarding the values of Armington elasticity through a Gaussian Quadrature numerical integration technique. Basically, the objective is to improve the linkage between econometirc estimates of key parameters and their use in CGE trade models.

The computed elasticity in the study by Hertel *et al.* (2007) are more econometrically founded than elasticity computed by the older methods. Nevertheless, the authors admit that the method could underestimate elasticity in developing countries, which are likely to import less-differentiated products than richer countries, because their estimates stems from a database of seven American countries, including the USA.

Thus, Valenzuela *et al.* (2008) carry out a sensitive analysis in the GTAP model (see subsection 1.3.1) using two different values of Armington elasticity for developing countries.

The results of the study shows, for example, that Saharan Africa loses slightly from its own full liberalization because the efficiency gain is more than offset by the loss in its terms of trade with the standard Armington elasticity value. Vice versa with a doubled Armington elasticity value in developing countries, the efficiency gain increases and the loss in terms of trade decreases in Saharan Africa, because the export demand elasticities also double in size. Thus, the overall effect on welfare after trade liberalization is positive in the area. This is a simple example that shows the importance of Armington elasticity value.

Another problem linked to Armington elasticity is the fiscal bias, which severely undermines the welfare calculation. Taylor and von Arnim (2006) set out an example concerning the GTAP/LINKAGE model, used by *World Bank* to simulate trade liberalization scenarios. In the basic GTAP model, the Armington assumption ensures that if a country removes tariff barriers in a sector, the country will increase imports in the sector because of the reduced import price. The GTAP model also assumes that a decrease in income tax, following tariff cuts on imports, is perfectly compensated by a new tax which distorts neither production nor demand.

However, the authors demonstrate that the negative direct impact of this new tax is greater than the positive indirect effect of tariff reduction via a lower price, if this new tax is a simple tax on aggregate consumption.

The implication is that the *World Bank* estimates of welfare gains from liberalisation are subject to biases because tariff suppression leads to demand contraction for imports if this direct effect on aggregate consumption is considered.

1.2.2 Firm conduct

The introduction of imperfect competition and increasing returns to scale in CGE models raises the question whether trade policy simulations are sensitive to the hypothesis about firm conduct.

Willenbockel (2004) provides a systematic synopsis of alternative formulations of imperfectly competitive supply behaviour in applied general equilibrium trade models. The proposed range of schemes is broad: a domestic Cournot scheme, an international Cournot scheme, a domestic Bertrand scheme, an international Bertrand scheme and an oligopoly with conjectural price and output variations.[8]

Willenbockel build a stylised model with simulated data. There are three countries (A, B, C) and two sectors (a perfectly competitive one and an imperfectly competitive one). He assumes that country A imposes a tariff in the imperfectly competitive sector. Thus, he examines the sensitivity of simulated trade policy effects to the specification choice of firm conduct. The firm behaviour is associated with different Armington and Dixit-Stiglitz elasticity values.

In addition, imperfect competition needs to calibrate three parameters: the Dixit-Stiglitz elasticity of substitution between firm-specific varieties, the mark-ups and the number of firms in each sector. Given that these parameters are linked by the Lerner equation, in CGE models with imperfect competition two of the three parameters are generally set extraneously while the remaining one is calibrated residually. At the calibration stage, Willenbockel uses two types of strategies, which can also be found in the empirical literature. In the first one, the number of firms and Dixit-Stiglitz elasticity are set extraneously while mark-up is calibrated residually (e.g. Brown and Stern, 1989). In the second one the number of firms and mark-ups are set extraneously, while the Dixit-Stiglitz elasticity value is calibrated residually (e.g. Gasiorek *et al*., 1992; Haaland and Norman, 1992; Willenbockel, 1994).

[8] With the domestic Cournot hypothesis, the firm assumes that its conjecture about the reactions of rivals only concerns the other domestic firms. With the international Cournot hypothesis, the firm assumes that its conjecture about the reactions of rivals also concerns foreign competitors. This assumption is not trivial. For example, the international Cournot scheme implies that foreign rival quantities remain fixed and foreign rival prices respond to marginal variations in firm output because any variation in firm output entails a shift in the demand curves of foreign rivals.

The results of trade experiment are very interesting. Willenbockel finds that simulated responses to the trade policy shock are robust to the choice of firm behaviour. However, the results are very sensitive to the strategy chosen at the calibration stage and to the benchmark mark-up values.

Thus, the main practical implication for applied studies is that it is more important to provide clear documentation of the numerical specification at the calibration stage than to conduct in-depth sensitivity analysis across a wide range of imperfectly competitive models at the theoretical stage.

1.2.3 Labour market

The strength of CGE models lies in the possibility of simultaneously considering price and quantity interactions in all markets, while taking into account all the direct and indirect effects of trade policy. This comprehensiveness is also the weakest point of CGE models because it requires a lot of data and, in turn, implies over-simplification of reality. One of the major simplifications regards the labour market, in particular, the assumption that the total level of employment is fixed.

In reality, trade policy is likely to have an impact on the level of total employment and the *policy maker* is often interested in assessing the effects of trade policy liberalization on employment. Standard CGE models do not allow for this kind of trade consequences; in fact, most of them assume exogenous unemployment levels.

As stated by Stiglitz and Charlton (2004, pp. 8-9), 'CGE models often do not account for the presence of persistent unemployment in developing countries. In the presence of unemployment, trade liberalization may simply move workers from low productivity protected sectors into unemployment'.

Ackerman (2005, p. 20) stress that this limitation explains 'why the gains to consumers from tariff reductions dominate the model estimates of the benefits of liberalization: producer impacts, positive or negative, have been largely suppressed by assumption'.

Nevertheless, efforts have been made to allow for varying levels of total employment. Recent studies for the *United Nations Conference on Trade and Development* (UNCTAD), using GTAP model, simulate trade liberalization under the assumption that the employment of unskilled labour in developing countries can change. In one such study Fernandez de Cordoba and Vanzetti (2005) find that the elimination of all industrial tariffs would lead to estimated increases in the employment of unskilled labour of between 5% and 8% in most of Asia, Africa and Central America.

The MIRAGE model is another attempt to consider variable total employment (see subsection 1.3.3). The labour market structure for developing countries is close to the UNCTAD framework but the model predicts different results for agriculture liberalization (Bouet *et al.*, 2005). The gains from agricultural trade liberalization are limited and are concentrated in developed countries, just as in the standard GTAP model.

1.3 Main global CGE models for trade policy evaluation

Let us now move on to a description of the main CGE trade models used by international organizations, such as the WB, the WTO, the EC and the OECD (*Organisation for Economic Co-operation and Development*), to simulate trade liberalization scenarios, as in the Uruguay and Doha negotiations. Three models are examined: GTAP, MEGABARE and MIRAGE. These models are not set out in detail because they are very rich and several versions of each model have been developed over the years. I will try to give the essence of the models by briefly explaining their origin, use and most important features. I will however go into more detail for MIRAGE model because I know more about it, having used it during my work experience at CEPII.

1.3.1. The GTAP model

'The *Global Trade Analysis Project* (GTAP) was established in 1992, with the objective of lowering the cost of entry for those seeking to conduct quantitative analyses of international economic issues in an economy-wide framework' (Hertel, 1997, p. 3).

A fully documented global dataset and a standard modelling framework are the two main characteristics of GTAP. In addition, a global network of researchers and a consortium of national and international agencies provide support for multi-country analyses of trade and resource issues.

The GTAP database is commonly used in global CGE models to assess trade policy reform. As noted in the introduction, the latest version (GTAP 7.0, Narayanan and Walmsley, 2008) is a large SAM. Besides providing the values for demand and production variables, It also contains complete bilateral trade information and transport and protection linkages among 113 countries or groups of countries and 57 sectors for the base year 2004. The lack of input-output tables makes it necessary to aggregate some developing countries. Bilateral trade flows stem from COMTRADE, the United Nations Commodity Trade Statistics Database. Tariff barriers are drawn from the MAcMap (*Market Access Maps*) database (Bouet *et al*., 2004) produced by CEPII and the ITC (*International Trade Centre*) research institutes, located respectively in Paris and Geneva.

I now describe the theoretical framework in the standard GTAP model.

The nested production technology in GTAP exhibits constant returns to scale and every sector produces a single output. Five primary factors are considered: land, natural resources, capital, unskilled and skilled capital. A CES technology is used to combine the five production factors to obtain the value added and a CES function is also used to aggregate the domestic and foreign intermediate inputs. Leontief technology uses the value added and the aggregate intermediate inputs in fixed proportions to produce output.

Among the primary factors, labour and capital are perfectly mobile across sectors, while land and natural resources are imperfectly mobile. However, land and natural resources are only used in the agricultural and primary energy sources sectors.

Capital is also perfectly mobile across countries. It is assumed that the other primary factors are generally immobile in the country or group of countries depending on the chosen geographical aggregation.

Regarding the demand side, a representative household collects all the income that is generated in the country or group of countries (depending on geographical aggregation). This income is shared through a Cobb-Douglas function across private household expenditure, government expenditure and savings. The constrained optimising behaviour of private consumption is represented in the GTAP model by the CDE (*Constant Difference of Elasticity*) implicit expenditure function, which takes into account the non-homotetic nature of final consumption. The CDE function is less general than the fully flexible functional forms, but is more flexible than the commonly used LES-CES (*Linear Expenditure System – Constant Elasticity of Substitution*) function.

Macroeconomic closure is neoclassical, therefore, investment is savings-driven. The international trade is modelled through the Armington assumption, as usual.

Different versions of GTAP models exist. Imperfect competition can be inserted as in Hertel *et al*. (1997) and François (1998). International technology spillovers have also been considered as in van Mejil and van Tongeren (1999). The dynamic version of the model, LINKAGE, was developed by Andrerson *et al*. (2005 a-b) for the WB. LINKAGE is solved recursively over a period of fifteen years. The dynamic side is represented by population growth and capital accumulation.

1.3.2 The MEGABARE model

The MEGABARE model was developed by Hanslow in 1996 at the *Australian Bureau of Agriculture and Resource Economics* (ABARE). It drew, in part, upon the structure and database of GTAP but it also contained significant advancements over the GTAP model of that time. The first major difference was the dynamic set-up of MEGABARE. In addition, it was applied not only to global trade liberalization but also to a variety of issues as environmental policy.

MEGABARE has evolved over the years. Its most recent version, GTEM (Pant, 2002), incorporates additional elements.[9]

Each production sector consists of several homogeneous firms that use identical technology and produce homogeneous products. There are two exceptions to this assumption: the electricity sector and the iron and steel sector. These sectors produce homogeneous outputs but employ non-homogeneous technologies. For example, electricity can be produced by using coal fire technology or hydroelectric technology.

Technological change is exogenous except for the infant renewable energy sector, such as solar, where a "learning by doing" process is modelled and the mining sector, where the factor productivity declines as the cumulative level of resource extraction increases.

Each year the labour supply is fixed but it evolves according to participation rates within the working-age population.

The capital account is open. Domestic savers purchase bonds on the global financial market and domestic investors sell bonds on the global financial market. A flexible global interest rate clears the global financial market. Nevertheless, it is assumed that rates of return on money invested in physical capital may differ between countries because of the risk characteristic and policy configurations of each country. As a result, any differences between the local rates of return on capital and the global cost of borrowing is the consequence of policy imperfections on the international capital market.

[9] GTEM stands for *Global Trade and Environment Model*.

1.3.3 The MIRAGE model

The MIRAGE model was developed by the French research institute CEPII in 2002 (see Bchir *et al*.) to simulate trade policy scenarios. At the instigation of the *European Commission* and French Finance Ministry the model was widely used to assess the entry of China into the WTO and to analyse the preferential bilateral agreements between the European Union and different partners, such as the Mercosul and ACP countries.[10]

In 2007 Decreux and Valin developed an updated version of the model, funded, in part, by the *European Commission*.

MIRAGE also uses GTAP and the MAcMap database. As stated above, MAcMap database is compiled by the CEPII and ITC. It provides *ad valorem* equivalent measure of specific tariff, *ad valorem* tariff and tariff quotas. In addition, preferential agreements are taken into account. As a result, MIRAGE is based on a description of trade barriers that is precise and preserves the bilateral dimension of the information.

Following, is an illustration of the theoretical structure of the model with reference to the latest version (2007).

Concerning the demand side, in each country or group of countries a representative household maximises utility function and owns factor endowments. Total demand is comprised up of final consumption, intermediate inputs and capital goods. Final consumption is modelled through a LES-CES function. With this kind of function, the elasticity of substitution is constant only across the sectoral consumptions over a minimum level.

The representative household includes the government, therefore it pays and earns taxes so that the public budget constraint is implicit to meeting the household budget constraint. Any decrease in tax revenues (e.g. as a consequence of trade liberalization) is assumed to be exactly compensated by a non-distorting replacement tax.

[10] Mercosul is a regional trade agreement among Argentina, Brazil, Paraguay and Uruguay established in 1991. Bolivia, Chile, Colombia, Ecuador, Peru and Venezuela are currently associate members. ACP stands for African, Caribbean and Pacific Group of States.

Horizontal and vertical product differentiation is introduced. Horizontal differentiation and increasing returns to scale are very close to the specification of Harrison *et al*. (1997). Each firm produces its own, unique variety. Symmetric firms compete in a Cournot-Nash way.

Vertical product differentiation distinguishes between two quality ranges, defined on a geographical basis. The first quality range includes goods produced in developing countries, while the second includes goods produced in developed countries. This geographical product differentiation leads up to the standard Armington level. Elasticity of substitution between the quality ranges is smaller than the Armington elasticity. Even if rudimentary, this assumption is a first attempt to allow for specialisation in quality ranges, which has been amply illustrated in the empirical literature (Fontagné and Freudenberg, 1997; Greenaway and Torstensson, 2000).

Now let us move to the supply side. As in the GTAP model, five primary factors are considered: land, natural resources, capital and skilled and unskilled capital.

CES technology uses land, natural resources, unskilled labour and a fictive factor to produce value added in each sector. The fictive factor is a CES bundle of capital and skilled labour. This structure is intended to take into account the well-documented complementarity between skilled labour and capital (Duffy, Papageorgiou and Perez-Sebastian, 2004). Therefore, the elasticity of substitution between skilled labour and capital is smaller than the elasticity of substitution between fictive factor and the other primary factors.

Leontief technology uses value added and intermediate inputs to produce output. Intermediate input in each sector is represented by a CES function of intermediate inputs from all the other sectors. As a result, intermediate inputs are imperfect substitutes.

The updated version of MIRAGE introduces interesting elements for modelling the labour market. As noted in subsection 1.2.3, a weak point of the CGE approach is the fixed labour supply, especially for developing counties. For this reason in MIRAGE, a dual labour market is considered for developing countries and unskilled labour. It follows the theoretical studies of Lewis (1954) and Harris and Todaro

(1970). A modern urban sector (industry and services) pays an efficiency wage to unskilled workers. This wage is independent of the labour supply. The traditional sector (i.e. agriculture), by contrast, uses a fixed quantity of unskilled labour which is paid at the level of its marginal productivity. This assumption stems from the high level of underemployment observed in rural areas of some developing countries. As a result, unskilled workers can respond to any labour demand in the modern urban sector, while their position is filled in the agricultural sector. This specification provides a simple way to depart from the standard assumption of exogenous unemployment levels used in most CGE models.

Regarding macroeconomic closure, MIRAGE, unlike the GTAP model, assumes that installed capital is immobile in each country or group of countries and in each sector; this is the so-called *putty-clay* hypothesis. In the GTAP model the assumption of perfect capital mobility across sectors and countries results in unrealistic cross-border capital flows. Using the results of econometric estimates directly to calibrate parameters would give more realistic results but would lack theoretical consistency. Therefore, the *putty-clay* hypothesis is used in MIRAGE. As a result, investment plays an important role because FDI (*Foreign Direct Investments*) are the only device for adjusting capital stock. An original modelling of FDI is used. It is a compromise solution between theoretical consistency and empirical realism. The first objective requires domestic investment allocation and FDI to be consistent and saving behaviour to be rational. The rate of return to capital in each country or group of countries and in each sector is a natural determinant of investment sharing across countries and sectors. In addition, the empirical literature (Chakrabarti, 2001) shows that this rate of return depends on the main determinants of FDI. For this reason, domestic and foreign investments are a function of the initial savings in each country or group or countries and the sectoral rate of return to capital in each country or group or countries.

As for the GTAP/LINKAGE and MEGABARE/GTEM models, a dynamic version of MIRAGE exists. The model is solved recursively over a period of 15 or 20 years. Each year, the capital evolves through the above-mentioned FDI mechanism and its depreciation rate while labour force growth is modelled according to the *World Bank* population projections.

1.4 Global CGE trade models at the sub-national level

The objective of this thesis is to build a global CGE trade model at the NUTS 1 level for the regions in the first 15 member states of the *European Union* (EU15).

There are CGE trade models at the sub-national level but this kind of model has generally been applied to a single region or a handful of regions because they are very demanding in terms of data.[11] To the best of my knowledge, only Australia and the European Union have developed and applied global CGE trade models to a considerable number of regions.

Three examples of this type of model are presented in the following sub-sections: the GTAP-CAPRI model, the MONASH-MRF model and the MIRAGE-DREAM model. The GTAP-CAPRI, MONASH-MRF and MIRAGE-DREAM models are not discussed in detail but the main features of each one will be outlined.

1.4.1 The GTAP-CAPRI model

The GTAP-CAPRI model is developed by Jansson, Kuiper and Adenaüer as a part of the SEAMLESS project (2009). SEAMLESS stands for *System for Environmental and Agricultural Modelling: Linking European Science and Society*. The project is carried out by a consortium of 30 partners, led by Wageningen University (Netherlands). Its aim is to combine the detailed modelling of agriculture in CAPRI and the economy-wide general equilibrium feedbacks in GTAP.

CAPRI is a *partial equilibrium* (PE) model which includes about 200 NUTS 2 regions of the 27 members of the European Union. The model also considers about

[11] Partridge and Rickman (1998) conduct a survey of such models, mostly for regions in the USA.

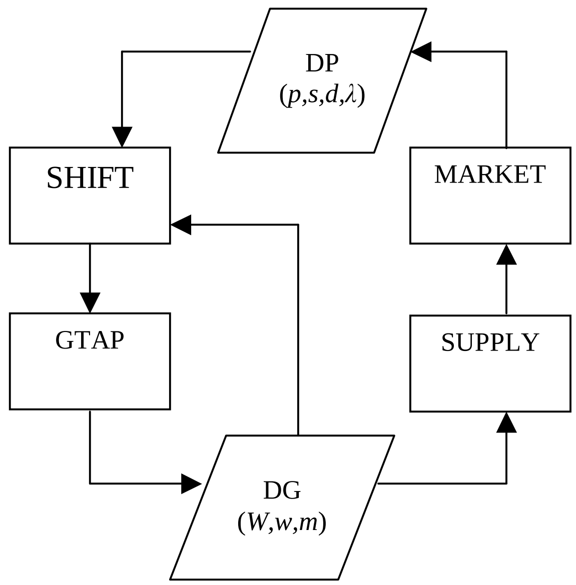
30 different crop production activities. The animal sector incorporates dairy cows, cattle raising as well as eight other animal activities.

In each NUTS 2 region a representative farm maximises profits subject to constraints such as utilisable agricultural area and production quotas.

As stated above, CAPRI is a PE model because non-agricultural variables, such as input prices and consumer income, are exogenous.

In principle, a joint solution of a GE and PE models is not different from the solution of a single extended GE model. Basically, the strategy followed here that links the GE and PE models consists in using endogenous outcomes of the GTAP for variables which are otherwise exogenous in the CAPRI. The GTAP agricultural sector is iteratively adapted to the CAPRI changes through an additional program which calibrates standard GTAP parameters to CAPRI results. The iterative process is illustrated in Figure 1.1.[12]

Figure 1.1: Iterative solution process in the GTAP-CAPRI model



[12] The figure is taken from Jansson *et al*. (2009).

Upper case letters denote the absolute value of the variable while the lower case letters in brackets denote % change from the baseline value. The variables are: the prices of GTAP primary factors (*W*), aggregate input and output price indexes in CAPRI (*p*), aggregate supply of agriculture in CAPRI (*s*), input demand for agriculture in CAPRI (*d*), land price in CAPRI (λ) and consumer expenditure in GTAP (*m*).

Within the CAPRI model, the solution process starts in the SUPPLY module, which computes the supply of agricultural goods at the NUTS regional level within the EU. The supply is aggregated to the member state level, and the supply functions of the MARKET module are recalibrated to replicate the solution of the SUPPLY model. The MARKET module is then solved for market clearing prices, using linear approximations of the last outcome of the SUPPLY model. To this point, the process is the standard CAPRI procedure. However, after the MARKET module has been solved, the results are aggregated at the GTAP level and stored in the DP file. The SHIFT module uses the *p, s, d* and λ values, stored in the DP file, and the outcome of the previous iteration of GTAP (DG file) to compute the shock to the key parameters of GTAP. When GTAP finishes by inserting the new values of *W, w* and *m* in the DG file, CAPRI resumes the execution and starts a new iteration by solving the SUPPLY and MARKET modules. The iteration process stops when the price changes are no more than 0.1%.

While GTAP-CAPRI model allows for very detailed trade policy simulations, the model is limited to the analysis of the agricultural sector.

1.4.2 The MONASH-MRF model

MONASH-MRF is a multi-regional, multi-sectoral CGE model of the Australian economy. The model and its database were developed by Peter, Horridge, Meagher, Naqvi and Parmenter in 1996 at the Centre of Policy Studies.[13]

[13] The Centre of Policy Studies, a research centre at Monash University, is devoted to quantitative analysis of issues relevant to Australian economic policy.

MONASH-MRF divides Australia in eight regional economies. There are four types of agents in the model: industries, households, governments and foreigners. In each region there are thirteen industrial sectors. The regional demand and supply of goods are determined by the optimising behaviour of the agents in competitive markets.

Concerning the production side, in each region firms use intermediate inputs and primary factors. Production is specified through a three-level nested technology. At the first level, the bundle of primary factors (value added) and intermediate inputs is modelled by a Leontief technology (i.e. they are used in fixed proportions with respect to the output). At the second level the primary factor bundle is a CES combination of labour, land and capital, while the intermediate input bundles are a CES combination of international imported goods and domestic Australian goods. At the third level intermediate inputs of domestic goods are formed as CES combination of goods from each of the eight regions while the input of labour is formed as a CES combination of labour inputs from eight different occupational categories. Thus, the intermediate inputs from different regions are not perfect substitutes in the MONASH-MRF model, such as domestic and foreign goods in the case of the Armington assumption.

The demand side is specified through a three-level structure. At the first level, in each region the representative household maximises a Stone-Geary utility function, leading to the *linear expenditure system* (LES). At the second level, imported and Australian domestic goods are modelled by a CES function as in the standard Armington scheme. At the third level a CES function is also used to represent the imperfect substitutability among goods from each of the eight regions. The MONASH-MRF model includes both the Federal and State governments. A single aggregate foreign purchaser of exports is considered. To model export demands, goods are divided into two groups, the traditional exports, agriculture and mining, and the remaining non-traditional exports.

MRF model can produce either comparative-static or forecasting simulations (dynamic set-up). A comparative static simulation can be interpreted as short-run or long-run effects according to the hypothesis about capital mobility. Short-run simulations are characterised by the assumption of fixed industry capital stock. Long run simulations assume that the industry capital stock is determined endogenously, while the world rate of capital return is exogenous. Finally, forecasting simulations allow for capital accumulation over the years and population growth.

It is important to describe the labour market. The MRF model allows for both: '(i) an exogenous determination of the regional population, with an endogenous determination of at least one variable of the regional labour market, chosen from regional unemployment, regional participation rates and regional wage and (ii) an exogenous determination of all the previously mentioned variables of the regional labour market and an endogenous determination of regional migration, and hence, of regional population' (Peter *et al*., 1996, p. 50).

A highly disaggregated version of the MONASH-MRF model was created by Horridge *et al*. in 2003. This version, named TERM model, is typically solved for approximately thirty regions and forty sectors.[14]

1.4.3 The MIRAGE-DREAM model

The MIRAGE-DREAM model was developed by Jean and Laborde in 2004 with the support of CEPII and *European Commission* (EC). The model is applied to 119 NUTS 1 regions in the EU25.

Jean and Laborde use two different dataset: GTAP and REGIO of EUROSTAT. The GTAP 5.3 database (see Dimaranan and Mc Dougall, 2002) is the source of national data, while REGIO provides information at the regional NUTS 1 level. However, some countries show a high rate of missing data and an excessive level of sector aggregation at the regional level. Thus, the authors draw additional data from national statistical institutes. Concerning sectoral aggregation, the European NACE (*Nomenclature Générale des Activités Économiques*) classification is mapped into

[14] TERM stands for *The Enormous Regional Model*.

the GTAP one in order to obtain a consistent harmonised dataset. The base year for both datasets is 1997.

Jean and Laborde make use of a two-stage strategy. In the first stage MIRAGE calculates the impact of trade policy shock for the EU25 as a whole. In the second stage the results of the impact are used as input for the DREAM model, i.e. the changes in EU25 import prices and export demand represent the exogenous shock in the DREAM model.

DREAM is a CGE model in which each of the 119 NUTS 1 regions is considered separately and the trade relationships of each region are described by the results of the MIRAGE model. For this reason, the theoretical structure of the DREAM model is as consistent as possible with that of MIRAGE. Nevertheless, some simplifying assumptions are introduced in the DREAM model in order to make it possible to consider each NUTS 1 region separately. The main simplifications are the following.

(i) The country mix of imports, as well as the country mix of exports are assumed to be constant across regions within each country in the EU25 according to GTAP database. This assumption is required due to the lack of well-suited trade data at the NUTS 1 level.

(ii) Unlike MIRAGE, all the sectors are characterised by perfect competition and constant returns to scale.

(iii) The composition of the intermediate inputs basket for each sector is assumed to be fixed (Leontief technology). In the MIRAGE model imperfect substitution across intermediate inputs from different sectors is modelled through a CES function.

Regarding the demand side, in each NUTS 1 region representative household maximises a LES-CES utility function, which is non-homotetic due to a minimum level of consumption. The main source of income for the household is the returns to the production factors it earns. Labour wages are assumed to be earned wholly by the representative regional household. In contrast the regional household earns capital income generated by the capital stock from different NUTS 1 regions, but the production in the region is made using the capital stock installed in the region.

The representative household saves a constant share of its disposable income. As in MIRAGE, total demand consists of final consumption, intermediate inputs and capital goods.

The geographical distribution of demand follows a three-level structure. At the first level, goods are divided into two groups: goods from developed countries and goods from developing countries. As in MIRAGE, this assumption allows for different product quality ranges. At the second level an Armington specification for each country divides the demand between domestic and foreign goods. At the third level, for each country within the EU25, a CES function defines the imperfect substitution across products from different NUTS 1 regions within the same country.

The production side is very close to that of MIRAGE. There are five factors of production: skilled labour, unskilled labour, capital, land and natural resources. A CES bundle is used to take into account the complementarity between capital and skilled labour. However, as stated above and unlike MIRAGE, intermediate inputs in each sector are used in fixed proportions.

Concerning the mobility of production factors across regions, land and natural resources are immobile in the region and are sector specific. Capital is assumed to be perfectly mobile across sectors and regions in the EU25. Unskilled and skilled labour is perfectly mobile across sectors. The imperfect labour mobility within each country of the EU25 is modelled through a CET function. No sensitivity analysis is conducted on the robustness of the results with respect to the different degrees of labour mobility. The value of the elasticity of migration is based mainly on Eichengreen work (1993).

The macroeconomic closure is neoclassical, the investment is savings-driven and is equal to the savings for the EU25 as a whole. For the EU25, the current balance (i.e. the difference between savings and investments) is exogenous and as a result, the EU25 current external balance is also exogenous. In contrast, the current account is endogenous in each region within the EU25.

Chapter 2

A global CGE trade model at the NUTS 1 level with perfect competition

2.1 Introduction

In the first chapter I set out the main global CGE trade models and their evolution over the years. Special attention was given to the analysis of global CGE trade models at the sub-national level.

Now I present my version of a global CGE model at the sub-national level. It is applied to the 68 NUTS 1 regions within the first 15 member states of the European Union (EU15). The model has been built starting from the updated version of the MIRAGE model (Decreux and Valin, 2007) but several important changes have been introduced. As a result, the model must be considered apart from MIRAGE, as my original contribution.

My approach is also different from that used by Jean and Laborde (2004) in the MIRAGE-DREAM model, where a NUTS 1 representative regional household as well as a NUTS 1 representative regional firm appear. Their model is very demanding both in terms of data and computational resources. However, the lack of well-suited data concerning trade across NUTS 1 regions and between NUTS 1 regions and countries outside of Europe makes it necessary to resort to simplifying assumptions.

In contrast, I have built a parsimonious CGE model which uses relatively little information at the NUTS 1 level, i.e. the value added, skilled and unskilled labour. Only the production side is considered at the NUTS 1 level. In each NUTS 1 region, a representative firm maximises profits. Simplifying assumptions are made for all the variables of production other than the value added, skilled and unskilled labour.

The demand side continues to be specified at the EU15 level. This means that imports, exports, domestic demand, as well as the associated prices, are at the EU15 level. This implies, for example, that the price of the goods, paid by the EU15 representative household, is the same in all the NUTS 1 regions. In a perfectly competitive equilibrium, the price is equal to the marginal cost. As a result, all the firms within the EU15 have the same marginal cost but they use inputs by different intensities according to the NUTS 1 region where the production takes place. Thus, the focus is on the production side at the NUTS 1 level.

In addition, the MIRAGE-DREAM model gives a poor economic interpretation of trade policy effects. For this reason, I have built a stylised model, which reproduces the main features of my big model, in order to better understand the underlying economic functioning.

Unlike the MIRAGE-DREAM model, I conduct a sensitivity analysis on trade policy results according to two different degrees of skilled/unskilled labour mobility (perfect immobility at the NUTS 1 level and high mobility within the EU15). Moreover, an integrated unskilled/skilled labour market within the EU27 is tested.

In this chapter I assume perfect competition and constant returns to scale to hold in all the sectors; in the third chapter the case of imperfect competition will be discussed in-depth.

The chapter is organized as follows. In section 2 the two datasets are described, the regional one and national one, as well as the procedure used to match them. In section 3 the chosen sectoral and geographical aggregations are presented. In section 4 the theoretical structure is set out. In section 5 the calibration strategy is described. In section 6 the trade policy shock is illustrated. In section 7 the results of trade policy on production reallocation across sectors in each region are presented as well as the results of the sensitivity analysis which is conducted to test the relevance of the assumption about skilled/unskilled labour mobility on production reallocation. Other interesting results are presented: the unskilled/skilled labour migration within the EU15, the change in the value added at the NUTS level and the changes in the trade patterns and welfare at the macro-area level. In section 8 a stylised model is proposed for interpreting the results.

2.2 Database

Two different databases are used: a national database and a sub-national database. The national database is GTAP 6 (Dimaranan and Mac Dougall, 2005). It is a large SAM for 87 countries or groups of countries and 57 sectors. It contains information on bilateral trade flows and transport linkages among countries. It also incorporates the MAcMap database for tariff barriers. MAcMap is a highly esteemed dataset on trade protection. It includes *ad valorem* equivalent measure of specific tariffs, *ad valorem* tariffs and tariff quotas. In addition, preferential agreements are taken into account in a quasi-exhaustive way. As a result, the description of trade barriers preserves the bilateral dimension of the information. A special procedure is designed to limit the extension of the bias that occurs when tariffs are aggregated according to the nomenclature chosen for the CGE analysis (Bouët *et al.*, 2004). The base year for the GTAP 6 version is 2001.

The sub-national database is derived from EUROSTAT. I draw on the methodology used by Laborde and Valin (2007) to obtain value added, skilled and unskilled labour at the NUTS 1 level. Laborde and Valin use *e2vabp95*, *sbs_r_NUTS_03* and *lf2eedu* EUROSTAT tables, which consider 247 NUTS 2 regions in the EU25.[1] The *e2vabp95* table contains the NUTS 2 value added for 16 NACE sectors. The *sbs_r_NUTS_03* table contains data on employment at the NUTS 2 level for 63 NACE sectors. The *lf2eedu* table contains NUTS 2 data on employment listed by the highest level of education attained.

The *sbs_r_NUTS_03* table does not contain any precise data for employment in the agricultural sector. Thus, it is supplemented by the *a2acc797* EUROSTAT table, which provides data on the production of 39 agricultural products. The agricultural employment is divided among the NUTS 2 regions according to the production share of each NUTS 2 region.

The *e2vabp95* table provides data on value added in only 16 NACE sectors. In order to have more detailed information, value added in each country is distributed at

[1] Data are not available for Bulgaria, Romania and the French Overseas Territories.

a more detailed sector level by using the GTAP 6 database. This new value is then distributed among the NUTS 2 regions according to employment share computed in the *sbs_r_NUTS_03* table.

To determine skilled and unskilled labour, Laborde and Valin refer to the *lf2eedu* table of EUROSTAT. The table provides the number of low-skilled, medium-skilled and high-skilled labour for each NUTS 2 region. The EUROSTAT database defines skilled and unskilled labour based on the ISCED (*International Standard Classification of Education*) classification, i.e. according to the highest level of education attained. In contrast, GTAP uses the ILO (*International Labour Organisation*) classification. In GTAP, the skilled labour (professional workers) category is made up of managers and administrators, professionals and para-professionals. Trades-persons, clerks, salespersons and personal service workers, plant and machine operators and drivers, labourers and related workers, and farm workers comprise the unskilled labour (production workers) category. Considering that the medium-level in EUROSTAT corresponds to the ISCED levels 3 and 4 and that the analysis is conducted over developed countries, Laborde and Valin match low and medium-levels of education with unskilled labour and the high level of education with skilled labour.

Unfortunately no data are available from EUROSTAT concerning the distribution of skilled and unskilled workers across sectors in the NUTS regions. Thus the authors adopt the following methodology to divide skilled and unskilled workers across sectors:

1) At the national level, a mean wage $\overline{W}_{l,c}$ is computed for each labour type *l* (unskilled and skilled) and for each European country *c* by dividing the country remuneration (GTAP data) by the number of employees in 2001 for each labour type *l* (unskilled and skilled) computed by using the *lf2eedu* table.

2) For each labour type *l*, each European country *c* and each sector *i*, GTAP data are then used to calculate the share $\alpha_{l,c,i}$ of skilled and unskilled labour remuneration in the total sectoral remuneration on a national basis.

The following formula is used:

$$\sum_{l} \alpha_{l,c,i} = 1 \tag{2.1}$$

3) It is assumed that the remuneration of each NUTS 2 region *nut2* within a country has the same sectoral skilled/unskilled distribution as the country to which it belongs. Thus, it is possible to determine the remuneration *REM* for each labour type *l*, each sector *i* and each NUTS 2 region *nut2* by multiplying the share $\alpha_{l,c,i}$ (GTAP data) by the total NUTS 2 remuneration in each sector *i* obtained from the *sbs_r_NUTS_03* and *a2acc797* EUROSTAT tables according to the following formula:

$$REM_{l,nut2,i} = \alpha_{l,c,i} REM_{nut2,i} \tag{2.2}$$

4) Finally, assuming the mean wage $\bar{W}_{l,c}$ to be homogeneous across sectors in each NUTS 2 region within a country, the value of employment *EMP* in each NUTS 2 region *nut2*, sector *i* and type *l* is determined as follows:

$$EMP_{l,nut2,i} = \frac{REM_{l,nut2,i}}{\bar{W}_{l,c}} \tag{2.3}$$

It should be noted that EUROSTAT tables have some missing values. Filling methodologies have been applied by the authors by using other complementary tables from EUROSTAT and GTAP information (see Laborde and Valin, 2007). Most of the EUROSTAT data are from 2003 which is the most recent year that has the smallest number of missing values. However, when no data are available in 2003, data from 2001 and 2002 are used.

To summarize, I can use a national database (GTAP 6) with 87 countries or groups of countries and 57 sectors, and a sub-national database (EUROSTAT) with 247 NUTS 2 regions and 39 NACE sectors.[2]

In the next section the sectoral and geographical aggregations chosen for the model are illustrated.

2.3 Sectoral and geographical aggregations

In this section I set out the sectoral and geographical aggregations chosen for the model and trade policy simulations.

Two levels define geographical aggregation: one level is for the three macro-areas and the other one is for the 68 NUTS 1 regions in the EU15. The macro-area level is used to define the demand side variables. There are three macro-areas: the EU15, the rest of Europe (REU) and the rest of the world (ROW). I distinguish between the EU15 and the REU because the EUROSTAT database is more precise for the first fifteen member states of the European Union. In addition, Bulgaria and Romania do not figure in the NUTS database. Finally, it is reasonable to think of the EU15 and REU as more homogenous economic macro-areas. The NUTS 1 geographical level is used to define production side variables. There are 68 NUTS 1 regions within the EU15. ROW and REU production variables continue to be defined at the macro-area geographical level.

Concerning sectoral aggregation, there are four sectors. A small number of sectors is preferable because the aim is not to assess trade policy effects with respect to a special sector but rather to understand general equilibrium effects of production reallocation across the NUTS 1 regions.

Table 2.1, Table 2.2 and Table 2.3 display chosen aggregations.

[2] 39 is a compromise based on different EUROSTAT tables which have been used in addition to the GTAP information incorporated into the NUTS 2 dataset.

Table 2.1: NUTS geographical level of aggregation (68 NUTS 1 regions)

	NUTS 1 regions
Austria	**East Austria, South Austria, West Austria**
Belgium	**Brussels Capital Region, Flemish Region, Walloon Region**
Denmark	**Denmark**
Finland	**Mainland Finland, Åland**
France	**Île-de-France, Parisian basin, Nord-Pas-de-Calais, East, West, South West, Centre East, Mediterranean**
Germany	**Baden-Wüttenberg, Bavaria, Berlin, Brandenburg, Bremen, Hamburg, Hessen, Mecklenburg-Vorpommern, Lower-Saxony, North Rhine-Westphalia, Rhineland-Palatinate, Saarland, Saxony, Saxony-Anhalt, Schleswig-Holstein, Thuringia**
Greece	**Voreia Ellada, Kentriki Ellada, Attica, Nisia Aigaiou-Kriti**
Ireland	**Ireland**
Italy	**North West, North East, Centre, South, Islands**
Luxembourg	**Luxembourg**
Netherlands	**North Netherlands, East Netherlands, West Netherlands, South Netherlands**
Portugal	**Portugal**
Spain	**North West, North East, Community of Madrid, Centre, East, South**
Sweden	**Sweden**
UK	**North East England, North West England, Yorkshire and the Humber, East Midlands, West Midlands, East of England, Greater London, South East England, South West England, Wales, Scotland, Northern Ireland**

Table 2.2: Macro-area geographical level of aggregation (three macro-areas)

Macro-areas	
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
REU	Bulgaria, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, Slovenia
ROW	Rest of the world

Table 2.3: Sectoral aggregation (four sectors)

Sectors	
AGM	Agriculture and minerals
PRM	Primary energy sources (petroleum, coal and gas)
IND	Manufactures
SERV	Services

2.4 The theoretical structure of the model

In this section the theoretical structure of the model is explained. The four main parts are identified: demand side, supply side, factor markets and macroeconomic closure. For notational conventions, list of variables, parameters and equations refer to the Appendixes at the end of the thesis.

2.4.1 Demand

As stated above, all demand variables are defined at the macro-area level mainly because of the lack of well-suited trade data among NUTS 1 regions and between

NUTS 1 regions and foreign countries. This implies that the price of each demand variable is equal for all the NUTS 1 regions. Unlike the DREAM-MIRAGE approach and for the sake of simplicity, trade-relationships are specified for the EU15 as whole and not by each single European country.

As in MIRAGE total demand is made up of final consumption, intermediate inputs and capital goods. In each macro-area a representative household chooses the optimal sectoral composition of its final consumption by maximising a LES-CES utility function subject to the household budget constraint.

The demand for capital goods in each sector is specified through a CES function. The intermediate inputs also enter in the production side, therefore this variable has been regionalized. However, the prices of the intermediate inputs are defined at the macro-area level.

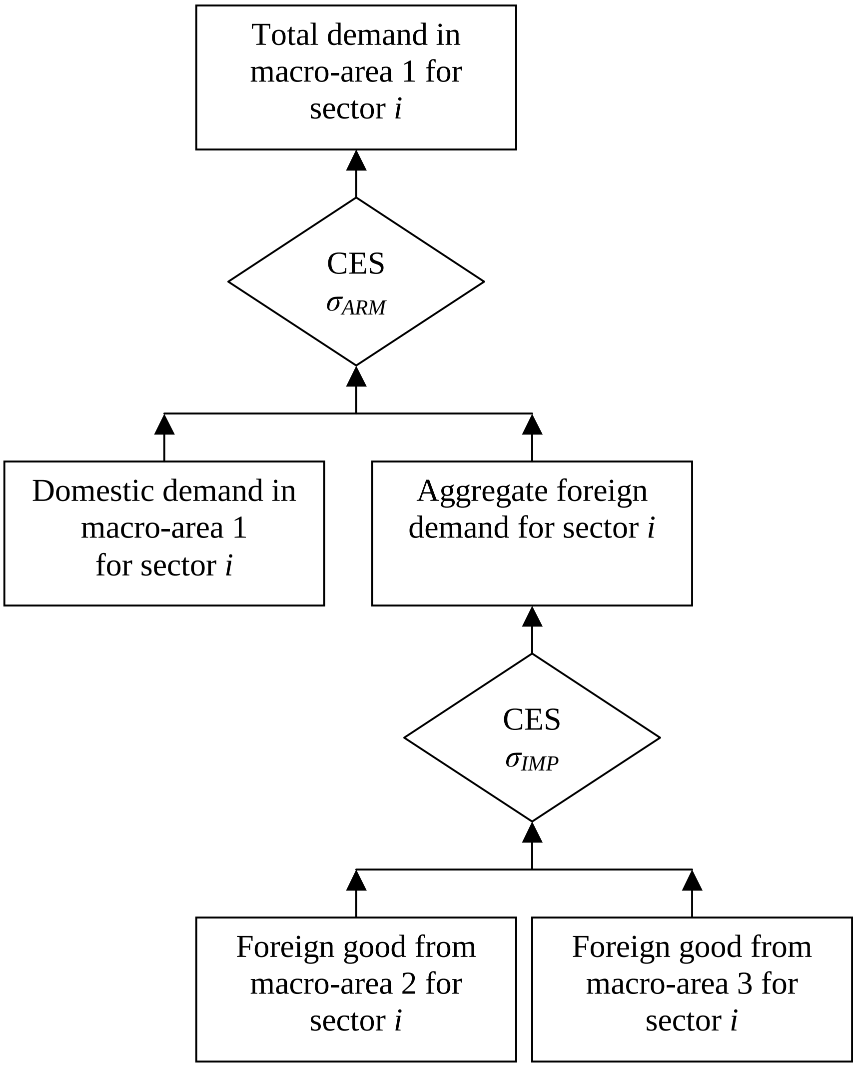
The standard Armington assumption is introduced. Product differentiation according to the macro-area geographical level of aggregation is modelled by a CES function.

As in MIRAGE, in each macro-area the representative household includes the government. The household pays and earns taxes so that the public budget constraint is implicit to meet its budget constraint. Any decrease in tax revenues (for example, as a consequence of trade liberalization) is assumed to be exactly compensated by a non-distorting replacement tax. The representative household owns the factor endowments.

The total demand at EU15 level is equal to the sum of the regional supplies at the NUTS level. As a result, it is supposed perfect substitutability across goods produced in different NUTS 1 regions (see Eq. (A.1) in the Appendix 4, List of Equations).

Figure 2.1 illustrates the demand structure in each sector and in each one of the three macro-areas. The rectangle shows the variable, the rhomb the functional form used; *i* represents general sectoral index, while σ_{ARM_i} and σ_{IMP_i} are, respectively, elasticity of substitution between domestic and foreign aggregate good and elasticity across foreign goods (see also Appendix 3, List of parameters).

Figure 2.1: Demand structure



2.4.2 Supply

The supply side is specified at the NUTS 1 level. Its structure is very similar to one used in the MIRAGE model, but the latter does not specify the production at the sub-national level.

In each one of the 68 NUTS 1 regions a representative firm maximises profits. It uses primary factors to obtain value added and intermediate inputs to obtain aggregate intermediate input. Value added and aggregate intermediate input are linked by a Leontief technology to produce output. Thus, perfect complementarity is assumed between value added and aggregate intermediate input.

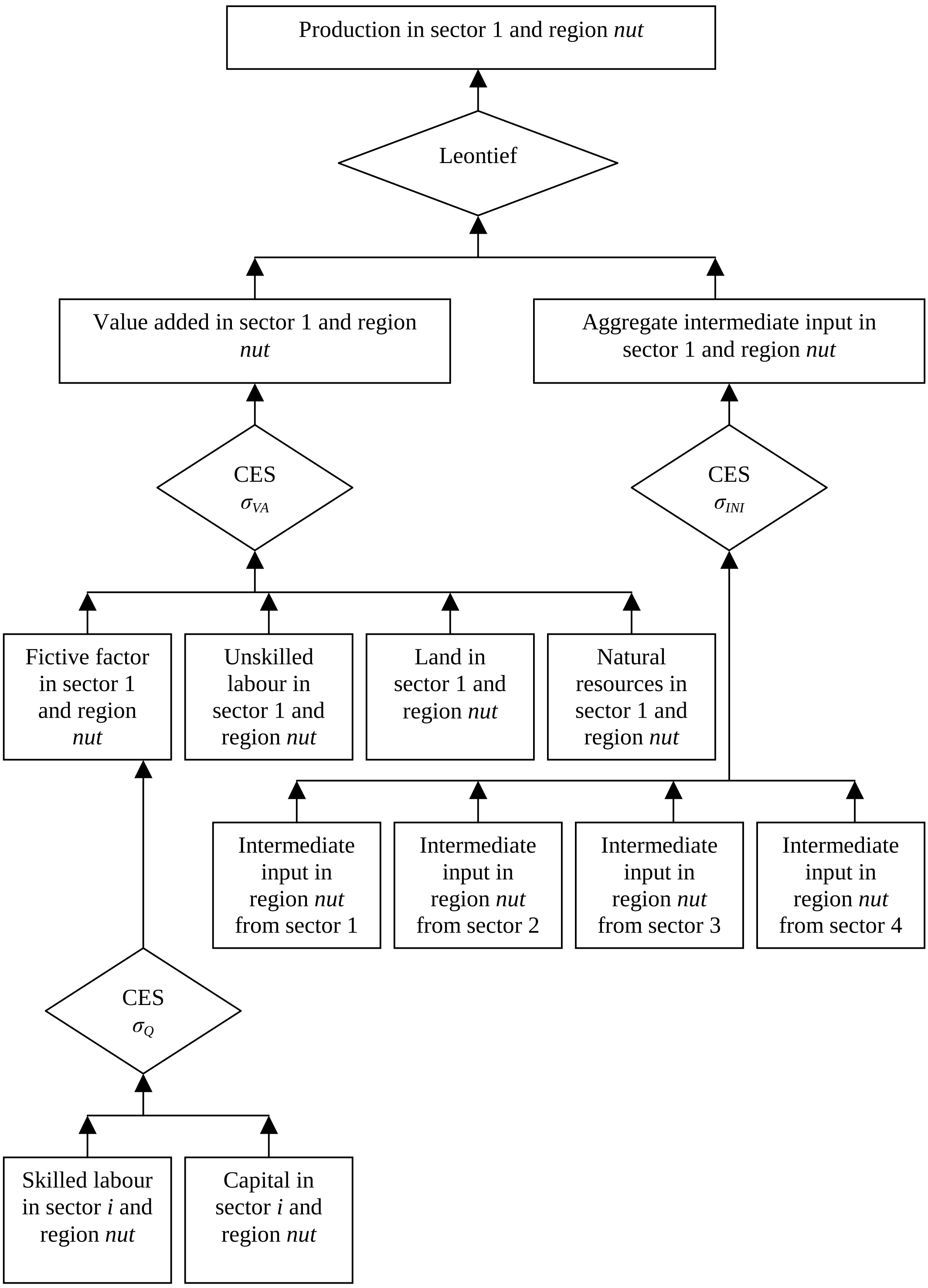
In every sector of each NUTS 1 region aggregate intermediate input is defined by a CES function among intermediate goods of all other sectors. Therefore, intermediate goods are used as intermediate inputs in the production side but they also enter in the demand side together with the final consumption and capital goods. For this reason the price of the intermediate inputs are at the macro-area level. This means that the all the NUTS 1 regions face the same price of the intermediate inputs within the EU15.

Concerning value added as in GTAP and MIRAGE models there are five primary factors: skilled labour, unskilled labour, capital, land and natural resources. The value added follows a two stage structure. At the first stage value added is given by a CES combination of land, natural resources, unskilled labour and a fictive factor. The latter is defined at the second stage. It is a bundle between capital and skilled labour; this modelling draws on MIRAGE and allows for the complementarity among the two primary factors which has been described in the empirical literature (Duffy, Papageorgiou and Perez-Sebastian, 2004). Therefore, as in MIRAGE, this implies that the elasticity of substitution between skilled labour and capital (σ_Q) is smaller than the elasticity of substitution between fictive factor and the other primary factors (σ_{VA}).

Perfect competition and constant returns to scale hold in all the sectors.

Figure 2.2 illustrates supply structure for each one of the 68 NUTS 1 regions and each one of the four sectors; *nut* represents the general index for the NUTS 1 region while σ_{VA}, σ_{INI} and σ_Q are, respectively, elasticity of substitution across primary factors, among intermediate inputs and between capital and skilled labour (see also Appendix 3, List of parameters). Sector 1 represents any of the four sectors.

Figure 2.2: Supply structure



2.4.3 Factor markets

Factor endowments are assumed to be fully employed.

Land and natural resources are immobile in each NUTS 1 region and in each sector. However, land is used only in agricultural sector and natural resources are only used in the agriculture and primary energy sources sectors.

Skilled and unskilled labour are perfectly mobile across the sectors. Concerning geographical labour mobility, in each macro-area skilled and unskilled workers maximise wage income subject to a CET (*Constant Elasticity of Transformation*) constraint. This implies imperfect mobility within the EU15 and different wages across the NUTS 1 regions.

Sensitivity analysis is conducted to test the relevance of the assumption about skilled/unskilled labour mobility; two different values (zero and ten) of the elasticity of migration in the CET function are simulated to analyse how the results of trade policy shock change at the NUTS 1 level by introducing labour mobility within the EU15.

The ROW and REU macro-areas are not divided into regions, thus it does not make sense to think about geographical unskilled/skilled labour mobility. Nevertheless, an integrated labour market within the EU27 can be considered. In this integrated labour market skilled and unskilled workers can move not only within the EU15 but also between the EU15 NUTS 1 regions and the rest of Europe (REU).

Unlike MIRAGE, capital supply is perfectly mobile across sectors and within each macro-area. It is then distributed among the sectors and the NUTS 1 regions according to the first order conditions for profit maximisation with respect to the capital factor.

2.4.4 Macro-economic closure

Macro-economic closure is neoclassical. Investment is savings-driven. It is determined by the income and the exogenous saving rate for the representative household in the macro-area. In equilibrium, the value of investment equals the value of total demand for capital goods.

The external current account balance is fixed, therefore the net flow of foreign income does not depend on a world interest rate. Unlike MIRAGE, the model does not take into account the role of FDI, which is useful to analyse especially in a dynamic set-up.

The model is static. As a result, no transitional dynamic is considered. Comparative static must be interpreted as medium or long-run effects because capital supply is perfectly mobile across sectors and within each macro-area, which are very large.

It is noteworthy to recall that income is defined at the macro-area level. Thus, the computation of welfare change by the standard equivalent variation measure cannot be carried out at the NUTS 1 level. As stated above, the focus of this work is on the production side, in particular the production reallocation across sectors at the NUTS 1 level.

2.5 Calibration

Calibration is a very important stage in the building of a CGE model. The calibration strategy is crucial as we saw in the first chapter because trade policy effects can be very sensitive to the value of the parameters.

In this model value added (*VA*), unskilled labour (*L*) and skilled labour (*H*) are taken from EUROSTAT database. Simplifying assumptions arise to determine the other variables of the production side. For this reason the repartition key of value added at the NUTS 1 level is used to regionalize the other production variables, according to the following formulas:

$$KEYVA_{i,nut} = \frac{VA_{i,nut}}{VA_{i,EU15}} \tag{2.4}$$

$$TE_{i,nut} = KEYVA_{i,nut} TE_{i,EU15} \quad (2.5)$$

$$RN_{i,nut} = KEYVA_{i,nut} RN_{i,EU15} \quad (2.6)$$

$$K_{i,nut} = KEYVA_{i,nut} K_{i,EU15} \quad (2.7)$$

$$INI_{j,i,nut} = KEYVA_{i,nut} INI_{j,i,EU15} \quad (2.8)$$

where *nut* represents the general index for the NUTS 1 region, *i* and *j* are sector indexes and *KEYVA* is the repartition key of value added; *TE*, *RN*, *K* and *INI* are, respectively, land, natural resources, capital and intermediate inputs (sold by sector *j* to sector *i*).[3] Eq. (2.8) implies an additional assumption for the intermediate inputs, i.e. the distribution of the intermediate inputs among the NUTS 1 regions in sector *i* does not depend on sector that sells the intermediate good.

It is reasonable to think that a greater valued added in the NUTS 1 region means a greater use of primary factors and intermediate inputs. However, this hypothesis neglects the fact that two equal NUTS 1 regions in terms of value added can use primary factors and intermediate inputs through different intensities, i.e. they can have different technologies. Data constraints force me to make this choice.

Thus, skilled and unskilled labour are the only two factors which preserve their original heterogeneity at the NUTS 1 level. In section 2.8 it will be shown that they are decisive for explaining trade policy effects.

All the variables and parameters are calibrated to reproduce the SAM in the base year (2001). Most of the parameters can be directly determined through the available data. However, for some such as the CES elasticities, this operation is not feasible and, therefore, I explicitly refer to the latest version of MIRAGE model (Decreux and Valin, 2007), which, in turn, draws elasticities from empirical literature or plausible assumptions.

[3] See also Appendix 1 and 2 at the end of the thesis for clarification about notation and variable definitions.

Final consumption, capital goods and intermediate inputs all have the same elasticity of substitution across sectors. Its value is 0.6 for all three variables.

The elasticity of substitution across unskilled labour, land, natural resources and fictive factor (σ_{VA}) is equal to 1.1 for all four sectors. The fictive factor is a combination between capital and skilled labour. As noted above, the fictive factor allows for skill labour/capital complementarity. For this reason the elasticity of substitution between skilled labour and capital (σ_{CAP}) is less than 1.1 and it is equal to 0.6.[4]

The elasticities of substitution between domestic and foreign aggregate good (σ_{ARM_i}), i.e. Armington elasticities, are drawn from the GTAP 6 database. The Armington elasticity and the elasticity of substitution across foreign goods (σ_{IMP_i}) are linked by the following relation:

$$\sigma_{IMP_i} - 1 = \sqrt{2}\left(\sigma_{ARM_i} - 1\right) \tag{2.9}$$

In the model the Armington elasticity is set exogenously and only depends on the sector; for agriculture it is equal to about 3.4, for primary energy sources 10.9, for manufactures 4.6 and for services 2.9. The elasticity of substitution across foreign goods is then calibrated residually using Eq. (2.9).

Another important parameter is the elasticity of migration in the CET function, which determines skilled and unskilled labour supplies in each NUTS 1 region. Putting this parameter equal to zero means perfect immobility at the NUTS 1 level. As the value increases, labour mobility within the EU15 increases.

In MIRAGE-DREAM the elasticity value of migration is chosen mainly on the basis of Eichengreen work (1993). Using a panel data analysis, Eichengreen finds that the elasticity of inter-regional migration with respect to unemployment and wage

[4] According to many studies (see Cahuc and Zylberberg for a survey, 1996) the elasticity of substitution between skilled labour or capital and unskilled labour is close to unity. However, Decreux *et al*. (2003) show that the true value of the parameter also depends on the level of sectoral aggregation.

differentials is smaller in the United Kingdom and Italy than that observed in the United States. This suggests that migration is less responsive to demand shocks in these European countries than in the United States.

A *Policy maker* is likely to be interested in labour reallocation across the NUTS 1 regions after a trade policy reform. Therefore, the elasticity of migration is a very interesting parameter. For this reason and unlike to MIRAGE-DREAM model, a sensitivity analysis has been conducted to test the relevance of this parameter for the determination of trade policy results. As a result, the parameter can assume two different values (zero and ten) according to the simulated scenario.

The numeraire is the utility price of the representative household in the ROW macro-area.

2.6 Trade policy simulation

CGE models are widely used to simulate scenarios of trade policy liberalization, for example in the Uruguay and Doha rounds. The latter is the current trade negotiations of the WTO. Its objective is to lower trade barriers around the world to help the development of the international trade. The Doha round started in 2001 and it still has not been accomplished.

Doha negotiations can be very complex. Indeed, the agreement must be accepted by all 153 WTO members (unanimity principle) and tariff cuts are harmonised in order to reduce trade distortions among countries.[5] In addition, the WTO fully recognizes the heterogeneity among its members; therefore no commitment is required from the least developed countries and less commitment is expected from the middle income countries. This means smaller rate cuts for tariffs and subsidies and longer implementation periods.

My model does not try to exactly simulate scenarios of trade policy liberalization in the current Doha round. The main objective is to shed light on possible outcomes

[5] For example, the so-called Swiss formula tends to cut higher tariff rates more than lower ones, since the latter are supposed to be less trade-distorting.

of global trade liberalization at the NUTS 1 level and to interpret the results. As noted above, the focus in on the production side.

I start from MIRAGE to model trade barriers. The picture of trade barriers is rich in the latest version of MIRAGE (Decreux and Valin, 2007).

The market access measure stems from the MAcMap database.[6] Domestic supports on land and output are also introduced; they are assumed to be proportional to the volume of output or factor. Production quotas are considered; they generate rents.

MIRAGE also introduces a price intervention mechanism to give more realism to the European agricultural trade policy and to make exportation subsidies endogenous. Basically three options are possible. When internal prices are higher than the intervention price (first option), no export support is given. When internal prices are lower than the intervention price (second option), producers receive subsidies to sustain production prices at the intervention level. Finally, an equation in the model forces the subsidies for exports to stay below the WTO ceiling (third option). For countries other than those in the European Union the export subsidy rate is set exogenously.

In my model the rich picture of trade barriers is put aside and attention is focused on the market access measure. This was done for two reasons: first, to preserve the simplicity of the model in order to be able to better interpret its outcomes at the NUTS 1 level, second, to make the most of the MAcMap database.

MAcMap (Bouet *et al*., 2004) is the most comprehensive tariff database currently available. It was expressly created for CGE trade models. As stated above, MAcMap provides a good measure of market access. This measure is a consistent *ad valorem* equivalent of specific tariffs, *ad valorem* tariffs and tariff quotas. Moreover, this dataset allows for preferential agreements, preserving the information at the bilateral level. Before the creation of the MAcMap database, assessment of multilateral trade policy liberalization was carried out without taking into account specific tariff nor preferential agreements.

[6] Market access for goods in the WTO consists of tariff and non-tariff measures. Non-tariff measures concern specific WTO agreements, such as the Agreement on Sanitary and Phytosanitary Trade Regulations. In this thesis it is supposed that market access only concerns tariffs.

A good point for CGE modellers and researchers is the special procedure, which is designed to limit the extension of the bias occurring when tariffs are aggregated according to the nomenclature chosen for the CGE analysis. In fact, in CGE trade models every sector aggregates a number of products. If one product is protected by a prohibitive tariff, it will probably be aggregated with products, with lower protection and significant initial imports. The average tariff computed for the sector would lead to overstate the impact of a tariff cut. Alternatively, the method consisting in using an import-weighted average suffers from a serious problem of endogeneity because the higher the tariff the lower the import flow. Using instead world imports as a weighting scheme, as proposed by Leamer (1974), avoids the endogeneity but fails to account for the specificity of each economy.

The solution adopted in MAcMap is a compromise between the need to avoid the endogeneity and the need to consider the specificity of each economy. Basically, imports from a reference group of similar countries are used as weights for the tariffs. Five groups of similar countries are identified according to a PPP GDP and a trade openness criteria. Total import by a group has to be normalized to account for the size of each economy.

The 2004 version of MAcMap is incorporated in the GTAP 6 database; the base year is 2001. The most recent version of MAcMap (see Boumellassa, Laborde and Mitaritonna, 2009) is used in GTAP 7; the base year is 2004. In my model GTAP 6 is used, thus the older version of the MAcMap database. However, global market access has not changed substantially from 2001 to 2004 mainly because the Doha round is still ongoing. Overall average tariff protection has decreased by 0.5 % from 5.6 % in 2004 to 5.1% in 2001. This reduction is primarily due to the middle income countries, which had to achieve their Uruguay round commitments within 2004 and to unilateral liberalizations.[7]

According to the MAcMap database and its *ad valorem* equivalent measure, the market access is the following in 2001. Agriculture is the most protected sector. The world average is 19.1%. Average agricultural protection ranges from 2.7% in

[7] China and India, for example, unilaterally cut tariffs for their industrial products to complete their WTO accession.

Australia to 59.6% in India. Manufacturing products outside textile and apparel are the least protected sector on average (4.2%). However, tariffs are low in developed countries but remain high in developing country. Tariffs in the textile and apparel sectors are also high in both developed and developing countries. Service market access is a problematic concept, since explicit tariffs do not exist. Sometimes equivalent tariffs for services are estimated using gravity equations. In my approach I only consider explicit tariffs.

Table 2.4 shows the *ad valorem* tariff rate for the geographical and sectoral nomenclature chosen in my model. Basically, the parameter enters in the demand side by the following equation:

$$PDEM_{i,mac,mac*} = PY_{i,mac} \cdot \left(1 + ATR_{i,mac,mac*}\right) \tag{2.10}$$

where *PDEM* is the price for the good *i* produced in the macro-area *mac* and paid by the macro-area *mac**, *PY* is the price (marginal cost) for the good *i* produced in macro-area *mac* and the parameter *ATR* is the *ad valorem* tariff rate applied by the macro-area *mac** and paid by the macro-area *mac* for the good *i*. Table 2.4 confirms the previous facts about trade barriers.[8] Since the agricultural sector is the most protected one, I decide to implement a multilateral tariff liberalization in agriculture. Therefore, all the *ad valorem* tariff rates are set to zero in the agricultural sector for all the macro-areas (values in bold in Table 2.4).

As noted at the beginning of this section, the trade policy simulation does not try to reproduce the current Doha round. Especially for the market access in the agricultural sector the definition of the tariff reduction involves very technical issues, such as the formula adopted for the cuts, the definition of the “sensitive products”, which are partly excluded from the general tariff reduction, and the commitments for the developing countries (Anania and Bureau, 2005).

[8] Not surprisingly, tariff barriers appear between EU15 and the rest of Europe, as 12 countries were not European members in 2001.

Consequently, the trade policy simulation in this model has to be interpreted as an illustrative exercise on the possible effects at the NUTS 1 level of a multilateral tariff liberalization in agriculture.

The role of export subsidies and domestic supports in agricultural trade liberalization is not assessed. However, it can be useful to recall a study of Hertel and Keeney (2005). The authors use the GTAP model to simulate a full liberalization of the agricultural sector by high-income countries. According to this work, full liberalization of agricultural sector determines an overall $47.6 billion gain. More than 90% of the benefits come from improved market access, i.e. the removal of the *ad valorem* equivalent tariffs, while the impact of supports and export subsidies is limited.[9]

Even if this model is used to assess tariff liberalization in agriculture, it can be applied to other sectors according to the special interest of the researcher.

Table 2.4: *Ad valorem* tariff rates

		ROW	EU15	REU
AGM	ROW	**14.73%**	**5.27%**	**5.65%**
AGM	EU15	**10.70%**		**10.37%**
AGM	REU	**12.69%**	**4.95%**	**6.11%**
PRM	ROW	1.64%		0.20%
PRM	EU15	0.01%		0.00%
PRM	REU	0.30%		0.88%
IND	ROW	5.10%	2.83%	6.85%
IND	EU15	6.10%		3.38%
IND	REU	6.97%	0.76%	3.97%

Notes: the second column shows macro-area paying tariff, the first row macro-area applying tariff.
Source: GTAP 6 database.

[9] Hertel and Keeney use MACMAP database for tariff barriers and OECD estimates for producer support in agriculture. The authors use data assembled by Aziz Elbehri of the U.S. Department of Agriculture's Economic Research Service for export subsidies. All the datasets are incorporated in GTAP 6 having 2001 as the reference year.

2.7 Simulation results

In this section the results of trade policy simulation (world agriculture liberalization) are presented. GAMS software and the CONOPT 3 algorithm are used; there are 5197 equations and 5197 variables.

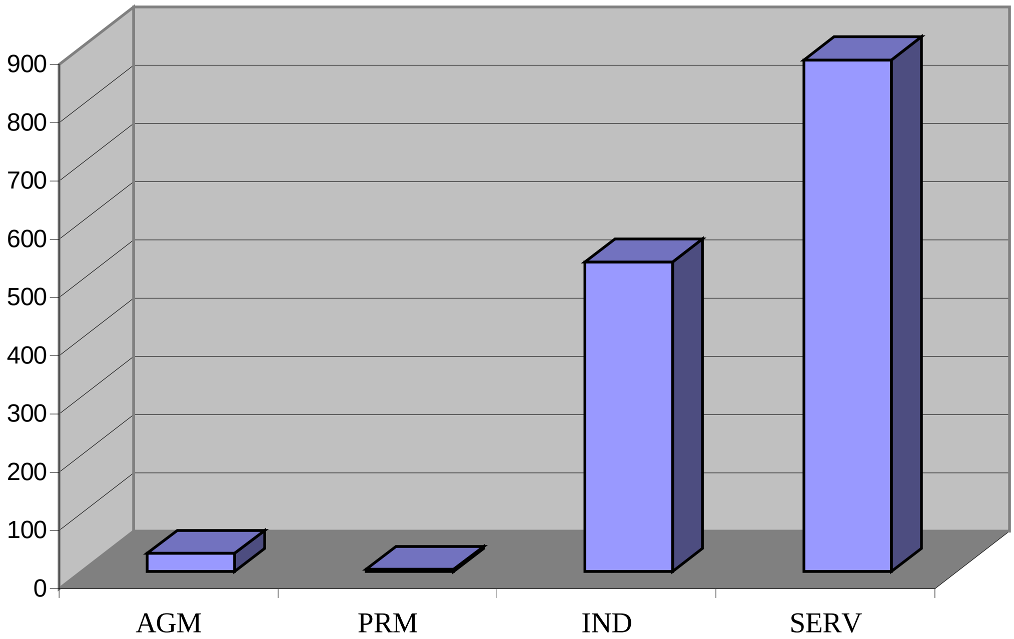
In subsection 2.7.1 the production reallocation in volume across sectors in the NUTS 1 regions is shown. In subsection 2.7.2 the impact of unskilled/skilled labour mobility on the results of previous subsection is assessed. Finally, in subsection 2.7.3 further interesting results such as unskilled/skilled labour migration within Europe and the change in total value added at the NUTS 1 level are illustrated; the changes in the trade patterns and welfare are also displayed at the macro-area level.

2.7.1 Production reallocation across sectors in the NUTS 1 regions after a world trade liberalization in the agricultural sector

In this section the results are shown regarding the production reallocation in volume across the four sectors in each of the 68 NUTS 1 region within the EU15 after a world trade liberalization in agricultural sector. In order to have an overview of the sectoral weight in the EU15 the value of each sector in 2001 (the base year in GTAP 6) is reported in *Figure 2.3*. Not surprisingly, services (SERV) is the most important sector (more than 2001 $8000 billion), followed by manufactures (IND) and the agricultural sector (AGM). The weight of primary energy sources is very small.

The results of this subsection are obtained under the assumption of unskilled/skilled labour immobility at the NUTS 1 level, i.e. workers have to stay in the NUTS 1 region to which they belong. This hypothesis is formalized by assuming that the elasticity of migration in the CET functions (see Appendix 4) is equal to zero, and denoting with the σ_L and σ_H, respectively, the elasticity of migration for the unskilled factor and skilled factor.

Figure 2.3: Production by sector in the EU15 macro-area



Source: GTAP 6 database.
Notes: Tens of $ billion in 2001 .

Before showing results at the NUTS 1 level, simulated effects of liberalization at the macro-area level are reported in Table 2.5. In the EU15 the AGM sector is affected the most, the production decreases in volume by about 1%. Variations are small in the other sectors and macro-areas. Thus, it is interesting to assess if reallocation effects are more important at the NUTS 1 level.

Table 2.5: % Production change in volume at the macro-area level

	ROW	EU15	REU
AGM	0.32%	-0.93%	-0.58%
PRM	-0.10%	0.07%	0.01%
IND	0.01%	0.00%	0.05%
SERV	-0.02%	0.05%	0.04%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 2.6 reports these effects for each one of the 68 NUTS regions. At first glance, it appears that positive and negative magnitudes are higher than the ones observed at the macro-area level. In addition, the changes are negative for all the NUTS 1 regions in the agricultural sector and both negative and positive in manufactures and services.

Table 2.6: % Production change in volume at the NUTS 1 level

	AGM	PRM	IND	SERV
North Netherlands (Netherlands)	-0.81%	0.05%	0.60%	-0.18%
East Netherlands (Netherlands)	-0.86%	0.05%	0.36%	-0.11%
West Netherlands (Netherlands)	-0.77%	0.05%	0.56%	-0.11%
South Netherlands (Netherlands)	-0.91%	0.06%	0.61%	-0.26%
Sweden	-0.86%	0.07%	0.15%	-0.06%
Denmark	-0.83%	0.05%	0.10%	-0.02%
Mainland Finland (Finland)	-0.86%	0.08%	0.08%	-0.03%
Åland (Finland)	-0.84%	0.05%	-0.36%	0.07%
Ireland	-2.15%	0.06%	7.02%	-2.31%
North East England (United Kingdom)	-0.76%	0.07%	-0.23%	0.06%
North West England (United Kingdom)	-0.72%	0.10%	-0.51%	0.14%
Yorkshire and the Humber (United Kingdom)	-0.71%	0.08%	-0.35%	0.10%
East Midlands (United Kingdom)	-0.74%	0.07%	-0.24%	0.09%
West Midlands (United Kingdom)	-0.76%	0.07%	-0.29%	0.10%
East of England (United Kingdom)	-0.74%	0.13%	-0.55%	0.13%
Greater London (United Kingdom)	-0.76%	0.06%	-0.73%	0.06%
South East England (United Kingdom)	-1.00%	0.11%	-0.28%	0.05%
South West England (United Kingdom)	-0.80%	0.07%	-0.29%	0.07%
Wales (United Kingdom)	-0.94%	0.07%	-0.04%	0.02%
Scotland (United Kingdom)	-0.82%	0.08%	-0.24%	0.05%
Northern Ireland (United Kingdom)	-1.10%	0.08%	0.89%	-0.18%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

cont Table 2.6: % Production change in volume at the NUTS 1 level

	AGM	PRM	IND	SERV
East Austria (Austria)	-1.74%	0.06%	2.40%	-0.59%
South Austria (Austria)	-2.47%	0.06%	2.99%	-1.15%
West Austria (Austria)	-1.95%	0.06%	1.55%	-0.63%
Baden-Württemberg (Germany)	-0.83%	0.09%	-0.30%	0.23%
Bavaria (Germany)	-0.90%	0.10%	-0.14%	0.09%
Berlin (Germany)	-0.76%	0.08%	-0.60%	0.11%
Brandenburg (Germany)	-0.92%	0.11%	-0.48%	0.14%
Bremen (Germany)	-0.73%	0.00%	-0.37%	0.14%
Hamburg (Germany)	-0.76%	0.08%	-0.50%	0.11%
Hessen (Germany)	-0.78%	0.10%	-0.47%	0.20%
Mecklenburg-Vorpommern (Germany)	-1.19%	0.09%	2.10%	-0.50%
Lower Saxony (Germany)	-0.79%	0.10%	-0.29%	0.13%
North Rhine-Westphalia (Germany)	-0.78%	0.10%	-0.35%	0.16%
Rhineland-Palatinate (Germany)	-0.83%	0.10%	-0.21%	0.11%
Saarland (Germany)	-0.76%	0.10%	-0.37%	0.19%
Saxony (Germany)	-0.87%	0.11%	-0.33%	0.14%
Saxony-Anhalt (Germany)	-0.79%	0.11%	-0.46%	0.15%
Schleswig-Holstein (Germany)	-0.81%	0.09%	-0.45%	0.15%
Thuringia (Germany)	-0.83%	0.11%	-0.38%	0.19%
Luxembourg	-1.10%	0.05%	1.06%	-0.27%
Brussels-Capital Region (Belgium)	-1.06%	0.06%	1.94%	-0.27%
Flemish Region (Belgium)	-0.94%	0.06%	0.29%	-0.11%
Walloon Region (Belgium)	-0.96%	0.07%	0.32%	-0.08%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

cont Table 2.6: % Production change in volume at the NUTS 1 level

	AGM	PRM	IND	SERV
Portugal	-1.47%	0.10%	-0.69%	0.47%
North West (Spain)	-0.89%	0.09%	-0.46%	0.21%
North East (Spain)	-0.78%	0.07%	-0.59%	0.39%
Community of Madrid (Spain)	-0.79%	0.09%	-1.15%	0.27%
Centre (Spain)	-0.85%	0.09%	-0.10%	0.11%
East (Spain)	-0.77%	0.08%	-0.84%	0.43%
South (Spain)	-0.85%	0.08%	-0.45%	0.15%
Voreia Ellada (Greece)	-1.10%	0.08%	0.17%	0.10%
Kentriki Ellada (Greece)	-0.93%	0.07%	-0.35%	0.30%
Attica (Greece)	-1.44%	0.07%	-1.38%	0.47%
Nisia Aigaiou-Kriti (Greece)	-0.55%	0.07%	-7.62%	1.62%
North West (Italy)	-0.78%	0.05%	-0.29%	0.20%
North East (Italy)	-0.81%	0.07%	-0.30%	0.23%
Centre (Italy)	-0.88%	0.07%	-0.25%	0.10%
South (Italy)	-1.08%	0.07%	0.04%	0.04%
Islands (Italy)	-0.97%	0.08%	0.02%	0.03%
Île-de-France (France)	-0.92%	0.07%	0.01%	-0.02%
Parisian basin (France)	-0.73%	0.09%	-0.20%	0.10%
Nord-Pas-de-Calais (France)	-0.82%	0.17%	-0.13%	0.05%
East (France)	-0.78%	0.07%	-0.17%	0.09%
West (France)	-0.81%	0.06%	0.01%	0.03%
South West (France)	-0.84%	0.06%	-0.10%	0.05%
Centre East (France)	-0.91%	0.09%	-0.23%	0.11%
Mediterranean (France)	-0.78%	0.07%	-0.60%	0.11%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

In Tables 2.7, 2.8 and 2.9 attention is focused on the ten greatest (positive and negative) changes in the AGM, IND and SERV sectors. PRM is neglected because the variations are generally small and the overall weight is not relevant in the EU15 economy.

Summarizing, South Austria and Ireland display, at the same time, the greatest decrease in agriculture, 2.47% and 2.15%, respectively, the highest increase in manufactures, 2.99% and 7.02%, respectively and the greatest decrease in services, 1.15% and 2.31%, respectively. In contrast, Nisia Aigaiou-Kriti (Greece) and Attica (Greece) have the greatest decrease in the IND sector (7.62% and 1.38%) but the greatest increase in the SERV sector (1.62% and 0.47%).

Using the MIRAGE-DREAM model and simulating a full agricultural liberalization (domestic support and export subsidies included), Jean and Laborde (2004) find that Ireland, Portugal, the NUTS 1 regions of Greece except Athens area, Central and Southern Spain and Southern Italy experience the greatest decreases of agricultural value added in volume.

Consistent with the previous results, in this model the ten strongest production decreases in the AGM sector include Voreia Ellada (Greece), Portugal and Ireland but also Austrian NUTS 1 regions are affected by the shock.

However, in the Jean and Laborde approach (2004) unskilled and skilled labour is imperfectly mobile within each European country of the EU25 and no alternative scenario is given. For this reason in the next subsection the role carried out by the labour mobility is looked at in-depth.

Table 2.7: The ten greatest % production decreases in volume at the NUTS 1 level

	AGM
South Austria (Austria)	-2.47%
Ireland	-2.15%
West Austria (Austria)	-1.95%
East Austria (Austria)	-1.74%
Portugal	-1.47%
Attica (Greece)	-1.44%
Mecklenburg-Vorpommern (Germany)	-1.19%
Northern Ireland	-1.10%
Luxembourg	-1.10%
Voreia Ellada (Greece)	-1.10%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 2.8: The ten greatest % production increases or decreases in volume at the NUTS 1 level

	IND
Nisia Aigaiou-Kriti (Greece)	-7.62%
Attica (Greece)	-1.38%
Community of Madrid (Spain)	-1.15%
Luxembourg	1.06%
West Austria (Austria)	1.55%
Brussels-Capital Region (Belgium)	1.94%
Mecklenburg-Vorpommern (Germany)	2.10%
East Austria (Austria)	2.40%
South Austria (Austria)	2.99%
Ireland	7.02%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 2.9: The ten greatest % production increases or decreases in volume at the NUTS 1 level

	SERV
Ireland	-2.31%
South Austria (Austria)	-1.15%
West Austria (Austria)	-0.63%
East Austria (Austria)	-0.59%
Mecklenburg-Vorpommern (Germany)	-0.50%
North East (Spain)	0.39%
East (Spain)	0.43%
Portugal	0.47%
Attica (Greece)	0.47%
Nisia Aigaiou-Kriti (Greece)	1.62%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

2.7.2 Sensitivity analysis on production reallocation with the introduction of unskilled/skilled labour mobility

In this scenario it is supposed that skilled and unskilled workers can respond to trade policy shock by moving from the NUTS 1 region, to which they belong. There are two possible options. In the first one EU15 workers can move only towards other NUTS 1 region within the EU15. In the second option, EU15 workers and REU workers can move within the EU27. As explained in the section 2.4.3, the unskilled/skilled labour mobility is modelled through a CET function in which σ_L and σ_H represent the elasticity of migration for unskilled factor and skilled factor, respectively. In the first option these parameters refer to the EU15 labour market while in the second option they refer to the EU27 labour market.

Jean and Laborde (2004) use elasticity of migration based on Eichengreen work (1993). As stated above, Eichengreen draws the value of this parameter from data of the United Kingdom and Italy and no distinction is made between unskilled and skilled labour. To the best of my knowledge no specific econometric estimates exist to calibrate unskilled/skilled elasticity of migration for the EU15 and the EU27 in CGE models. Therefore, a sensitivity analysis was carried out to evaluate the impact of the labour mobility hypothesis on trade policy results. As a result, the elasticity values of migration (σ_L and σ_H) are set to 10. Thus, the scenario of previous subsection, characterised by unskilled/skilled labour immobility at the NUTS 1 level, can be compared with the present one, characterised by high mobility within the EU15 or the EU27.

Table 2.10 reports results for production change in volume at the macro-area level under the assumption of unskilled/skilled labour mobility across the NUTS 1 regions within the EU15. The results in Table 2.10 compared to those in Table 2.5 confirm that the AGM is the most affected sector in the EU15 macro-area even if the percent change (-0.76%) is less in magnitude than in the case of labour immobility. The economic responses in services and manufactures remain about the same except for the EU15 manufactures, which are characterised by an increase of 0.13%.

Table 2.10: % Production change in volume at the macro-area level

	ROW	EU15	REU
AGM	0.32%	-0.76%	-0.57%
PRM	-0.07%	0.16%	0.05%
IND	0.01%	0.13%	0.05%
SERV	-0.02%	0.08%	0.04%

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 2.11, Table 2.12 and Table 2.13 display the results of the ten greatest (positive and negative) changes in the AGM, IND and SERV sectors at the NUTS 1 level.

According to Table 2.11, the Austrian agricultural sector is the most stricken because all three of its NUTS 1 regions (South Austria, West Austria and East Austria) are in the first three position of the ranking, however the changes are not great (between 1% and 2%).

In contrast, Table 2.12 and Table 2.13 show a very strong reallocation of production in manufactures and services with inverse patterns for some NUTS 1 regions. Indeed, two Greek NUTS 1 regions, Nisia Aigaiou-Kriti and Kentriki Ellada, have the highest positive values for production change in services, 18.64% and 7.53%, respectively, and the greatest negative values for production change in manufactures, -90.00% and -21.04%, respectively. Conversely, Luxembourg and Ireland have the highest positive values for production change in manufactures, 23.33% and 31.40%, respectively, and the greatest negative values for production change in services, -6.06%and -11.09%, respectively. These results do not intend to be realistic because the labour mobility is likely to be too high, but they are a guide to the relevance of the assumption about labour mobility.

Table 2.11: The ten greatest % production decreases in volume at the NUTS 1 level

	AGM
South Austria (Austria)	-1.72%
West Austria (Austria)	-1.43%
East Austria (Austria)	-1.28%
Ireland	-1.28%
Portugal	-1.27%
Attica (Greece)	-1.22%
Voreia Ellada (Greece)	-0.95%
Luxembourg	-0.94%
South (Italy)	-0.91%
Islands (Italy)	-0.82%

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 2.12: The ten greatest % production increases or decreases in volume at the NUTS 1 level

	IND
Nisia Aigaiou-Kriti (Greece)	-90.00%
Kentriki Ellada (Greece)	-21.04%
Attica (Greece)	-10.24%
Portugal	-9.51%
Île-de-France (France)	10.93%
East Austria (Austria)	11.19%
West Netherlands (Netherlands)	11.23%
Brussels Capital Region (Belgium)	17.87%
Luxembourg	23.33%
Ireland	31.40%

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 2.13: The ten greatest % production increases or decreases in volume at the NUTS 1 level

	SERV
Ireland	-11.09%
Luxembourg	-6.06%
East Austria (Austria)	-3.19%
North East (Spain)	2.99%
East (Spain)	3.25%
Voreia Ellada (Greece)	3.41%
Attica (Greece)	3.56%
Portugal	5.61%
Kentriki Ellada (Greece)	7.53%
Nisia Aigaiou-Kriti (Greece)	18.64%

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 2.14 reports the results for production change in volume at the macro-area level under the assumption of unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$). Table 2.14 confirms the results of Table 2.10 with the exception of the REU macro-area, which takes advantage of the integrated labour market within the EU27. Indeed, with respect to Table 2.10 the Rest of Europe shows a lesser AGM decrease (-0.46%) and a greater IND and SERV increase (0.17% and 0.14%).

Table 2.14: % Production change in volume at the macro-area level

	ROW	EU15	REU
AGM	0.32%	-0.76%	-0.46%
PRM	-0.06%	0.16%	0.15%
IND	0.01%	0.13%	0.17%
SERV	-0.02%	0.08%	0.14%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

Table 2.15, Table 2.16 and Table 2.17 display the results of the ten greatest (positive and negative) changes in the AGM, IND and SERV sectors for the 68 NUTS 1 regions. The results of these three tables do not significantly change with respect to Tables 2.11, 2.12 and 2.13.

Table 2.15: The ten greatest % production decreases in volume at the NUTS 1 level

	AGM
South Austria (Austria)	-1.74%
West Austria (Austria)	-1.44%
Ireland	-1.30%
East Austria (Austria)	-1.29%
Portugal	-1.27%
Attica (Greece)	-1.22%
Voreia Ellada (Greece)	-0.94%
Luxembourg	-0.94%
South (Italy)	-0.91%
Islands (Italy)	-0.81%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

Table 2.16: The ten greatest % production increases or decreases in volume at the NUTS 1 level

	IND
Nisia Aigaiou-Kriti (Greece)	-95.00%
Kentriki Ellada (Greece)	-21.28%
Attica (Greece)	-10.46%
Portugal	-9.65%
Île-de-France (France)	10.79%
West Netherlands (Netherlands)	11.24%
East Austria (Austria)	11.67%
Brussels Capital Region (Belgium)	18.23%
Luxembourg	23.34%
Ireland	32.84%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

Table 2.17: The ten greatest % production increases or decreases in volume at the NUTS 1 level

	SERV
Ireland	-11.60%
Luxembourg	-6.08%
East Austria (Austria)	-3.34%
South Netherlands (Netherlands)	-3.05%
East (Spain)	3.29%
Voreia Ellada (Greece)	3.48%
Attica (Greece)	3.61%
Portugal	5.65%
Kentriki Ellada (Greece)	7.60%
Nisia Aigaiou-Kriti (Greece)	19.64%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

2.7.3 Further interesting results

In this subsection further interesting results of trade policy simulation are presented. The *policy maker* is likely to be interested in labour reallocation across the NUTS 1 region after the agricultural liberalization. For this reason in Tables 2.18 and 2.19 migration results are reported for unskilled and skilled labour levels, respectively, under the assumption of unskilled/skilled labour mobility across the NUTS 1 regions within the EU15.

Table 2.18: Unskilled labour migration within the EU15

	Change in *L* supply
Ireland	1.29%
Luxembourg	0.67%
Brussels Capital Region (Belgium)	0.55%
Île-de-France (France)	0.41%
South Netherlands (Netherlands)	0.36%
West Netherlands (Netherlands)	0.35%
East Austria (Austria)	0.31%
North Netherlands (Netherlands)	0.28%
East Netherlands (Netherlands)	0.24%
Brandenburg (Germany)	-0.27%
Community of Madrid (Spain)	-0.28%
Voreia Ellada (Greece)	-0.32%
South (Spain)	-0.32%
Centre (Spain)	-0.33%
North West (Spain)	-0.33%
Attica (Greece)	-0.37%
North East (Spain)	-0.37%
East (Spain)	-0.39%
Kentriki Ellada (Greece)	-0.55%
Nisia Aigaiou-Kriti (Greece)	-0.96%

Notes: The 20 greatest % increases or decreases in unskilled labour supply (σ_L = 10).

Table 2.19: Skilled labour migration within the EU15

	Change in *H* supply
Portugal	2.00%
Nisia Aigaiou-Kriti (Greece)	1.90%
Kentriki Ellada (Greece)	1.11%
Attica (Greece)	0.77%
Voreia Ellada (Greece)	0.67%
East (Spain)	0.49%
Centre (Spain)	0.44%
North West (Spain)	0.44%
South (Spain)	0.41%
North East (Spain)	0.40%
Brandenburg (Germany)	0.39%
East Netherlands (Netherlands)	-0.41%
North Netherlands (Netherlands)	-0.44%
East Austria (Austria)	-0.51%
South Netherlands (Netherlands)	-0.57%
West Netherlands (Netherlands)	-0.59%
Brussels Capital Region (Belgium)	-0.67%
Île-de-France (France)	-0.74%
Ireland	-1.55%
Luxembourg	-1.73%

Notes: The 20 greatest % increases or decreases in skilled labour supply ($\sigma_H = 10$).

It is interesting to note that the NUTS 1 regions displaying the highest sectoral production reallocation also show the highest levels of unskilled/skilled labour reallocation. The labour reallocation follows an inverse pattern in these NUTS 1 regions according to their sectoral specialisation. For example, Ireland and Luxembourg absorb unskilled labour because they increase production in the IND sector and decrease production in the SERV sector after the trade shock while Kentriki Ellada and Nisia Aigaiou-Kriti absorb skilled labour because they decrease production in the IND sector and increase production in the SERV sector. Basically, the results do not change with the integrated labour market within the EU27 for the NUTS 1 regions, as it is shown in Tables 2.20 and 2.21. However, it can be noted that the REU experiences an unskilled/skilled labour immigration.

Table 2.20: Unskilled labour migration within the EU27

	Change in *L* supply
REU (Rest of Europe)	0.24%
Ireland	1.34%
Luxembourg	0.66%
Brussels Capital Region (Belgium)	0.56%
Île-de-France (France)	0.40%
South Netherlands (Netherlands)	0.35%
West Netherlands (Netherlands)	0.34%
East Austria (Austria)	0.31%
North Netherlands (Netherlands)	0.27%
Mecklenburg-Vorpommern (Germany)	0.24%
Brandenburg (Germany)	-0.28%
Community of Madrid (Spain)	-0.30%
South (Spain)	-0.34%
Centre (Spain)	-0.34%
Voreia Ellada (Greece)	-0.34%
North West (Spain)	-0.35%
North East (Spain)	-0.39%
Attica (Greece)	-0.39%
East (Spain)	-0.41%
Kentriki Ellada (Greece)	-0.57%
Nisia Aigaiou-Kriti (Greece)	-1.03%

Notes: The 20 greatest % increases or decreases in unskilled labour supply (σ_L = 10). REU change in unskilled labour supply is also included.

Table 2.21: Skilled labour migration within the EU27

	Change in *H* supply
REU (Rest of Europe)	0.16%
Portugal	2.00%
Nisia Aigaiou-Kriti (Greece)	1.98%
Kentriki Ellada (Greece)	1.11%
Attica (Greece)	0.77%
Voreia Ellada (Greece)	0.67%
East (Spain)	0.49%
Centre (Spain)	0.44%
North West (Spain)	0.44%
South (Spain)	0.41%
North East (Spain)	0.41%
Brandenburg (Germany)	0.37%
East Netherlands (Netherlands)	-0.42%
North Netherlands (Netherlands)	-0.45%
East Austria (Austria)	-0.55%
South Netherlands (Netherlands)	-0.58%
West Netherlands (Netherlands)	-0.60%
Brussels Capital Region (Belgium)	-0.68%
Île-de-France (France)	-0.74%
Ireland	-1.62%
Luxembourg	-1.74%

Notes: The 20 greatest % increases or decreases in skilled labour supply ($\sigma_H = 10$). REU change in skilled labour supply is also included.

Welfare analysis cannot be carried out at the macro-area level. Therefore, a Laspeyres index is used to evaluate the percent change in the overall value added at the NUTS 1 level. Table 2.22, 2.23 and 2.24 display value added changes corresponding to the three different scenarios about labour mobility.

Table 2.22: The 20 greatest % value added increases or decreases within the EU15

	Change
Ireland	0.45%
Nisia Aigaiou-Kriti (Greece)	0.28%
Attica (Greece)	0.06%
Mecklenburg-Vorpommern (Germany)	0.06%
Portugal	0.04%
Kentriki Ellada (Greece)	0.04%
East (Spain)	0.03%
North East (Spain)	0.02%
Community of Madrid (Spain)	0.02%
North East (Italy)	0.02%
Brussels Capital Region (Belgium)	-0.02%
Île-de-France (France)	-0.02%
North Netherlands (Netherlands)	-0.02%
East Netherlands (Netherlands)	-0.03%
South Austria (Austria)	-0.03%
West Netherlands (Netherlands)	-0.03%
South Netherlands (Netherlands)	-0.03%
West Austria (Austria)	-0.04%
East Austria (Austria)	-0.05%
Luxembourg	-0.07%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 2.23: The 20 greatest % value added increases or decreases within the EU15

	Change
Nisia Aigaiou-Kriti (Greece)	3.47%
Ireland	1.75%
Kentriki Ellada (Greece)	1.18%
Portugal	0.90%
Attica (Greece)	0.62%
Voreia Ellada (Greece)	0.51%
East (Spain)	0.34%
North East (Spain)	0.27%
North East (Spain)	0.18%
Flemish Region (Belgium)	-0.19%
North Netherlands (Netherlands)	-0.20%
Greater London (United Kingdom)	-0.20%
Denmark	-0.21%
East Netherlands (Netherlands)	-0.28%
Brussels Capital Region (Belgium)	-0.31%
East Austria (Austria)	-0.32%
South Netherlands (Netherlands)	-0.35%
West Netherlands (Netherlands)	-0.47%
Île-de-France (France)	-0.79%
Luxembourg	-1.48%

Notes: Unskilled/skilled labour mobility across the NUTS 1 region within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 2.24: The 20 greatest % value added increases or decreases within the EU27

	Change
Nisia Aigaiou-Kriti (Greece)	3.64%
Ireland	1.83%
Kentriki Ellada (Greece)	1.18%
Portugal	0.88%
Attica (Greece)	0.62%
Voreia Ellada (Greece)	0.51%
East (Spain)	0.34%
North East (Spain)	0.27%
North East (Spain)	0.18%
Flemish Region (Belgium)	-0.20%
Greater London (United Kingdom)	-0.21%
North Netherlands (Netherlands)	-0.21%
Denmark	-0.22%
East Netherlands (Netherlands)	-0.28%
Brussels Capital Region (Belgium)	-0.31%
East Austria (Austria)	-0.35%
South Netherlands (Netherlands)	-0.36%
West Netherlands (Netherlands)	-0.48%
Île-de-France (France)	-0.79%
Luxembourg	-1.50%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

The changes are small in the first scenario (labour immobility) but not negligible in the second and third ones (labour mobility within the EU15 and the EU27). The NUTS 1 regions, characterised by a stronger production reallocation, are the ones which experience the most important gains from trade policy reform in terms of increase of value added (Nisia Aigaiou-Kriti, Kentriki Ellada, Ireland, Portugal) and the most important losses from trade policy reform in terms of decrease of value added (West Netherlands and Luxembourg).

The changes in the trade patterns, i.e. the change in the sectoral imports and exports at the macro-area level, are set out in Tables 2.25, 2.26 and 2.27.

Table 2.25: % Trade pattern change in volume at the macro-area level

		ROW	EU15	REU
AGM	ROW	53.80%	18.80%	15.00%
AGM	EU15	31.59%	-5.09%	39.78%
AGM	REU	43.68%	18.48%	18.49%
PRM	ROW	-0.11%	-0.08%	-0.09%
PRM	EU15	0.06%	0.09%	0.08%
PRM	REU	0.01%	0.04%	0.02%
IND	ROW	-0.01%	0.02%	-0.07%
IND	EU15	-0.04%	0.00%	-0.11%
IND	REU	0.09%	0.12%	0.02%
SERV	ROW	-0.07%	-0.28%	-0.19%
SERV	EU15	0.25%	0.04%	0.13%
SERV	REU	0.09%	-0.12%	-0.03%

Notes: The second column shows the exporting macro-area, the first row the importing macro-area. Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 2.26: % Trade pattern change in volume at the macro-area level

		ROW	EU15	REU
AGM	ROW	53.80%	19.00%	15.00%
AGM	EU15	31.62%	-4.91%	39.81%
AGM	REU	43.68%	18.68%	18.49%
PRM	ROW	-0.11%	0.25%	-0.10%
PRM	EU15	-0.16%	0.19%	-0.16%
PRM	REU	0.04%	0.40%	0.05%
IND	ROW	-0.02%	0.06%	-0.11%
IND	EU15	0.04%	0.14%	-0.05%
IND	REU	0.09%	0.17%	-0.01%
SERV	ROW	-0.07%	-0.29%	-0.19%
SERV	EU15	0.30%	0.08%	0.18%
SERV	REU	0.08%	-0.14%	-0.04%

Notes: The second column shows the exporting macro-area, the first row the importing macro-area. Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 2.27: % Trade pattern change in volume at the macro-area level

		ROW	EU15	REU
AGM	ROW	53.80%	19.00%	15.07%
AGM	EU15	31.62%	-4.91%	39.90%
AGM	REU	43.76%	18.75%	18.64%
PRM	ROW	-0.11%	0.26%	0.01%
PRM	EU15	-0.17%	0.19%	-0.05%
PRM	REU	0.04%	0.41%	0.17%
IND	ROW	-0.02%	0.06%	-0.05%
IND	EU15	0.04%	0.14%	0.01%
IND	REU	0.18%	0.26%	0.14%
SERV	ROW	-0.07%	-0.30%	-0.13%
SERV	EU15	0.30%	0.07%	0.24%
SERV	REU	0.13%	-0.09%	0.07%

Notes: The second column shows the exporting macro-area, the first row the importing macro-area. Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

Not surprisingly, the greatest variations strike the AGM sector. It should be noted that, even if export changes are small in the other sectors at the macro-area level, the NUTS 1 regions experience appreciable reallocation effects in production volume, which makes the NUTS model useful.

Finally, welfare analysis is carried out at the macro-area level. Table 2.28 lays out the welfare gains measured in equivalent variation (EV) $ million under the three different labour market scenarios.

Table 2.28: Equivalent variation at the macro-area level

	ROW	EU15	REU
$\sigma_L = \sigma_H = 0$ within EU15	5462	157	75
$\sigma_L = \sigma_H = 10$ within EU15	5616	176	87
$\sigma_L = \sigma_H = 10$ within EU27	5618	-160	408

Notes: $ million.

Under the assumption of unskilled/skilled labour immobility at the NUTS 1 level within the EU15, ROW gains about $5462 million. The gain are limited for the EU15 and REU, $157 and $75 million, respectively.

Increasing labour mobility within the EU15 in the second scenario results in a slight improvement in welfare. Indeed, the ROW gains $5616 million and the EU15 and REU, $176 and $87 million, respectively. However the gain for Europe as a whole continues to be almost insignificant.

Finally, assuming an integrated labour market within the EU27, the welfare increase for the ROW macro-area is only $2 million. Interestingly, the EU15 loses and the REU wins in the third scenario. The liberalization of agriculture determines a gain of about $408 million for the REU and a loss by $160 million for the EU15. Nevertheless, gains and losses continue to be almost insignificant for Europe.

It is worth noting that other studies produce much higher estimates of equivalent variation. For example, using the GTAP model with perfect competition and constant returns to scale in all the sectors, Hertel and Keeney (2005) find that full liberalization of agriculture (market access, domestic support and export subsidies) produce a $55 billion gain for the world as a whole. Using MIRAGE model with imperfect competition in services and manufactures, Bouet *et al.* (2005) implement a likely Doha round agricultural liberalization. They find a $18 billion gain for the world as a whole.

In addition in both these two studies, the baseline equilibrium, in which trade liberalization is implemented, considers as achieved the European enlargement and other commitments that took place by the end of 2004 (e.g. China accession in the WTO). As a result, my model is likely to overestimate further the welfare gain of the tariff liberalization in agriculture because the world picture of tariff barriers refers to that of 2001. These different results could depend on the NUTS regional level adopted to define the production structure.

2.8 Interpretation of the results

CGE trade models are criticized because they do not allow the results to be interpreted adequately. As stated by Panagariya and Duttagupta (2001, p. 3), 'unearthing the features of CGE models that drive them is often a time-consuming exercise. This is because their sheer size, facilitated by recent advances in computer technology, make it difficult to pinpoint the precise source of a particular result. They often remain a black box. Indeed, frequently, authors are themselves unable to explain their results intuitively'.

For this reason I have built a stylised model in order to interpret the results and better understand the economic functioning of the big model.

The focus of this model is on the production side. Welfare analysis can be carried out only at the macro-area level. Therefore, the interpretation is given for the production reallocation across sectors in each NUTS 1 region after the tariff liberalization in agriculture under the hypothesis of perfect unskilled/skilled labour immobility at the NUTS 1 level. In fact, this kind of effect can be considered as the most important result in the model.

There are two main features concerning the results of trade policy simulation:

- ✓ different negative magnitudes of production change in the agricultural sector (AGM) across the NUTS 1 regions,
- ✓ different (positive and negative) magnitudes of production change across the NUTS 1 regions in the other sectors, manufactures (IND) and services (SERV).

The stylised model aims at explaining the reasons for such results.

Before the presentation of the stylised model, it is worth noting that skilled and unskilled labour are the only two primary factors for which data at the NUTS 1 level are available. As a results, they can be considered as the main source of heterogeneity across the NUTS 1 regions. It is possible to understand this by looking at the formula of the value added for the general NUTS 1 region at the calibration stage.

According to Eqs. (2.5), (2.6) and (2.7) value added (*VA*) can be written as:

$$VA_{i,nut} = KEYVA_{i,nut}\left(TE_{i,EU15} + RN_{i,EU15} + K_{i,EU15}\right) + L_{i,nut} + H_{i,nut} \qquad (2.11)$$

All the land (*TE*), natural resources (*RN*) and capital (*K*) variables use the repartition key of valued added (*KEYVA*) to determine their NUTS 1 level. It is assumed that all the prices associated with the above-mentioned variables are initialised to unity at the calibration stage. Using Eq. (2.4), the Eq. (2.11) can be rearranged as:

$$VA_{i,nut} = \left(L_{i,nut} + H_{i,nut}\right)\frac{VA_{i,EU15}}{VA_{i,EU15} - \left(TE_{i,EU15} + RN_{i,EU15} + K_{i,EU15}\right)} \qquad (2.12)$$

In the Eq. (2.12) it is clear that the source of the value added heterogeneity across the NUTS 1 regions stems from the skilled and unskilled labour at the NUTS 1 level.

Let us now move on to the description of the stylised model. The assumptions of the stylised model are the following:

1) two countries (home and foreign countries),
2) two regions (*A* and *B* regions) which both belong to the home country,
3) two factors, the unskilled labour (*L*) and skilled labour (*H*), which are assumed to be perfectly immobile at the regional level and perfectly mobile across sectors,
4) two sectors, sector 1 that is unskilled labour intensive, and sector 2 that is skilled labour intensive,
5) a CES function, which uses unskilled and skilled labour to produce value added, and a Leontief technology which uses value added and intermediate inputs to produce output,
6) constant returns to scale and perfect competition in both sectors,

7) a demand structure which reproduces that used in the big model (the Armington hypothesis is used to model the foreign trade). The elasticities of substitution in the CES functions are the same of those used in the big model.

Assumption 4, in turn, implies that:

$$\frac{\alpha L_{1,A}}{\alpha H_{1,A}} > \frac{\alpha L_{2,A}}{\alpha H_{2,A}} \tag{2.13}$$

$$\frac{\alpha L_{1,B}}{\alpha H_{1,B}} > \frac{\alpha L_{2,B}}{\alpha H_{2,B}} \tag{2.14}$$

where αL and αH are parameters of the CES value added function for the unskilled and skilled factors. These parameters can be considered as factor intensity indicators.

Given that in the big model a full tariff liberalization is implemented in the agricultural sector, I suppose that all the tariffs are removed in the unskilled intensive sector (sector 1) for both home and foreign countries in the stylised model.

Two cases are given for the stylised model. In the first case, *A* and *B* regions have the same technologies:

$$\frac{\alpha L_{1,A}}{\alpha H_{1,A}} = \frac{\alpha L_{1,B}}{\alpha H_{1,B}} \tag{2.15}$$

$$\frac{\alpha L_{2,A}}{\alpha H_{2,A}} = \frac{\alpha L_{2,B}}{\alpha H_{2,B}} \tag{2.16}$$

Eqs (2.15) and (2.16), in turn, imply that *A* and *B* have the same ratio of the unskilled/skilled labour endowments:

$$\frac{L_A}{H_A} = \frac{L_B}{H_B} \tag{2.17}$$

Trade liberalization in the unskilled labour intensive sector is simulated for the case 1. The results for the production relative change ($\Delta Y/Y$) are the following:

$$\frac{\Delta Y_{1,A}}{Y_{1,A}} = \frac{\Delta Y_{1,B}}{Y_{1,B}} < 0 \tag{2.18}$$

$$\frac{\Delta Y_{2,A}}{Y_{2,A}} = \frac{\Delta Y_{2,B}}{Y_{2,B}} > 0 \tag{2.19}$$

From Eqs. (2.18) and (2.19) it is clear that different technologies between *A* and *B* regions are crucial to explain different magnitudes of the production relative change between *A* and *B* regions. This result does not depend on the region size, i.e. the factor endowments of the regions.

The first case of the stylised model helps one to understand that different technologies are decisive in order to explain the different magnitudes of trade policy shock but does not help to understand which characteristics the technologies must have across sectors and regions in order to replicate the two main features of trade policy simulation in the big model. The second case of the stylised model meets this need. In the case 2 it is supposed that *A* and *B* regions have different technologies:

$$\frac{\alpha L_{1,A}}{\alpha H_{1,A}} \neq \frac{\alpha L_{1,B}}{\alpha H_{1,B}} \tag{2.20}$$

$$\frac{\alpha L_{2,A}}{\alpha H_{2,A}} \neq \frac{\alpha L_{2,B}}{\alpha H_{2,B}} \tag{2.21}$$

One condition is needed in the stylised model to replicate the results of the big model:

$$\frac{\alpha L_{1,A}}{\alpha H_{1,A}} - \frac{\alpha L_{2,A}}{\alpha H_{2,A}} < \frac{\alpha L_{1,B}}{\alpha H_{1,B}} - \frac{\alpha L_{2,B}}{\alpha H_{2,B}} \tag{2.22}$$

Eq. (2.22) is a technological condition on the sectoral difference between the ratios of the unskilled labour intensity to the skilled labour intensity. Both the left and right members of Eq. (2.22) have to be positive because they are the difference of the ratios between the unskilled and skilled labour intensive sector.

In case 2 Eq. (2.22) determines the following results:

$$\frac{\Delta Y_{1,B}}{Y_{1,B}} < \frac{\Delta Y_{1,A}}{Y_{1,A}} < 0 \tag{2.23}$$

$$\frac{\Delta Y_{2,B}}{Y_{2,B}} > \frac{\Delta Y_{2,A}}{Y_{2,A}} > 0 \tag{2.24}$$

In the big model there are four sectors while in the stylised model there are only two sectors. The result of this simplification is that the different (positive and negative) magnitudes in the IND and SERV sectors become different positive magnitudes in the skilled labour intensive sector. It can also be noted that a region (*B*) experiences the largest production reallocation across sectors.

In order to explain the production reallocation across sectors in each NUTS 1 region, I concentrate my attention on Eq. (2.22), the technological condition which gives the key parameter for interpreting the results, i.e. the sectoral difference between the ratios of the unskilled labour intensity to the skilled labour intensity. I use the following parameter in the big model as proxy of the key parameter in Eq. (2.22):

$$\frac{\alpha L_{i,nut}}{\alpha Q_{i,nut}} - \frac{\alpha L_{j,nut}}{\alpha Q_{j,nut}} \tag{2.25}$$

where *i* and *j* are sector indexes, *nut* is the index of the NUTS 1 regions and αL and αQ are parameters of the CES value added function for the unskilled and fictive factors. It is noteworthy to recall that the fictive factor (*Q*) is a CES bundle of capital and skilled labour (see the list of variables in Appendix 2). Indeed, in the big model the valued added is specified through a two-level nested technology (see *Figure 2.2*).

To show how the parameter determines the % production changes, in Table 2.29 and Table 2.30 I match the ten greatest % production decreases in volume at the NUTS 1 level for the AGM sector with the ten highest values of the *α(agm/ind)* and *α(agm/serv)* parameters. The latter is the difference between the ratios of the unskilled labour intensity to the fictive factor intensity in the AGM and SERV sectors, respectively. The former is the difference between the ratios of the unskilled labour intensity to the fictive factor intensity, respectively, in the AGM and IND sectors.

Table 2.29: The ten greatest % production decreases in volume at the NUTS 1 level (AGM sector) and the ten highest values of the *α(agm/ind)* parameter

	Δ*Y/Y* (AGM)		*α(agm/ind)*
South Austria (Austria)	**-2.47%**	**South Austria (Austria)**	**4.79**
Ireland	**-2.15%**	**West Austria (Austria)**	**3.50**
West Austria (Austria)	**-1.95%**	Kentriki Ellada (Greece)	3.15
East Austria (Austria)	**-1.74%**	Nisia Aigaiou-Kriti (Greece)	2.96
Portugal	**-1.47%**	**Portugal**	**2.91**
Attica (Greece)	**-1.44%**	**East Austria (Austria)**	**2.73**
Mecklenburg-Vor. (Germany)	-1.19%	**Voreia Ellada (Greece)**	**2.65**
Northern Ireland	-1.10%	**Attica (Greece)**	**2.09**
Luxembourg	-1.10%	**Ireland**	**1.58**
Voreia Ellada (Greece)	**-1.10%**	South (Italy)	1.41

Notes: $\alpha(agm/ind) = \left(\alpha L_{agm,nut} / \alpha Q_{agm,nut}\right) - \left(\alpha L_{ind,nut} / \alpha Q_{ind,nut}\right)$

Table 2.30: The ten greatest % production decreases in volume at the NUTS 1 level (AGM sector) and the ten highest values of the *α(agm/serv)* parameter

	$\Delta Y/Y$ (AGM)		*α(agm/serv)*
South Austria (Austria)	**-2.47%**	**South Austria (Austria)**	**5.05**
Ireland	-2.15%	**Portugal**	**4.41**
West Austria (Austria)	**-1.95%**	**West Austria (Austria)**	**3.79**
East Austria (Austria)	**-1.74%**	Kentriki Ellada (Greece)	3.67
Portugal	**-1.47%**	Nisia Aigaiou-Kriti (Greece)	3.41
Attica (Greece)	**-1.44%**	**Voreia Ellada (Greece)**	3.25
Mecklenburg-Vor. (Germany)	-1.19%	**East Austria (Austria)**	2.98
Northern Ireland	-1.10%	**Attica (Greece)**	2.72
Luxembourg	-1.10%	South (Italy)	2.02
Voreia Ellada (Greece)	**-1.10%**	Islands (Italy)	1.63

Notes: $\alpha(agm/serv) = \left(\alpha L_{agm,nut} / \alpha Q_{agm,nut}\right) - \left(\alpha L_{serv,nut} / \alpha Q_{serv,nut}\right)$

It is possible to see that seven % production changes match the corresponding key parameters for the NUTS 1 regions in Table 2.29 and six % production changes match the corresponding key parameter for the NUTS 1 regions in Table 2.30 (the % production changes and corresponding key parameters, which match each other, are reported in bold). Therefore, given the production decrease in the agriculture sector for all of the EU15 regions, the most affected regions will be those in which there is a stronger sectoral difference between AGM and the other sectors in the relative use of the unskilled and skilled factors. For example, South Austria experiences the greatest decrease in AGM and uses more intensively the unskilled labour in the AGM sector and the skilled labour in the IND and SERV sectors with respect to the other NUTS 1 regions.

An analogous argument can be made to explain the different (positive and negative) % production changes in the IND and SERV sectors, which are displayed respectively, in Table 2.31 and in Table 2.32.

Table 2.31: The ten greatest % production increases or decreases in volume at the NUTS 1 level (IND sector) and the ten highest values of the *α(agm/ind)* parameter

	Δ*Y/Y* (IND)		*α(agm/ind)*
Nisia Aigaiou-Kriti (Greece)	**-7.62%**	**South Austria (Austria)**	**4.79**
Attica (Greece)	**-1.38%**	**West Austria (Austria)**	**3.50**
Community of Madrid (Spain)	-1.15%	Kentriki Ellada (Greece)	3.15
Luxembourg	1.06%	**Nisia Aigaiou-Kriti (Greece)**	**2.96**
West Austria (Austria)	**1.55%**	Portugal	2.91
Brussels-Capital Region	1.94%	**East Austria (Austria)**	**2.73**
Mecklenburg-Vor. (Germany)	2.10%	Voreia Ellada (Greece)	2.65
East Austria (Austria)	**2.40%**	**Attica (Greece)**	**2.09**
South Austria (Austria)	**2.99%**	**Ireland**	**1.58**
Ireland	**7.02%**	South (Italy)	1.41

Notes: $\alpha(agm/ind) = \left(\alpha L_{agm,nut} / \alpha Q_{agm,nut}\right) - \left(\alpha L_{ind,nut} / \alpha Q_{ind,nut}\right)$

Table 2.32: The ten greatest % production increases or decreases in volume at the NUTS 1 level (SERV sector) and the ten highest values of the *α(agm/serv)* parameter

	Δ*Y/Y* (SERV)		*α(agm/serv)*
Ireland	-2.31%	**South Austria (Austria)**	**5.05**
South Austria (Austria)	**-1.15%**	**Portugal**	**4.41**
West Austria (Austria)	**-0.63%**	**West Austria (Austria)**	**3.79**
East Austria (Austria)	-0.59%	Kentriki Ellada (Greece)	3.67
Mecklenburg-Vor. (Germany)	-0.50%	**Nisia Aigaiou-Kriti (Greece)**	**3.41**
North East (Spain)	0.39%	Voreia Ellada (Greece)	3.25
East (Spain)	0.43%	**East Austria (Austria)**	**2.98**
Portugal	**0.47%**	**Attica (Greece)**	**2.72**
Attica (Greece)	**0.47%**	South (Italy)	2.02
Nisia Aigaiou-Kriti (Greece)	**1.62%**	Islands (Italy)	1.63

Notes: $\alpha(agm/serv) = \left(\alpha L_{agm,nut} / \alpha Q_{agm,nut}\right) - \left(\alpha L_{serv,nut} / \alpha Q_{serv,nut}\right)$

So far the reasons, which cause different magnitudes in the three sectors, have been explained but it is also important to understand the sign of the production change across the NUTS 1 regions. In the agricultural sector there is no doubt because the sign is the same for all the NUTS 1 regions and, thus, this can be interpreted as a result of the demand side at the macro-area level. In contrast, the sign changes according with the NUTS 1 region in manufactures and services. This can be interpreted as a result of the improved efficiency in the allocation of the inputs, i.e. as a result of the supply side at the NUTS 1 level.

Table 2.33 and Table 2.34 help us to understand the different signs in the IND sector.

Table 2.33: The ten greatest % production increases or decreases in volume at the NUTS 1 level (IND sector) and the ten highest values of the *α(ind/serv)* parameter

	Δ*Y/Y* (IND)		*α(ind/serv)*
Nisia Aigaiou-Kriti (Greece)	**-7.62%**	Portugal	1.50
Attica (Greece)	**-1.38%**	North East (Italy)	0.75
Community of Madrid (Spain)	-1.15%	North West (Italy)	0.66
Luxembourg	1.06%	Centre (Italy)	0.63
West Austria (Austria)	1.55%	**Attica (Greece)**	**0.63**
Brussels-Cap. Region (Belgium)	1.94%	South (Italy)	0.61
Mecklenburg-Vor. (Germany)	2.10%	Voreia Ellada (Greece)	0.60
East Austria (Austria)	2.40%	Kentriki Ellada (Greece)	0.52
South Austria (Austria)	2.99%	Islands (Italy)	0.51
Ireland	7.02%	**Nisia Aigaiou-Kriti (Greece)**	**0.45**

Notes: $\alpha(ind / serv) = \left(\alpha L_{ind,nut} / \alpha Q_{ind,nut}\right) - \left(\alpha L_{serv,nut} / \alpha Q_{serv,nut}\right)$

Table 2.34: The ten greatest % production increases or decreases in volume at the NUTS 1 level (IND sector) and the ten lowest values of the *α(ind/serv)* parameter

	$\Delta Y/Y$ (IND)		*α(ind/serv)*
Nisia Aigaiou-Kriti (Greece)	-7.62%	**Ireland**	**-0.02**
Attica (Greece)	-1.38%	**Mecklenburg-Vo (Germany)**	**0.05**
Community of Madrid (Spain)	-1.15%	Northern Ireland (U.K)	0.14
Luxembourg	1.06%	**Brussels-Ca. Reg. (Belgium)**	**0.14**
West Austria (Austria)	1.55%	Walloon Region (Belgium)	0.19
Brussels-Ca. Reg. (Belgium)	**1.94%**	Scotland (United Kingdom)	0.20
Mecklenburg-Vor. (Germany)	**2.10%**	North East England (U.K.)	0.21
East Austria (Austria)	2.40%	Mainland Finland (Finlnad)	0.21
South Austria (Austria)	2.99%	Greater London (U.K)	0.21
Ireland	**7.02%**	Brandenburg (Germany)	0.22

Notes: $\alpha(ind/serv) = \left(\alpha L_{ind,nut} / \alpha Q_{ind,nut}\right) - \left(\alpha L_{serv,nut} / \alpha Q_{serv,nut}\right)$

For example, the Greek regions, Nisia Aigaiou-Kriti and Attica, experience the greatest decrease in the IND sector and have a *α(ind/serv)* value included within the ten highest values. This means that these regions use the unskilled labour in the IND sector and the skilled labour in the SERV sector more intensively with respect to the other NUTS 1 regions. In contrast, Ireland experiences the greatest increase in the IND sector and has the lowest *α(ind/serv)* value. This means that Ireland uses unskilled labour and skilled labour by similar intensities in both the IND and SERV sectors with respect to the other NUTS 1 regions.

A similar argument can be used for the SERV sector. Tables 2.35 and 2.36 indicate Nisia Aigaiou-Kriti, Attica and Portugal as the regions with the greatest increase in the SERV sector. These regions also have a *α(ind/serv)* value included within the ten highest values. In contrast, Ireland experiences the greatest decrease in the SERV sector and has the lowest *α(ind/serv)* value.

Thus, the increases and decreases of the production change in the IND and SERV sectors are characterised by inverse patterns at the NUTS 1 level.

Table 2.35: The ten greatest % production increases or decreases in volume at the NUTS 1 level (SERV sector) and the ten highest values of the *α(ind/serv)* parameter

	$\Delta Y/Y$ (SERV)		*α(ind/serv)*
Ireland	-2.31%	**Portugal**	**1.50**
South Austria (Austria)	-1.15%	North East (Italy)	0.75
West Austria (Austria)	-0.63%	North West (Italy)	0.66
East Austria (Austria)	-0.59%	Centre (Italy)	0.63
Mecklenburg-Vor (Germany)	-0.50%	**Attica (Greece)**	**0.63**
North East (Spain)	0.39%	South (Italy)	0.61
East (Spain)	0.43%	Voreia Ellada (Greece)	0.60
Portugal	**0.47%**	Kentriki Ellada (Greece)	0.52
Attica (Greece)	**0.47%**	Islands (Italy)	0.51
Nisia Aigaiou-Kriti (Greece)	**1.62%**	**Nisia Aigaiou-Kriti (Greece)**	**0.45**

Notes: $\alpha(ind\ /\ serv) = \left(\alpha L_{ind,nut} / \alpha Q_{ind,nut}\right) - \left(\alpha L_{serv,nut} / \alpha Q_{serv,nut}\right)$

Table 2.36: The ten greatest % production increases or decreases in volume at the NUTS 1 level (SERV sector) and the ten lowest values of the *α(ind/serv)* parameter

	$\Delta Y/Y$ (SERV)		*α(ind/serv)*
Ireland	**-2.31%**	**Ireland**	**-0.02**
South Austria (Austria)	-1.15%	**Mecklenburg-Vo. Germany)**	**0.05**
West Austria (Austria)	-0.63%	Northern Ireland (UK)	0.14
East Austria (Austria)	-0.59%	Brussels Ca. Reg. (Belgium)	0.14
Mecklenburg-Vor. (Germany)	**-0.50%**	Walloon Region (Belgium)	0.19
North East (Spain)	0.39%	Scotland (UK)	0.20
East (Spain)	0.43%	North East England (UK)	0.21
Portugal	0.47%	Mainland Finland (Finlnad)	0.21
Attica (Greece)	0.47%	Greater London (UK)	0.21
Nisia Aigaiou-Kriti (Greece)	1.62%	Brandenburg (Germany)	0.22

Notes: $\alpha(ind\ /\ serv) = \left(\alpha L_{ind,nut} / \alpha Q_{ind,nut}\right) - \left(\alpha L_{serv,nut} / \alpha Q_{serv,nut}\right)$

In Tables 2.33, 2.34, 2.35, 2.36 only two out of ten or three out of ten production changes match the corresponding key parameters. This means that further channels, in addition to the sectoral difference between the ratios of the unskilled labour intensity to the skilled labour intensity, could exist in the model that determine the sign in the IND and SERV sectors. However, the above-mentioned channel, based on the *α(ind/serv)* parameter value, is likely to be very important because it involves the NUTS 1 regions which shows the highest increases and decreases in the IND and SERV sectors, i.e. Ireland and Nisia Aigaiou-Kriti.

To summarize, trade policy strikes the AGM sector and causes a production decrease in the AGM sector for all of the NUTS 1 regions. The NUTS 1 regions, which use unskilled labour in the AGM sector and skilled labour in the IND and SERV sectors more intensively with respect to the other NUTS 1 regions, are the most affected regions in the AGM sector. The decrease in the AGM production, in turn, determines a production reallocation and reduces the labour demand for unskilled labour. As a result, in general the unskilled factor loses (the wage goes down) and the skilled factor wins (the wage goes up). However, in the NUTS 1 regions which use the unskilled labour in the IND sector and the skilled labour in the SERV sector more intensively, the IND production goes down and the SERV production goes up. In contrast, in the NUTS 1 regions, which use the unskilled and skilled factors in the IND and SERV sectors by similar intensities, the IND production goes up and the SERV production goes down.

The introduction of unskilled/skilled labour mobility within the EU15 and the EU27 determines smaller decreases in the AGM sector and, not surprisingly, a larger production reallocation between the IND and SERV sectors, as shown in Tables 2.10 through Table 2.17. Strong *amplification* effects are observed in these two sectors for the NUTS 1 regions, which experienced strong decreases or increases in the case of unskilled/skilled labour immobility. These *amplification* effects occur because workers can move toward the regions where they receive a higher wage. This is also the reason why the Greek regions and Portugal exhibit a stronger skilled immigration (Table 2.19 and Table 2.21) while Ireland and Luxembourg have a stronger unskilled immigration (Table 2.18 and Table 2.20).

Welfare analysis cannot be carried out at the macro-area level. Nevertheless, the % change in the overall value added can be evaluated at the NUTS 1 through a Laspeyres index. It is interesting to note in Tables 2.22, 2.23 and 2.24 that labour mobility increases the losses and gains in terms of value added, in particular for the NUTS 1 regions in which there is a stronger production reallocation.

Chapter 3

A global CGE trade model at the NUTS 1 level with imperfect competition

3.1 Introduction

In the second chapter I set out a global CGE trade model at the NUTS level. Perfect competition and constant returns to scale were assumed to hold in all the sectors. The perfect competition in the goods market implies a first best solution but the market is likely to have imperfections and to be characterised by oligopolistic behaviour. Imperfect competition should be considered to give a greater realism to the trade policy scenario. In addition, it is interesting to compare the trade policy results in a perfect competition framework with the trade policy results in an imperfect competition framework. The comparison in terms of productive efficiency or welfare can be interpreted as the distance between the first best solution and a second best solution.

Norman (1990) explains the need to take into account the imperfect competition in CGE models. He builds simplified models (three sectors and two countries) to investigate the consequences of trade liberalization. He finds that imperfect competition makes a significant quantitative difference (compared to the standard, perfectly competitive theory) to the effects of trade liberalization on inter-industry trade patterns. In addition, the Armington assumption is a good approximation of product differentiation only with respect to the intra-industry trade but is not a substitute for explicit incorporation of oligopolistic interaction and product differentiation at the firm level.

Imperfect competition is now also incorporated in the GTAP and MIRAGE models. However, in MIRAGE agriculture continues to be characterised by perfect competition and constant returns to scale because of the high number of producers in this sector. This assumption is also preserved in my approach.[1]

In this chapter I present my version of a global CGE trade model at the sub-national level with imperfect competition. It is applied to the 68 NUTS 1 regions within the first 15 member states of the European Union (EU15). As in the version with perfect competition, the demand side continues to be specified at the EU15 level. This means that imports, exports, domestic demand, as well as the associated prices, are at the EU15 level. The imperfect competition is modelled through a Cournot-Nash scheme, where the strategic variable is the quantity produced by each NUTS 1 region. It is supposed that all the NUTS 1 firms, producing in the EU15 macro-area, face the same price in the macro-area where they sell their product. As a result, in each macro-area there is a unique price-elasticity of the demand which is perceived by all the NUTS 1 firms producing in the EU15 macro-area.

The chapter is organized as follows. In section 2 the theoretical structure is set out. In section 3 the calibration strategy is described. The chosen sectoral and geographical aggregations remain the same, as well as the trade policy simulation. In section 4 the results of the trade policy on the reallocation of production and varieties across sectors at the NUTS 1 level are presented. The results of the sensitivity analysis on the reallocation of production and varieties across sectors at the NUTS 1 level with the introduction of the skilled/unskilled labour mobility are also shown. As in the previous chapter, other interesting results are presented: the unskilled/skilled labour migration within the EU15 and the EU27, the change in the total value added at the NUTS level and the changes in the trade patterns and welfare at the macro-area level. All the results are compared with those obtained in the perfect competition case. An interpretation for the imperfect competition case is given in section 5.

[1] In my approach the primary energy sources sector is also considered perfectly competitive because in the MIRAGE model it is considered perfectly competitive. Even if this is controversial, I preferred to preserve the sectoral structuring of MIRAGE. However, the weight of the PRM sector is very small in the European economy (see *Figure 2.3*).

3.2 The theoretical structure of the model

In this section I explain the theoretical structure of the model: the demand side, the supply side, the factor markets and macroeconomic closure. Particular attention is given at the demand side, which is substantially modified by the introduction of the imperfect competition. As in Chapter 2, I refer to the Appendixes at the end of the thesis for notational conventions, list of variables, parameters and equations.

3.2.1 Demand

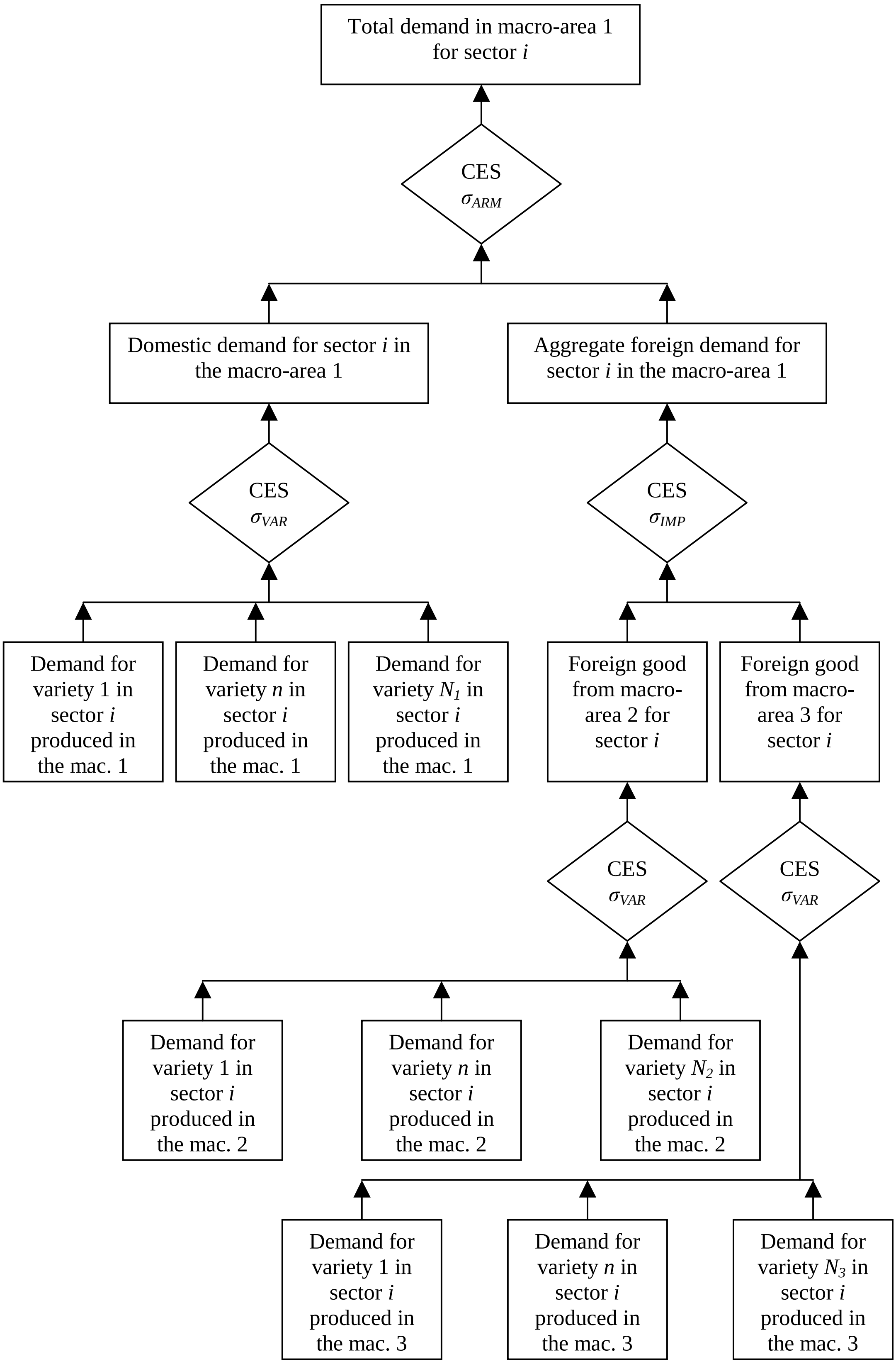
All the demand variables are defined at the macro-area level. This implies that the price of each demand variable is equal for all the NUTS 1 regions. As in the perfect competition case, total demand is made up of final consumption, intermediate inputs and capital goods.[2] In each macro-area a representative household chooses the optimal sectoral composition of its final consumption by maximising a LES-CES utility function subject to the household budget constraint. With this type of function there is a minimum level of consumption which makes the consumer preferences non-homothetic.

Figure 3.1 illustrates the demand structure in each sector and in each one of the three macro-areas. As usual, I put the variable in the rectangle and the functional form used in the rhomb; *i* represents the general sectoral index while σ_{ARM_i}, σ_{IMP_i} and σ_{VAR_i} are, respectively, the elasticity of substitution between domestic and foreign aggregate good, the elasticity across foreign goods and the elasticity of substitution across varieties.

The standard Armington assumption is made to model foreign trade. Thus, the domestic and aggregate foreign goods are not perfect substitutes. Also, the imports from different macro-areas are not perfect substitutes.

[2] The intermediate inputs also enter in the production side. Therefore, they are regionalized.

Figure 3.1: demand structure



So far the structure of the demand has not changed with respect to the perfect competition case. At the following stage, the horizontal product differentiation is introduced. I follow the approach used in MIRAGE which is, in turn, derived from the one used by Harrison *et al.* (1997). This approach is applied to the demand side, while some changes are made for the production side which is regionalized at the NUTS 1 level.

A Nash-Cournot scheme is supposed to hold in the manufactures and services sectors. The strategic variable is the quantity produced by each NUTS 1 firm. In each NUTS 1 region and imperfectly competitive sector there are $N_{i,nut}$ symmetric firms, where $N_{i,nut}$ is the number of varieties in sector i of the NUTS 1 region nut. Each firm produces a unique variety. The standard Lerner equation allows for the endogenous determination of the mark-ups μ:

$$\mu_{i,mac,mac*} = \frac{P_{i,mac,mac*}}{PY_{i,mac}} = \frac{1}{1 - \frac{1}{EP_{i,mac,mac*}}} \quad (3.1)$$

where $\mu_{i,mac,mac*}$ is the mark-up applied in the macro-area $mac*$ by each firm of sector i producing in the macro-area mac, $P_{i,mac,mac*}$ is the price applied in the macro-area $mac*$ by each firm of sector i producing in the macro-area mac, $EP_{i,mac,mac*}$ is the price-elasticity of the demand, as perceived by the firm producing in sector i and in the macro-area mac and selling its product in the macro-area $mac*$, and $PY_{i,mac}$ is the marginal cost of the firm of sector i producing in the macro-area mac. The marginal cost is determined by the equality between supply and demand at the macro-area level for the general variety using the following equation:

$$\sum_{nut \in EU15} Y_{i,nut} = DVAR_{i,EU15} + \sum_{mac \neq EU15} DEMVAR_{i,EU15,mac} \quad (3.2)$$

where $Y_{i,nut}$ is the production of the general variety in sector i and in the NUTS 1 region nut, $DVAR_{i,EU15}$ is the domestic demand for the general variety produced in sector i of the EU15 macro-area and $DEMVAR_{i,EU15,mac}$ is the demand in the macro-area *mac* for the general variety of sector i produced in the EU15 macro-area. It is clear that in the ROW and REU macro-areas the production (Y) continues to be defined at the macro-area level. Eq. (3.2) gives the equilibrium for the two geographical levels. It is worth noting that the demand for the general variety is specified at the macro-area level and is satisfied by different representative firms in the NUTS 1 regions. As a result, in each imperfectly competitive sector and in each NUTS 1 region there are $N_{i,nut}$ symmetric firms which produce $N_{i,nut}$ varieties. It is assumed that all the firms within the EU15 have the same marginal cost ($PY_{i,mac}$). However, they differ in the use of the inputs (the factor intensity), as noted in the second chapter. The factor intensity depends on the NUTS level.

The total number of varieties by sector in the EU15 ($N_{i,EU15}$) is given by the following formulas:

$$N_{i,EU15} = \sum_{nut \in EU15} N_{i,nut} \tag{3.3}$$

The number of varieties in each sector and in each NUTS 1 region is endogenously determined by the zero-profit condition according to the following equation:

$$\begin{aligned} 0 = {} & PVA_{i,nut} VA_{i,nut} + PAINI_{i,nut} AINI_{i,nut} + \\ & - PY_{i,EU15} N_{i,nut} \left(\frac{DVAR_{i,EU15}}{1 + EP_{i,EU15,EU15}} + \sum_{mac \neq EU15} \frac{DEMVAR_{i,EU15,mac}}{1 + EP_{i,EU15,mac}} \right) \end{aligned} \tag{3.4}$$

where $VA_{i,nut}$ and $AINI_{i,nut}$ are, respectively, the value added and the aggregate intermediate input in sector i and in the NUTS 1 region *nut*, $PVA_{i,nut}$ and $PAINI_{i,nut}$ are the associated prices and $EP_{i,EU15,EU15}$ and $EP_{i,EU15,mac}$ are, respectively, the perceived price-elasticity of the demand for the domestic good in sector i and in the macro-area EU15 and the perceived price-elasticity of the demand in sector i and in the macro-area *mac* for the firm producing in the macro-area EU15.

In the REU and ROW macro-areas Eq. (3.4) becomes the following:

$$
\begin{aligned}
&0 = PVA_{i,mac}VA_{i,mac} + PAINI_{i,mac}AINI_{i,mac} + \\
&-PY_{i,mac}N_{i,mac}\left(\frac{DVAR_{i,mac}}{1+EP_{i,mac,mac}} + \sum_{mac^{*}\neq mac}\frac{DEMVAR_{i,mac,mac^{*}}}{1+EP_{i,mac,mac^{*}}}\right)
\end{aligned}
\tag{3.5}
$$

I assume an international Cournot oligopoly under market segmentation. This means that each firm conjectures that all domestic and foreign rivals keep their supply quantities to the market of the macro-area *mac* fixed when it varies its own quantity in the market of the same macro-area *mac*. It is possible to demonstrate that in this case the perceived price-elasticities of the demand are given by the following two equations:

$$
N_{i,mac}\left(EP_{i,mac,mac} + \frac{1}{\sigma_{VAR_i}}\right) = \left(\frac{1}{\sigma_{VAR_i}} - \frac{1}{\sigma_{ARM_i}}\right) + \left(\frac{1}{\sigma_{ARM_i}} - \frac{1}{\sigma_C}\right)SDT_{i,mac}
\tag{3.6}
$$

$$
\begin{aligned}
&N_{i,mac}\left(EP_{i,mac,mac^{*}} + \frac{1}{\sigma_{VAR_i}}\right) = \left(\frac{1}{\sigma_{VAR_i}} - \frac{1}{\sigma_{IMP_i}}\right) + \\
&+\left(\frac{1}{\sigma_{IMP_i}} - \frac{1}{\sigma_{ARM_i}}\right)SM_{i,mac,mac^{*}} + \left(\frac{1}{\sigma_{ARM_i}} - \frac{1}{\sigma_C}\right)ST_{i,mac,mac^{*}} \\
&mac \neq mac^{*}
\end{aligned}
\tag{3.7}
$$

where σ_{VAR_i} parameter is the elasticity of substitution across varieties in sector *i*, σ_C is the sectoral elasticity of substitution across goods of the total demand in the macro-area *mac*, $SDT_{i,mac}$, $SM_{i,mac,mac^{*}}$ and $ST_{i,mac,mac^{*}}$ are, respectively, the share of the domestic demand over the total demand in the macro-area *mac* and sector *i*, the share of the imports from macro-area *mac* to macro-area *mac** in sector *i* over the total imports of the macro-area *mac** in sector *i* and the share of the imports from macro-area *mac* to macro-area *mac** in sector *i* over the total demand of the macro-area *mac** in sector *i* (see the list of equations in Appendix 4 for the mathematic expression of the shares).[3]

In order to avoid the problem of dependency of the equilibria on the choice of the numeraire, which can occur in the CGE models with imperfect competition, it is supposed that firms have not full information about all the general equilibrium effects of their actions, i.e. the firms rule out the possibility that their production decision influences the aggregate income via factor prices and profit feedback effects (the so-called Ford effect).

3.2.2 Supply

The structure of the supply side remains essentially unchanged with respect to the perfect competition case. A Leontief technology uses value added and aggregate intermediate input to obtain the output. There are five primary factors: unskilled labour, skilled labour, natural resources, land and capital. A CES bundle is used to model the complementarity between capital and skilled labour factors. The elasticity of substitution between capital and skilled labour is less than one used to model the substitutability across land, natural resources, unskilled labour and the fictive factor (*Q*), i.e. the CES bundle. A CES function links natural resources, land, unskilled labour and the fictive factor (*Q*). In every sector of each NUTS 1 region aggregate intermediate input is defined by a CES function among intermediate goods of all other sectors. As noted above, intermediate inputs are one of the components of the total demand together with final consumption and capital goods. The variable is regionalized but its price is at the macro-area level.

The main difference between the production in the perfect competition case and the production in the imperfect competition case is the presence of a fixed cost. The fixed cost makes the total average cost decrease as the output increases. This takes into account the role carried out by the economies of scale.

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[3] A technical derivation of Eqs. (3.6) and (3.7) is given by Willenbockel (2004).

The fixed cost ($fc_{i,nut}$) is measured in terms of units of output. In the NUTS 1 region *nut* and in sector *i* it is derived from the formula of total cost:

$$N_{i,nut} PY_{i,EU15} \left(Y_{i,nut} + fc_{i,nut} \right) = PVA_{i,nut} VA_{i,nut} + AINI_{i,nut} PAINI_{i,nut} \qquad (3.8)$$

3.2.3 Factor markets

The imperfect competition in the goods market does not influence the structure of the factor endowments which continue to be fully employed.

The supply of land and natural resources is at the NUTS 1 level. These two primary factors are used only in the agriculture and primary energy sources sectors.

Skilled and unskilled labour are perfectly mobile across the sectors. Concerning geographical labour mobility, as in the first chapter, in each macro-area skilled and unskilled workers maximise wage income subject to a CET (*Constant Elasticity of Transformation*) constraint. This implies imperfect mobility within the EU15 and different wages across the NUTS 1 regions.

Two different values of the elasticity of migration in the CET function are supposed. When the elasticity is equal to zero perfect immobility of the unskilled/skilled labour at the NUTS 1 level is assumed. When the elasticity is equal to ten a high mobility within the EU15 is assumed. As a result, two really different scenarios are simulated: regional labour immobility and high labour mobility within the EU15. The sensitivity analysis is carried out to assess the impact of labour mobility on the production and labour reallocation across sectors at the NUTS 1 level after the trade policy shock.

In addition, an integrated labour market within the EU27 can be considered. In this integrated labour market skilled and unskilled workers can move not only within the EU15 but also between the EU15 NUTS 1 regions and the rest of Europe (REU).

The capital supply is perfectly mobile across sectors and within each macro-area.

3.2.4 Macro-economic closure

The introduction of imperfect competition does not modify the macro-economic closure. It is neoclassical; the investment is determined by the income and the exogenous saving rate for the representative household in the macro-area. In equilibrium the value of investment equals the value of total demand for capital goods. The external current account balance is fixed.

Comparative static is used to interpret the trade policy effects. These effects must be considered as medium or long-run effects because the capital is perfectly mobile across sectors and within each macro-area, which are very large. In addition, the zero-profit condition holds.

3.3 Calibration

As shown by Willenbockel (see subsection 1.2.2), the calibration is a very important moment for the modelling of imperfect competition in the CGE models. Imperfect competition requires three parameters to be calibrated: the elasticity of substitution across varieties, the mark-up and the number of firms. Two of the three parameters are generally set extraneously, while the remaining one is calibrated residually through the Lerner relationship.

This method is not considered fully satisfactory in MIRAGE because the available information is only used for two out of the three parameters. Moreover, the consistency of the results is assessed ex-post. As a result, an original method is used in MIRAGE which takes into account all the available information about the three parameters, not only their value, but also their variance. For each sector, the parameter values, which will be used in the model, are chosen as to minimize the logarithmic distance between the parameter and its external estimate. The distance is weighted by the inverted variance of the logarithm of estimates. The minimisation problem is subject to the consistency constrains with respect to the values of the three parameters (the zero-profit condition is also taken into account).

The formula is the following:

$$\min_{\sigma_{VAR_i},\mu_i,N_i}\left\{\frac{1}{v\left(\ln\hat{\sigma}_{VAR_i}\right)}\left[\ln\left(\frac{\sigma_{VAR_i}}{\hat{\sigma}_{VAR_i}}\right)\right]^2+\frac{1}{v\left(\ln\hat{\mu}_i\right)}\left[\ln\left(\frac{\mu_i}{\hat{\mu}_i}\right)\right]^2+\frac{1}{v\left(\ln\hat{N}_i\right)}\left[\ln\left(\frac{N_i}{\hat{N}_i}\right)\right]^2\right\}$$
$$s.t.\quad \sigma_{VAR_i}>1,\quad \mu_i>1,\quad N_i>1 \qquad (3.9)$$
$$s.t.\quad \pi_i\left(\sigma_{VAR_i},\ \mu_i, N_i\right)=0$$

where N, μ, σ_{VAR} and π are, respectively, the number of firms, the mark-up, the elasticity of substitution across varieties and the profit. The hat (^) denotes the external estimate and v the variance. The geographical index is neglected for the sake of simplicity.

The data source for the external estimates are the following. The elasticity of substitution across varieties is linked to the elasticity of substitution across foreign goods according to an equation close to Eq. (2.9), which, in turn, linked the Armington elasticity and the elasticity of substitution across foreign goods:

$$\sigma_{VAR_i}-1=\sqrt{2}\left(\sigma_{IMP_i}-1\right) \qquad (3.10)$$

As consequence, σ_{VAR_i} is derived from σ_{IMP_i} which is derived from σ_{ARM_i}. The latter is drawn from the GTAP 6 database and is assumed to be the same across countries or groups of countries for a given sector.

The values chosen for the mark-ups are based on estimates by Oliveira-Martins, Scarpetta and Pilat (1996) for manufactures and by Oliveira-Martins and Scarpetta (1999) for services. However, these econometric analyses are carried out for developed countries. For this reason in MIRAGE it is supposed that the mark-ups for low-income countries are given by the following formula (*LIC* and *HIC* indexes stand for low and high-income countries):

$$\mu_{i,LIC}=\left(\mu_{i,HIC}-1\right)1.5+1 \qquad (3.11)$$

Concerning the number of firms, this parameter seems to be the easiest one to calibrate since good estimates of the Herfindhal index by sector exist. However, the real problem lies elsewhere: a sector is not necessarily a competition field. Indeed, the sectoral aggregation chosen in a CGE model can imply that firms are not all direct competitors to each other within a sector. Therefore, in MIRAGE sectors are divided in sub-sectors to allow for the different competition fields. 'The competition field has the same size whatever the sector. The estimates by Davies and Lyons (1996) are used as a first estimate for the number of firm by sector in Europe. The number of sub-sectors within each sector is assumed to be proportionate to output value in the EU. The equivalent number of firms (which only matters in the model as the inverse of firms' average market share) is then computed as the first "gross" estimate for the number of firms, divided by the number of sub-sectors. The number of firms in other areas is then assumed to be the same than in Europe' (Bchir et al., 2002, p.43).

I follow the approach of MIRAGE for the calibration of the key parameters in the imperfect competition. The elasticity of substitution across varieties and the mark-ups remain the same because they are specified at the macro-area level. In contrast, the number of firms is at the NUTS 1 level. Therefore, I use the zero-profit condition, the Eq. (3.4), to distribute at the NUTS level the total number of firms by sector in the EU15, which I draw from MIRAGE.

As in the first chapter, the numeraire is the utility price of the representative household in the macro-area ROW.

3.4 Simulation results

In this section the results of the trade policy shock are presented. The shock is unchanged with respect to the second chapter. A world tariff liberalization in the agricultural sector is implemented. Thus, all the *ad valorem* tariff rates are set to zero in the agricultural sector for all three macro-areas.

GAMS software and the CONOPT 3 algorithm are used. I have 5677 equations and 5677 variables. As mentioned above, imperfect competition is assumed to hold in the IND and SERV sectors, while AGM continues to be characterised by perfect competition.

This section is organized as follows. In subsection 3.4.1, I show the production reallocation in volume across sectors in the NUTS 1 regions. The imperfect competition allows the number of varieties and the average production per firm at the NUTS 1 level to be determined. As a consequence, these two variables are also displayed for the NUTS 1 regions, which experience the ten greatest % production increases or decreases. In subsection 3.4.2, I assess the impact of unskilled/skilled labour mobility on the outcomes of the previous subsection. Finally, in subsection 3.4.3 I illustrate further interesting results as unskilled/skilled labour migration within Europe and the change in the total value added at the NUTS 1 level. The changes in the trade pattern and welfare are also displayed at the macro-area level. The welfare analysis is carried out through the usual equivalent variation measure as well as through the number of varieties according to the "love of variety" approach of Krugman (1979).

3.4.1 Production reallocation across sectors in the NUTS 1 regions after a world trade liberalization in the agricultural sector

In this section I show the results on production volume reallocation across the four sectors in each of the 68 NUTS 1 regions within the EU15 after a world tariff liberalization in the agricultural sector. The results in this subsection are obtained under the assumption of unskilled/skilled labour immobility at the NUTS 1 level, i.e. workers have to stay in the NUTS 1 region to which they belong. This hypothesis is formalized by assuming that the elasticity of migration in the CET functions is equal to zero, and denoting with σ_L and σ_H the elasticity of migration for the unskilled factor and the skilled factor, respectively.

Before showing the outcomes at the NUTS level, I report the simulated effects of liberalization at the macro-area level in Table 3.1. In the EU15, the AGM sector is again the most affected, the % production decrease in volume is more than 1%. The changes are smaller in the other sectors and macro-areas with the exception of SERV in the REU macro-area, which exhibits a 1.23% decrease. However, in the imperfect competition case, the variations in the IND and SERV sectors are greater than those observed in the perfect competition case; the signs are also different (see Table 2.5 for a comparison). This suggests that imperfect competition matters for inter-industry production reallocation at the macro-area level. It is interesting to assess what happens at the NUTS 1 level.

Table 3.1: % Production change in volume at the macro-area level

	ROW	EU15	REU
AGM	0.26%	-1.08%	-0.37%
PRM	-0.09%	-0.17%	0.79%
IND	-0.07%	-0.19%	0.28%
SERV	0.24%	0.67%	-1.23%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 3.2 reports these effects for each of the 68 NUTS regions. At first glance, it clearly appears that positive and negative magnitudes are higher than the ones observed at the macro-area level (especially for the manufactures and services sectors). In addition, the changes are negative for all the NUTS 1 regions in the agricultural sector (as in the perfect competition case), positive for all the NUTS 1 regions except Ireland in services and negative and positive in manufactures.

Table 3.2: % Production change in volume at the NUTS 1 level

	AGM	PRM	IND	SERV
Portugal	-1.71%	-0.17%	-0.72%	1.29%
North West (Spain)	-1.05%	-0.18%	-0.51%	1.92%
North East (Spain)	-0.93%	-0.16%	-0.66%	1.81%
Community of Madrid (Spain)	-0.94%	-0.17%	-1.34%	1.03%
Centre (Spain)	-1.01%	-0.17%	-0.08%	1.52%
East (Spain)	-0.92%	-0.17%	-0.95%	0.95%
South (Spain)	-1.01%	-0.17%	-0.50%	0.98%
Voreia Ellada (Greece)	-1.28%	-0.16%	0.25%	2.70%
Kentriki Ellada (Greece)	-1.10%	-0.16%	-0.29%	4.14%
Attica (Greece)	-1.67%	-0.16%	-1.53%	2.18%
Nisia Aigaiou-Kriti (Greece)	-0.65%	-0.16%	-8.62%	8.73%
North West (Italy)	-0.93%	-0.16%	-0.40%	0.59%
North East (Italy)	-0.96%	-0.16%	-0.40%	0.76%
Centre (Italy)	-1.04%	-0.16%	-0.35%	0.56%
South (Italy)	-1.26%	-0.17%	-0.02%	0.58%
Islands (Italy)	-1.13%	-0.17%	-0.14%	1.10%
Île-de-France (France)	-1.06%	-0.17%	-0.24%	0.28%
Parisian basin (France)	-0.87%	-0.17%	-0.29%	0.67%
Nord-Pas-de-Calais (France)	-0.96%	-0.22%	-0.23%	1.51%
East (France)	-0.92%	-0.17%	-0.26%	1.16%
West (France)	-0.95%	-0.16%	-0.07%	0.70%
South West (France)	-0.98%	-0.16%	-0.20%	0.86%
Centre East (France)	-1.05%	-0.17%	-0.36%	0.84%
Mediterranean (France)	-0.91%	-0.17%	-0.94%	0.82%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

cont Table 3.2: % Production change in volume at the NUTS 1 level

	AGM	PRM	IND	SERV
East Austria (Austria)	-1.91%	-0.16%	2.12%	0.65%
South Austria (Austria)	-2.68%	-0.16%	2.97%	1.96%
West Austria (Austria)	-2.13%	-0.16%	1.42%	1.03%
Baden-Württemberg (Germany)	-0.97%	-0.17%	-0.41%	0.74%
Bavaria (Germany)	-1.04%	-0.18%	-0.26%	0.50%
Berlin (Germany)	-0.89%	-0.17%	-0.86%	1.36%
Brandenburg (Germany)	-1.06%	-0.18%	-0.72%	2.45%
Bremen (Germany)	-0.87%	0.01%	-0.56%	5.58%
Hamburg (Germany)	-0.89%	-0.17%	-0.78%	1.87%
Hessen (Germany)	-0.92%	-0.17%	-0.63%	0.92%
Mecklenburg-Vorpommern (Germany)	-1.33%	-0.21%	1.93%	2.57%
Lower Saxony (Germany)	-0.94%	-0.18%	-0.41%	0.82%
North Rhine-Westphalia (Germany)	-0.92%	-0.17%	-0.45%	0.45%
Rhineland-Palatinate (Germany)	-0.98%	-0.18%	-0.33%	1.49%
Saarland (Germany)	-0.90%	-0.18%	-0.51%	4.83%
Saxony (Germany)	-1.02%	-0.18%	-0.47%	1.37%
Saxony-Anhalt (Germany)	-0.93%	-0.18%	-0.64%	2.44%
Schleswig-Holstein (Germany)	-0.95%	-0.17%	-0.66%	1.98%
Thuringia (Germany)	-0.98%	-0.18%	-0.52%	2.63%
Luxembourg	-1.25%	-0.15%	0.75%	4.43%
Brussels-Capital Region (Belgium)	-1.21%	-0.17%	1.61%	1.88%
Flemish Region (Belgium)	-1.09%	-0.16%	0.20%	0.71%
Walloon Region (Belgium)	-1.10%	-0.17%	0.20%	1.69%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

cont Table 3.2: % Production change in volume at the NUTS 1 level

	AGM	PRM	IND	SERV
North Netherlands (Netherlands)	-0.94%	-0.15%	0.47%	2.99%
East Netherlands (Netherlands)	-1.00%	-0.16%	0.23%	1.36%
West Netherlands (Netherlands)	-0.90%	-0.16%	0.29%	0.41%
South Netherlands (Netherlands)	-1.05%	-0.16%	0.47%	1.11%
Sweden	-1.00%	-0.17%	0.06%	0.43%
Denmark	-0.97%	-0.15%	-0.07%	0.68%
Mainland Finland (Finland)	-1.00%	-0.17%	0.00%	0.92%
Åland (Finland)	-0.96%	-0.15%	-1.86%	2.32%
Ireland	-2.31%	-0.18%	6.91%	-1.26%
North East England (United Kingdom)	-0.90%	-0.17%	-0.38%	2.18%
North West England (United Kingdom)	-0.85%	-0.21%	-0.69%	0.87%
Yorkshire and the Humber (United Kingdom)	-0.85%	-0.18%	-0.48%	1.09%
East Midlands (United Kingdom)	-0.88%	-0.17%	-0.36%	1.27%
West Midlands (United Kingdom)	-0.90%	-0.17%	-0.41%	1.01%
East of England (United Kingdom)	-0.88%	-0.25%	-0.77%	0.96%
Greater London (United Kingdom)	-0.91%	-0.16%	-1.07%	0.44%
South East England (United Kingdom)	-1.15%	-0.20%	-0.54%	0.55%
South West England (United Kingdom)	-0.94%	-0.18%	-0.46%	0.99%
Wales (United Kingdom)	-1.10%	-0.17%	-0.15%	1.87%
Scotland (United Kingdom)	-0.96%	-0.18%	-0.45%	0.94%
Northern Ireland (United Kingdom)	-1.26%	-0.17%	0.80%	2.89%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

In Tables 3.3, 3.4 and 3.5 attention is focused on the ten greatest (positive and negative) production changes in the AGM, IND and SERV sectors. In Table 3.4 and Table 3.5 the number of varieties (*N*) and the average production per firm ($\bar{Y}$) at the NUTS 1 level are also displayed for the NUTS 1 regions which experience the ten greatest production increases or decreases. The PRM sector is neglected because the variations are generally small and its overall weight is not relevant in the EU15 economy.

Table 3.3: The ten greatest % production decreases in volume at the NUTS 1 level

	AGM
South Austria (Austria)	-2.68%
Ireland	-2.31%
West Austria (Austria)	-2.13%
East Austria (Austria)	-1.91%
Portugal	-1.71%
Attica (Greece)	-1.67%
Mecklenburg-Vorpommern (Germany)	-1.33%
Voreia Ellada (Greece)	-1.28%
Northern Ireland (United Kingdom)	-1.26%
South (Italy)	-1.26%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 3.4: The ten greatest % production increases or decreases in volume at the NUTS 1 level and the associated changes in the number of varieties (*N*) and average production per firm ($\overline{Y}$)

	IND	IND (*N*)	IND ($\overline{Y}$)
Ireland	6.91%	6.91%	0.00%
South Austria (Austria)	2.97%	2.98%	-0.01%
East Austria (Austria)	2.12%	2.13%	-0.01%
Mecklenburg-Vorpommern (Germany)	1.93%	1.94%	-0.01%
Brussels-Capital Region (Belgium)	1.61%	1.62%	-0.02%
West Austria (Austria)	1.42%	1.42%	0.00%
Community of Madrid (Spain)	-1.34%	-1.33%	-0.01%
Attica (Greece)	-1.53%	-1.51%	-0.01%
Åland (Finland)	-1.86%	-0.95%	-0.92%
Nisia Aigaiou-Kriti (Greece)	-8.62%	-8.54%	-0.08%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 3.5: The ten greatest % production increases or decreases in volume at the NUTS 1 level and the associated changes in the number of varieties (*N*) and average production per firm ($\overline{Y}$)

	SERV	SERV (*N*)	SERV ($\overline{Y}$)
Nisia Aigaiou-Kriti (Greece)	8.73%	1.80%	6.81%
Bremen (Germany)	5.58%	0.19%	5.38%
Saarland (Germany)	4.83%	0.25%	4.57%
Luxembourg	4.43%	-0.22%	4.66%
Kentriki Ellada (Greece)	4.14%	0.29%	3.83%
North Netherlands	2.99%	-0.15%	3.15%
Northern Ireland (United Kingdom)	2.89%	-0.17%	3.07%
Voreia Ellada (Greece)	2.70%	0.08%	2.61%
Thuringia (Germany)	2.63%	0.24%	2.39%
Ireland	-1.26%	-2.28%	1.04%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Summarizing, South Austria and Ireland display, at the same time, the greatest decrease in agriculture, respectively, -2.68% and -2.31% and the greatest increase in manufactures, respectively, 2.97% and 6.91% (as in the perfect competition case). Ireland is also the NUTS 1 region which exhibits the greatest decrease in the SERV sector (-1.26%) but unlike the perfect competition case, it is the only region which decreases its production in this sector. In contrast Nisia Aigaiou-Kriti (Greece) has, respectively, the greatest increase in the SERV sector (8.73%) and the greatest decrease in the IND sector (-8.62%). The overall picture at the NUTS 1 level is close to that described in the perfect competition case (see the next section for a detailed comparison).

Concerning the number of varieties (N) and the average production per firm ($\bar{Y}$) in the manufactures and services sectors, it is worth noting that in the IND sector the change is almost completely driven by N, while in the SERV sector it is driven by the combination of the two above-mentioned variables with the prevalence of $\bar{Y}$.

3.4.2 Sensitivity analysis on production reallocation with the introduction of unskilled/skilled labour mobility

In this scenario I suppose that skilled and unskilled workers can respond to the agricultural trade liberalization shock not only by changing the sector but also by emigrating from the NUTS 1 region, to which they belong, to another NUTS 1 region. There are two possible options. In the first one EU15 workers can move only towards other NUTS 1 region within the EU15. In the second option EU15 workers and REU workers can move within the EU27. As explained in the first chapter, the unskilled/skilled labour mobility is modelled through a CET function in which σ_L and σ_H represent, respectively, the elasticity of migration for unskilled factor and skilled factor. In the first option these parameters refer to the EU15 labour market, while in the second option they refer to the EU27 labour market. The aim is to assess the impact of labour mobility on the trade policy outcomes.

Table 3.6 reports the results for production change in volume at the macro-area level under the assumption of unskilled/skilled labour mobility across the NUTS 1 regions within the EU15. The results of Table 3.6 compared to Table 3.1 confirms AGM as the most affected sector in the EU15 even if the % change (-0.81%) is less in magnitude than in the labour immobility case (the same dynamic was observed in the perfect competition case). The economic responses in services and manufactures remain about the same in the world with the important exception of the EU15 manufactures, which change the sign of the % variation from negative to positive with respect to Table 3.1.

Table 3.6: % Production change in volume at the macro-area level

	ROW	EU15	REU
AGM	0.27%	-0.81%	-0.36%
PRM	-0.02%	-0.13%	0.87%
IND	-0.08%	0.52%	0.27%
SERV	0.25%	0.24%	-1.24%

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 3.6 also shows that in the imperfect competition case the variations in the IND and SERV sectors are greater than those observed in the perfect competition case (see Table 2.10 for a comparison). As in the previous subsection, this suggests that imperfect competition influences inter-industry production reallocation at the macro-area level. Let us now move on to the NUTS 1 level.

Tables 3.7, 3.8 and 3.9 display the results of the ten greatest (positive and negative) changes in the AGM, IND and SERV sectors at the NUTS 1 level. The number of varieties (N) and average production per firm ($\overline{Y}$) are also displayed for the IND and SERV sectors.

Table 3.7: The ten greatest % production decreases in volume at the NUTS 1 level

	AGM
South Austria (Austria)	-1.77%
Ireland	-1.64%
West Austria (Austria)	-1.50%
East Austria (Austria)	-1.41%
Portugal	-1.15%
Luxembourg	-1.10%
Attica (Greece)	-1.07%
South (Italy)	-0.98%
Brussels-Capital Region (Belgium)	-0.96%
Île-de-France (France)	-0.92%

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 3.8: The ten greatest % production increases or decreases in volume at the NUTS 1 level and the associated changes in the number of varieties (N) and average production per firm ($\overline{Y}$)

	IND	IND (N)	IND ($\overline{Y}$)
Ireland	50.86%	50.85%	0.00%
Luxembourg	33.95%	33.92%	0.02%
Brussels-Capital Region (Belgium)	27.75%	27.74%	0.01%
East Austria (Austria)	16.68%	16.68%	0.00%
West Netherlands (Netherlands)	16.41%	16.41%	0.00%
Île-de-France (France)	15.53%	15.53%	0.00%
Portugal	-14.88%	-14.88%	0.00%
Attica (Greece)	-16.04%	-16.05%	0.01%
Kentriki Ellada (Greece)	-34.83%	-34.84%	0.01%
Nisia Aigaiou-Kriti (Greece)	-89.99%	-89.99%	0.04%

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 3.9: The ten greatest % production increases or decreases in volume at the NUTS 1 level and the associated changes in the number of varieties (N) and average production per firm ($\overline{Y}$)

	SERV	SERV (N)	SERV ($\overline{Y}$)
Nisia Aigaiou-Kriti (Greece)	26.88%	18.65%	6.94%
Kentriki Ellada (Greece)	16.63%	12.25%	3.90%
Portugal	9.52%	8.62%	0.82%
Voreia Ellada (Greece)	8.44%	5.63%	2.66%
Attica (Greece)	7.30%	5.51%	1.70%
Bremen (Germany)	6.24%	0.73%	5.48%
East Austria (Austria)	-3.68%	-4.82%	1.20%
Île-de-France (France)	-3.78%	-4.03%	0.26%
Luxembourg	-4.52%	-8.83%	4.74%
Ireland	-17.11%	-17.98%	1.06%

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

According to Table 3.7, Austria is affected much in the agricultural sector because all three of its NUTS 1 regions (South Austria, West Austria and East Austria) are in the first four positions of the ranking; however the changes are not very great (between 1% and 2%).

In contrast, Table 3.8 and Table 3.9 show a very strong reallocation of production in manufactures and services with inverse patterns for some NUTS 1 regions. Indeed, two Greek NUTS 1 regions, Nisia Aigaiou-Kriti and Kentriki Ellada, have the highest positive values for production change in services, respectively 26.88% and 16.63%, and the highest negative values for production change in manufactures, respectively -89.99% and -34.83%. Conversely, Ireland and Luxembourg have the highest positive values for production change in manufactures, respectively 50.86% and 33.95%, and the highest negative values for production change in services, respectively -17.11 and -4.52%. As in the subsection 2.7.2, these results are not intended to be realistic, because the labour mobility is probably too high, but they are a guide regarding the relevance of the assumption about labour mobility.

The outcomes do not differ substantially from those obtained in the perfect competition case. Concerning the number of varieties (*N*) and the average production per firm ($\overline{Y}$) and unlike the previous subsection, it is useful to note that in both the IND and SERV sectors the production changes are almost completely driven by *N*. Thus, the labour mobility assumption modifies the weight of these two variables on the overall production change by sector.

Table 3.10 reports results for production change in volume at the macro-area level under the assumption of unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$). Table 3.10 confirms the results of Table 3.6 with the important exception of the REU macro-area, which clearly loses in the integrated labour market within the EU27. Indeed, with respect to Table 3.6, the REU changes the sign of the IND % variation (from positive to negative) and shows a greater decreases in the AGM and SERV sectors (-1.28% and -2.10). This situation is completely opposite to that observed in the perfect competition case where the REU gained from the integrated labour market within the EU27.

Table 3.10: % production change in volume at the macro-area level

	ROW	EU15	REU
AGM	0.27%	-0.82%	-1.28%
PRM	-0.04%	-0.17%	0.52%
IND	-0.08%	0.68%	-0.90%
SERV	0.24%	0.16%	-2.10%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

Tables 3.11, 3.12 and 3.13 display the results of the ten greatest (positive and negative) changes in AGM, IND and SERV sectors for the 68 NUTS 1 regions. The results of these three tables do not significantly change with respect to Tables 3.7, 3.8 and 3.9.

Table 3.11: The ten greatest % production decreases in volume at the NUTS 1 level

	AGM
South Austria (Austria)	-1.60%
Ireland	-1.47%
West Austria (Austria)	-1.41%
East Austria (Austria)	-1.33%
Portugal	-1.19%
Luxembourg	-1.12%
Attica (Greece)	-1.08%
South (Italy)	-1.01%
Île-de-France (France)	-0.95%
Brussels-Capital Region (Belgium)	-0.95%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

Table 3.12: The ten greatest % production increases or decreases in volume at the NUTS 1 level and the associated changes in the number of varieties (N) and average production per firm ($\overline{Y}$)

	IND	IND (N)	IND ($\overline{Y}$)
Ireland	40.40%	40.40%	0.00%
Luxembourg	34.98%	34.96%	0.01%
Brussels-Capital Region (Belgium)	25.67%	25.66%	0.01%
Île-de-France (France)	17.25%	17.25%	0.00%
West Netherlands (Netherlands)	16.91%	16.91%	0.00%
Portugal	-14.09%	-14.10%	0.00%
Attica (Greece)	-14.66%	-14.66%	0.01%
Brandenburg (Germany)	-14.84%	-14.84%	0.00%
Kentriki Ellada (Greece)	-33.76%	-33.77%	0.01%
Nisia Aigaiou-Kriti (Greece)	-89.99%	-89.99%	0.04%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

Table 3.13: The ten greatest % production increases or decreases in volume at the NUTS 1 level and the associated changes in the number of varieties (N) and average production per firm ($\overline{Y}$)

	SERV	SERV (N)	SERV ($\overline{Y}$)
Nisia Aigaiou-Kriti (Greece)	26.95%	18.80%	6.86%
Kentriki Ellada (Greece)	16.37%	12.04%	3.86%
Portugal	9.40%	8.51%	0.81%
Voreia Ellada (Greece)	7.93%	5.16%	2.64%
Attica (Greece)	6.96%	5.19%	1.68%
Brandenburg (Germany)	6.79%	4.42%	2.27%
West Netherlands (Netherlands)	-3.00%	-3.47%	0.49%
Île-de-France (France)	-4.14%	-4.39%	0.26%
Luxembourg	-4.71%	-8.98%	4.70%
Ireland	-13.36%	-14.26%	1.05%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

As noted in the second chapter, the introduction of unskilled/skilled labour mobility within the EU15 and the EU27 determines smaller decreases in the AGM sector and, not surprisingly, a larger production reallocation between the IND and SERV sectors with respect to the labour immobility scenario. Strong *amplification* effects are observed in these two sectors for the NUTS 1 regions, which experienced strong decreases or increases in the case of unskilled/skilled labour immobility. These *amplification* effects occur because workers can now move toward the regions where they receive a higher wage.

3.4.3 Further interesting results

In this subsection I present further interesting results of the trade policy shock. In order to assess the labour reallocation across the NUTS 1 regions after the trade policy simulation, in Tables 3.14 and 3.15 I report migration results, respectively, for unskilled and skilled labour under the assumption of unskilled/skilled labour mobility across the NUTS 1 regions within the EU15.

Table 3.14: Unskilled labour migration within the EU15

	Change in *L* supply
Ireland	2.12%
Luxembourg	0.99%
Brussels-Capital Region (Belgium)	0.87%
Île-de-France (France)	0.60%
South Netherlands (Netherlands)	0.55%
West Netherlands (Netherlands)	0.52%
East Austria (Austria)	0.49%
Mecklenburg-Vor. (Germany)	0.43%
North Netherlands (Netherlands)	0.43%
Brandenburg (Germany)	-0.39%
Community of Madrid (Spain)	-0.44%
South (Spain)	-0.49%
Centre (Spain)	-0.49%
North West (Spain)	-0.50%
Voreia Ellada (Greece)	-0.51%
North East (Spain)	-0.57%
Attica (Greece)	-0.58%
East (Spain)	-0.60%
Kentriki Ellada (Greece)	-0.86%
Nisia Aigaiou-Kriti (Greece)	-0.90%

Notes: The 20 greatest % increases or decreases in unskilled labour supply (σ_L = 10).

Table 3.15: Skilled labour migration within the EU15

	Change in *H* supply
Portugal	3.04%
Nisia Aigaiou-Kriti (Greece)	1.91%
Kentriki Ellada (Greece)	1.71%
Attica (Greece)	1.18%
Voreia Ellada (Greece)	1.03%
East (Spain)	0.74%
Centre (Spain)	0.66%
North West (Spain)	0.65%
North East (Spain)	0.61%
South (Spain)	0.61%
Brandenburg (Germany)	0.55%
East Netherlands (Netherlands)	-0.61%
North Netherlands (Netherlands)	-0.66%
East Austria (Austria)	-0.79%
South Netherlands (Netherlands)	-0.86%
West Netherlands (Netherlands)	-0.87%
Brussels-Capital Region (Belgium)	-1.02%
Île-de-France (France)	-1.07%
Ireland	-2.50%
Luxembourg	-2.51%

Notes: The 20 greatest % increases or decreases in skilled labour supply ($\sigma_H = 10$).

As in Tables 2.18 and 2.19, the NUTS 1 regions displaying the highest sectoral production reallocation also show the highest unskilled/skilled labour reallocation. The labour reallocation follows an inverse pattern in these NUTS 1 regions according to their sectoral specialisation. For example, Ireland and Luxembourg absorb unskilled labour because they have an increase in the IND sector and a decrease in the SERV sector after the trade shock while Kentriki Ellada and Nisia Aigaiou-Kriti absorb skilled labour because they have a decrease in the IND sector and an increase in the SERV sector after the trade shock. Basically, the results do not change with the integrated labour market within the EU27 for the NUTS 1 regions, as it is shown in Table 3.16 and Table 3.17. In general, these outcomes are very close to those obtained in the case of perfect competition.

Table 3.16: Unskilled labour migration within the EU27

	Change in *L* supply
Ireland	1.75%
Luxembourg	1.14%
Brussels-Capital Region (Belgium)	0.84%
Île-de-France (France)	0.74%
West Netherlands (Netherlands)	0.62%
South Netherlands (Netherlands)	0.61%
East Austria (Austria)	0.53%
North Netherlands (Netherlands)	0.50%
East Netherlands (Netherlands)	0.46%
North West (Italy)	0.42%
Centre (Italy)	0.41%
North East (Italy)	0.40%
South (Italy)	0.37%
South (Spain)	-0.36%
North West (Spain)	-0.36%
Attica (Greece)	-0.40%
North East (Spain)	-0.43%
East (Spain)	-0.46%
Kentriki Ellada (Greece)	-0.71%
Nisia Aigaiou-Kriti (Greece)	-0.77%
REU (Rest of Europe)	-2.12%

Notes: The 20 greatest % increases or decreases in unskilled labour supply (σ_L = 10). REU change in unskilled labour supply is also included.

Table 3.17: Skilled labour migration within the EU27

	Change in *H* supply
Portugal	3.12%
Nisia Aigaiou-Kriti (Greece)	2.02%
Kentriki Ellada (Greece)	1.77%
Attica (Greece)	1.18%
Voreia Ellada (Greece)	1.04%
East (Spain)	0.76%
Brandenburg (Germany)	0.70%
Centre (Spain)	0.68%
North West (Spain)	0.68%
South (Spain)	0.64%
North East (Spain)	0.62%
East Austria (Austria)	-0.55%
East Netherlands (Netherlands)	-0.57%
North Netherlands (Netherlands)	-0.60%
South Netherlands (Netherlands)	-0.77%
West Netherlands (Netherlands)	-0.85%
Brussels-Capital Region (Belgium)	-0.96%
Île-de-France (France)	-1.12%
REU (Rest of Europe)	-1.49%
Ireland	-1.98%
Luxembourg	-2.50%

Notes: The 20 greatest % increases or decreases in skilled labour supply (σ_H = 10). REU change in skilled labour supply is also included.

The only notable exception is the Rest of Europe (REU), which is characterised by unskilled/skilled labour emigration (-2.12% and -1.49%) while in the perfect competition case, the REU was characterised by unskilled/skilled labour immigration.

As explained in the second chapter, welfare analysis cannot be carried out at the macro-area level. Therefore, I use a Laspeyres index to evaluate the % change in the overall value added at the NUTS 1 level. Tables 3.18, 3.19 and 3.20 display value added changes corresponding to the three different scenarios about labour mobility.

Table 3.18: The 20 greatest % value added increases or decreases within the EU15

	Change
Ireland	0.44%
Nisia Aigaiou-Kriti (Greece)	0.31%
Attica (Greece)	0.06%
Mecklenburg-Vor. (Germany)	0.05%
Portugal	0.04%
Kentriki Ellada (Greece)	0.03%
East (Spain)	0.03%
North East (Italy)	0.03%
North East (Spain)	0.02%
Community of Madrid (Spain)	0.02%
Flemish Region (Belgium)	-0.02%
Brussels-Capital Region (Belgium)	-0.02%
East Netherlands (Netherlands)	-0.03%
South Austria (Austria)	-0.03%
West Netherlands (Netherlands)	-0.03%
South Netherlands (Netherlands)	-0.03%
West Austria (Austria)	-0.04%
North Netherlands (Netherlands)	-0.04%
East Austria (Austria)	-0.05%
Luxembourg	-0.06%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 3.19: The 20 greatest % value added increases or decreases within the EU15

	Change
Nisia Aigaiou-Kriti (Greece)	3.48%
Ireland	2.84%
Kentriki Ellada (Greece)	1.90%
Portugal	1.35%
Attica (Greece)	0.94%
Voreia Ellada (Greece)	0.82%
East (Spain)	0.51%
North East (Spain)	0.40%
North West (Spain)	0.26%
Flemish Region (Belgium)	-0.30%
Greater London (United Kingdom)	-0.30%
Denmark	-0.33%
North Netherlands (Netherlands)	-0.35%
East Netherlands (Netherlands)	-0.42%
Brussels-Capital Region (Belgium)	-0.47%
East Austria (Austria)	-0.51%
South Netherlands (Netherlands)	-0.54%
West Netherlands (Netherlands)	-0.70%
Île-de-France (France)	-1.14%
Luxembourg	-2.17%

Notes: Unskilled/skilled labour mobility across the NUTS 1 region within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 3.20: The 20 greatest % value added increases or decreases within the EU27

	Change
Nisia Aigaiou-Kriti (Greece)	3.60%
Ireland	2.27%
Kentriki Ellada (Greece)	1.96%
Portugal	1.50%
Attica (Greece)	0.98%
Voreia Ellada (Greece)	0.84%
East (Spain)	0.55%
North East (Spain)	0.44%
North West (Spain)	0.32%
Brandenburg (Germany)	0.31%
South (Spain)	0.29%
North Netherlands (Netherlands)	-0.29%
Greater London (United Kingdom)	-0.30%
East Austria (Austria)	-0.31%
East Netherlands (Netherlands)	-0.36%
Brussels-Capital Region (Belgium)	-0.45%
South Netherlands (Netherlands)	-0.46%
West Netherlands (Netherlands)	-0.66%
Île-de-France (France)	-1.20%
Luxembourg	-2.13%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

The changes are small in the first scenario (labour immobility) but not negligible in the second and third ones (labour mobility within the EU15 and the EU27). The NUTS 1 regions, characterised by a stronger production reallocation, are the ones which experience the most important gains from trade policy reform in terms of increase of value added (Nisia Aigaiou-Kriti, Kentriki Ellada, Ireland, Portugal) and the most important losses from trade policy reform in terms of decrease of value added (West Netherlands, Île-de-France and Luxembourg). Also here, the outcomes are close to those illustrated in the model with perfect competition.

The changes in the trade patterns, i.e. the change in the sectoral imports and exports at the macro-area level, are set out in Tables 3.21, 3.22 and 3.23 for the three different scenarios.

Table 3.21: % Trade pattern change in volume at the macro-area level

		ROW	EU15	REU
AGM	ROW	53.67%	19.11%	14.62%
AGM	EU15	30.91%	-5.25%	38.73%
AGM	REU	44.39%	19.42%	18.75%
PRM	ROW	-0.12%	-0.09%	0.00%
PRM	EU15	-0.23%	-0.19%	-0.12%
PRM	REU	0.72%	0.69%	0.78%
IND	ROW	-0.08%	0.19%	-0.57%
IND	EU15	-0.39%	-0.12%	-0.86%
IND	REU	0.75%	1.02%	0.23%
SERV	ROW	-0.23%	-1.09%	2.74%
SERV	EU15	1.09%	0.22%	4.12%
SERV	REU	-4.70%	-5.52%	-1.83%

Notes: The second column shows the exporting macro-area, the first row the importing macro-area. Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 3.22: % Trade pattern change in volume at the macro-area level

		ROW	EU15	REU
AGM	ROW	53.66%	19.59%	14.61%
AGM	EU15	30.77%	-4.98%	38.57%
AGM	REU	44.41%	19.93%	18.77%
PRM	ROW	-0.13%	0.54%	-0.04%
PRM	EU15	-0.83%	-0.17%	-0.75%
PRM	REU	0.76%	1.39%	0.81%
IND	ROW	-0.11%	0.22%	-0.68%
IND	EU15	-0.18%	0.17%	-0.73%
IND	REU	0.76%	1.09%	0.16%
SERV	ROW	-0.23%	-1.03%	2.80%
SERV	EU15	1.08%	0.28%	4.16%
SERV	REU	-4.78%	-5.54%	-1.86%

Notes: The second column shows the exporting macro-area, the first row the importing macro-area. Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 3.23: % Trade pattern change in volume at the macro-area level

		ROW	EU15	REU
AGM	ROW	53.67%	19.57%	13.26%
AGM	EU15	30.79%	-4.98%	36.96%
AGM	REU	44.72%	20.16%	17.61%
PRM	ROW	-0.12%	0.50%	-1.32%
PRM	EU15	-0.85%	-0.22%	-2.04%
PRM	REU	1.64%	2.21%	0.36%
IND	ROW	-0.10%	0.26%	-1.13%
IND	EU15	-0.17%	0.21%	-1.20%
IND	REU	-0.22%	0.13%	-1.28%
SERV	ROW	-0.23%	-0.99%	2.10%
SERV	EU15	1.09%	0.32%	3.46%
SERV	REU	-5.23%	-5.96%	-2.99%

Notes: The second column shows the exporting macro-area, the first row the importing macro-area. Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

As in the perfect competition case (see Tables 2.25, 2.26 and 2.27 for a comparison), the greatest variations occur in the AGM sector. However, unlike the perfect competition case, the changes in imports are not negligible also in the other sectors at the macro-area level. For example, the REU macro-areas decreases its exports toward the EU15 and ROW by more than 4% in the SERV sector. In contrast, the EU15 macro-area increases its exports toward the REU and ROW by more than 1% in the same sector. Therefore, the term of trade effect, which is driven by the change in the demand at the macro-area level after the agricultural liberalization, is of benefit to the EU15 and is to the detriment of the REU.

Finally, welfare analysis is carried out at the macro-area level. Table 3.24 lays out the welfare gains measured in EV $ million under the three different labour market scenarios.

Table 3.24: Equivalent variation at the macro-area level

	ROW	EU15	REU
$\sigma_L = \sigma_H = 0$ within EU15	-78925	1289	-6645
$\sigma_L = \sigma_H = 10$ within EU15	-80526	4286	-6759
$\sigma_L = \sigma_H = 10$ within EU27	-79522	8055	-11217

Notes: $ million.

Under the assumption of unskilled/skilled labour immobility at the NUTS 1 level within the EU15, the ROW loses about $78925 million, REU loses $6645 million and EU15 is the only winner because it gains $1289 million. In the second scenario, i.e. labour mobility within the EU15, the ROW loses $80526 million, REU loses $6759 million and EU15 gains $4286 million. Finally, by assuming an integrated labour market within the EU27, the ROW loses $79522 million, REU loses $11217 million and EU15 gains $8055 million. This picture of the welfare change is very different from that obtained in the perfect competition case. In the perfect competition case, the shock caused welfare gains, even if very limited, especially if compared to those obtained in other studies (Hertel and Keeney, 2005; Bouet *et al*., 2005). In addition, by assuming an integrated labour market within the EU27, the REU macro-area was the winner, while the EU15 macro-area was the loser. In the imperfect competition case, the outcomes are reversed: the EU15 wins and the REU loses. Moreover and significantly, it is possible to note that the tariff liberalization in the agricultural sector causes a decrease in the overall welfare at the world level in all three labour market scenarios. This is a very striking result but great caution should be exercised because the outcomes could depend on the NUTS regional level adopted to define the production structure, as already underlined in the second chapter. However, in my model the hypothesis about the perfect/imperfect competition in the goods market is crucial for analysing the welfare effect of trade policy liberalization.

The welfare analysis is also carried out also by assessing the change in the number of varieties (*N*) at the macro-area level according to the "love of variety" approach of Krugman (1979). Tables 3.25, 3.26 and 3.27 confirm the fact that in the Rest of the world (ROW) the welfare also decreases in terms of number of varieties in all three labour market scenarios.

Concerning the EU15 and REU, Tables 3.25, 3.26 and 3.27 again show that the EU15 is the winning macro-area while the REU is the loser. Indeed, by assuming perfect labour immobility at the NUTS 1 level, the number of varieties for the EU15 decreases by 0.13% in the IND sector but increases by 0.09% in the SERV sector; in contrast, the number of varieties for the REU increases by 0.22% in the IND sector but exhibits a strong decrease in the SERV sector (-5.59%).

By assuming labour mobility at the NUTS 1 level, the number of varieties for the EU15 increases by 0.11% in the IND sector and by 0.14% in the SERV sector; in contrast, the number of varieties for the REU increases by 0.20% in the IND sector but continues to exhibit a strong decrease in the SERV sector (-5.70%).

Assuming an integrated labour market within the EU27 is the worst scenario for the REU which experiences a decrease in both the IND and SERV sectors (-0.79% and -6.43%); in contrast, the EU15 shows increases in both the IND and SERV sectors (0.12% and 0.17).

These outcomes are consistent with the effects of trade policy liberalization on the trade patterns and welfare measured in terms of equivalent variation.

It is possible to conclude that the distance between the first best solution (perfect competition) and a second best solution (imperfect competition) is appreciable in terms of welfare, while the results for the production reallocation at the NUTS level do not seem very different between perfect and imperfect competition.

Table 3.25: % Change in the number of varieties (*N*) at the macro-area level

	ROW	EU15	REU
IND	-0.05%	-0.13%	0.22%
SERV	-1.15%	0.09%	-5.59%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 3.26: % Change in the number of varieties (*N*) at the macro-area level

	ROW	EU15	REU
IND	-0.07%	0.11%	0.20%
SERV	-1.17%	0.14%	-5.70%

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 3.27: % Change in the number of varieties (*N*) at the macro-area level

	ROW	EU15	REU
IND	-0.06%	0.12%	-0.79%
SERV	-1.15%	0.17%	-6.43%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

3.5 Interpretation of the results

The previous section shows that imperfect competition influences the welfare analysis and the production reallocation across sectors at the macro-area level. At first glance, the results at the NUTS 1 level do not differ very much between imperfect competition and perfect competition.

In this section an in-depth comparison is carried out to verify if the production reallocation at the NUTS 1 level does not change much using the perfect or imperfect competition scheme.

Tables 3.28, 3.29 and 3.30 display the ten greatest % decreases or increases in production at the NUTS 1 level for the AGM, IND and SERV sectors in the two schemes (perfect and imperfect competition) under the assumption of perfect labour immobility at the NUTS 1 level. The NUTS 1 regions and the associated production changes, which match each other, are reported in bold.

Table 3.28: The ten greatest % production decreases in volume at the NUTS 1 level in the model with perfect competition (*pc*) and imperfect competition (*ic*)

	AGM (*pc*)		AGM (*ic*)
South Austria (Austria)	**-2.47%**	**South Austria (Austria)**	**-2.68%**
Ireland	**-2.15%**	**Ireland**	**-2.31%**
West Austria (Austria)	**-1.95%**	**West Austria (Austria)**	**-2.13%**
East Austria (Austria)	**-1.74%**	**East Austria (Austria)**	**-1.91%**
Portugal	**-1.47%**	**Portugal**	**-1.71%**
Attica (Greece)	**-1.44%**	**Attica (Greece)**	**-1.67%**
Mecklenburg-Vo. (Germany)	**-1.19%**	**Mecklenburg-Vo. (Germany)**	-1.33%
Northern Ireland	**-1.10%**	**Voreia Ellada (Greece)**	**-1.28%**
Luxembourg	-1.10%	**Northern Ireland (UK)**	**-1.26%**
Voreia Ellada (Greece)	**-1.10%**	South (Italy)	-1.26%

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 3.29: The ten greatest % production increases or decreases in volume at the NUTS 1 level in the model with perfect (*pc*) and imperfect competition (*ic*)

	IND (*pc*)		IND (*ic*)
Ireland	**7.02%**	**Ireland**	**6.91%**
South Austria (Austria)	**2.99%**	**South Austria (Austria)**	**2.97%**
East Austria (Austria)	**2.40%**	**East Austria (Austria)**	**2.12%**
Mecklenburg-Vo. (Germany)	**2.10%**	**Mecklenburg-Vo. (Germany)**	**1.93%**
Brussels-Cap. Reg. (Belgium)	**1.94%**	**Brussels-Cap. Reg. (Belgium)**	**1.61%**
West Austria (Austria)	**1.55%**	**West Austria (Austria)**	**1.42%**
Luxembourg	1.06%	**Community of Madrid (Spain)**	**-1.34%**
Community of Madrid (Spain)	**-1.15%**	**Attica (Greece)**	**-1.53%**
Attica (Greece)	**-1.38%**	Åland (Finland)	-1.86%
Nisia Aigaiou-Kriti (Greece)	**-7.62%**	**Nisia Aigaiou-Kriti (Greece)**	**-8.62%**

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

Table 3.30: The ten greatest % production increases or decreases in volume at the NUTS 1 level in the model with perfect (*pc*) and imperfect competition (*ic*)

	SERV (*pc*)		SERV (*ic*)
Nisia Aigaiou-Kriti (Greece)	**1.62%**	**Nisia Aigaiou-Kriti (Greece)**	**8.73%**
Attica (Greece)	0.47%	Bremen (Germany)	5.58%
Portugal	0.47%	Saarland (Germany)	4.83%
East (Spain)	0.43%	Luxembourg	4.43%
North East (Spain)	0.39%	Kentriki Ellada (Greece)	4.14%
Mecklenburg-Vo. (Germany)	-0.50%	North Nether. (Netherlands)	2.99%
East Austria (Austria)	-0.59%	Northern Ireland (UK)	2.89%
West Austria (Austria)	-0.63%	Voreia Ellada (Greece)	2.70%
South Austria (Austria)	-1.15%	Thuringia (Germany)	2.63%
Ireland	**-2.31%**	**Ireland**	**-1.26%**

Notes: Unskilled/skilled labour immobility at the NUTS 1 level within the EU15 ($\sigma_L = \sigma_H = 0$).

In the agricultural sector and manufactures nine regions out of ten match each other. In services only two regions out of ten match each other; however, they are the NUTS 1 regions which exhibit the greatest decrease and the greatest increase. In addition, in the SERV sector the sign of the production change is always positive with the imperfect competition scheme except for Ireland. In contrast, the sign is equally positive and negative with the perfect competition scheme. An unexpected result is the increase in the SERV sector of Northern Ireland, which has a value of the key parameter *α(ind/serv)*, i.e. the sectoral difference between the ratios of the unskilled labour intensity to the skilled labour intensity in the IND and SERV sectors, which is among the ten lowest values of this parameter (see Tables 2.34 and 2.36). As reported in section 2.8, further channels, in addition to the sectoral difference between the ratios of the unskilled labour intensity to the skilled labour intensity, are likely to work in determining the sign in the IND and SERV sectors. It is interesting to note that the increase in the SERV sector for the Nisia Aigaiou-Kriti jumps from 1.62% in the perfect competition to 8.73% in the imperfect competition while the decrease in the same sector for Ireland falls from -2.31% to -1.26% (see Table 3.30).

Tables 3.31, 3.32 and 3.33 display the ten greatest decreases or increases of production at the NUTS 1 level for the AGM, IND and SERV sectors in the two schemes (perfect and imperfect competition) under the assumption of labour mobility across the NUTS 1 regions within the EU15. The NUTS 1 regions and the associated production changes, which match each other, are reported in bold.

In the agricultural sector and services eight regions out of ten match each other while in manufactures ten regions out of ten match each other. The increases are amplified in the IND and SERV sectors moving from the perfect to the imperfect competition scheme.

Table 3.31: The ten greatest % production decreases in volume at the NUTS 1 level in the model with perfect competition (*pc*) and imperfect competition (*ic*)

	AGM (*pc*)		AGM (*ic*)
South Austria (Austria)	**-1.72%**	**South Austria (Austria)**	**-1.77%**
West Austria (Austria)	**-1.43%**	**Ireland**	**-1.64%**
East Austria (Austria)	**-1.28%**	**West Austria (Austria)**	**-1.50%**
Ireland	**-1.28%**	**East Austria (Austria)**	**-1.41%**
Portugal	**-1.27%**	**Portugal**	**-1.15%**
Attica (Greece)	**-1.22%**	**Luxembourg**	**-1.10%**
Voreia Ellada (Greece)	-0.95%	**Attica (Greece)**	**-1.07%**
Luxembourg	**-0.94%**	**South (Italy)**	**-0.98%**
South (Italy)	**-0.91%**	Brussels-Cap. Reg. (Belgium)	-0.96%
Islands (Italy)	-0.82%	Île-de-France (France)	-0.92%

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 3.32: The ten greatest % production increases or decreases in volume at the NUTS 1 level in the model with perfect (*pc*) and imperfect competition (*ic*)

	IND (*pc*)		IND (*ic*)
Ireland	**31.40%**	**Ireland**	**50.86%**
Luxembourg	**23.33%**	**Luxembourg**	**33.95%**
Brussels Ca. Reg. (Belgium)	**17.87%**	**Brussels-Ca. Reg. (Belgium)**	**27.75%**
West Nether. (Netherlands)	**11.23%**	**East Austria (Austria)**	**16.68%**
East Austria (Austria)	**11.19%**	**West Nether. (Netherlands)**	**16.41%**
Île-de-France (France)	**10.93%**	**Île-de-France (France)**	**15.53%**
Portugal	**-9.51%**	**Portugal**	**-14.88%**
Attica (Greece)	**-10.24%**	**Attica (Greece)**	**-16.04%**
Kentriki Ellada (Greece)	**-21.04%**	**Kentriki Ellada (Greece)**	**-34.83%**
Nisia Aigaiou-Kriti (Greece)	**-90.00%**	**Nisia Aigaiou-Kriti (Greece)**	**-89.99%**

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Table 3.33: The ten greatest % production increases or decreases in volume at the NUTS 1 level in the model with perfect (*pc*) and imperfect competition (*ic*)

	SERV (*pc*)		SERV (*ic*)
Nisia Aigaiou-Kriti (Greece)	**18.64%**	**Nisia Aigaiou-Kriti (Greece)**	**26.88%**
Kentriki Ellada (Greece)	**7.53%**	**Kentriki Ellada (Greece)**	**16.63%**
Portugal	**5.61%**	**Portugal**	**9.52%**
Attica (Greece)	**3.56%**	**Voreia Ellada (Greece)**	**8.44%**
Voreia Ellada (Greece)	**3.41%**	**Attica (Greece)**	**7.30%**
East (Spain)	3.25%	Bremen (Germany)	6.24%
North East (Spain)	2.99%	**East Austria (Austria)**	**-3.68%**
East Austria (Austria)	**-3.19%**	Île-de-France (France)	-3.78%
Luxembourg	**-6.06%**	**Luxembourg**	**-4.52%**
Ireland	**-11.09%**	**Ireland**	**-17.11%**

Notes: Unskilled/skilled labour mobility across the NUTS 1 regions within the EU15 ($\sigma_L = \sigma_H = 10$).

Finally, Tables 3.34, 3.35 and 3.36 display the ten greatest % decreases or increases of production at the NUTS 1 level for the AGM, IND and SERV sectors in the two schemes (perfect and imperfect competition) under the assumption of labour mobility between the NUTS 1 regions (EU15) and REU within the EU27. The NUTS 1 regions and the associated production changes, which match each other, are reported in bold.

In the agricultural sector eight regions out of ten match each other, in manufactures nine regions out of ten match each other and in services seven regions out of ten match each other. As in the labour mobility scenario within the EU15, the increases are amplified in the IND and SERV sectors moving from the perfect to the imperfect competition scheme. An unexpected result is the increase in the SERV sector of Brandenburg, which has a value of the key parameter *α(ind/serv)*, i.e. the sectoral difference between the ratios of the unskilled labour intensity to the skilled labour intensity in the IND and SERV sectors, which is among the ten lowest values of this parameter (see Table 2.34 and 2.36).

Table 3.34: The ten greatest % production decreases in volume at the NUTS 1 level in the model with perfect competition (*pc*) and imperfect competition (*ic*)

	AGM (*pc*)		AGM (*ic*)
South Austria (Austria)	**-1.74%**	**South Austria (Austria)**	**-1.60%**
West Austria (Austria)	**-1.44%**	**Ireland**	**-1.47%**
Ireland	**-1.30%**	**West Austria (Austria)**	**-1.41%**
East Austria (Austria)	**-1.29%**	**East Austria (Austria)**	**-1.33%**
Portugal	**-1.27%**	**Portugal**	**-1.19%**
Attica (Greece)	**-1.22%**	**Luxembourg**	**-1.12%**
Voreia Ellada (Greece)	-0.94%	**Attica (Greece)**	**-1.08%**
Luxembourg	**-0.94%**	**South (Italy)**	**-1.01%**
South (Italy)	**-0.91%**	Île-de-France (France)	-0.95%
Islands (Italy)	-0.81%	Brussels-Cap. Reg. (Belgium)	-0.95%

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

Table 3.35: The ten greatest % production increases or decreases in volume at the NUTS 1 level in the model with perfect (*pc*) and imperfect competition (*ic*)

	IND (*pc*)		IND (*ic*)
Ireland	**32.84%**	**Ireland**	**40.40%**
Luxembourg	**23.34%**	**Luxembourg**	**34.98%**
Brussels Cap. Reg. (Belgium)	**18.23%**	**Brussels-Cap. Reg. (Belgium)**	**25.67%**
East Austria (Austria)	11.67%	**Île-de-France (France)**	**17.25%**
West Nether. (Netherlands)	**11.24%**	**West Nether. (Netherlands)**	**16.91%**
Île-de-France (France)	**10.79%**	**Portugal**	**-14.09%**
Portugal	**-9.65%**	**Attica (Greece)**	**-14.66%**
Attica (Greece)	**-10.46%**	Brandenburg (Germany)	-14.84%
Kentriki Ellada (Greece)	**-21.28%**	**Kentriki Ellada (Greece)**	**-33.76%**
Nisia Aigaiou-Kriti (Greece)	**-95.00%**	**Nisia Aigaiou-Kriti (Greece)**	**-89.99%**

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

Table 3.33: The ten greatest % production increases or decreases in volume at the NUTS 1 level in the model with perfect (*pc*) and imperfect competition (*ic*)

	SERV (*pc*)		SERV (*ic*)
Nisia Aigaiou-Kriti (Greece)	**19.64%**	**Nisia Aigaiou-Kriti (Greece)**	**26.95%**
Kentriki Ellada (Greece)	**7.60%**	**Kentriki Ellada (Greece)**	**16.37%**
Portugal	**5.65%**	**Portugal**	**9.40%**
Attica (Greece)	**3.61%**	**Voreia Ellada (Greece)**	**7.93%**
Voreia Ellada (Greece)	**3.48%**	**Attica (Greece)**	**6.96%**
East (Spain)	3.29%	Brandenburg (Germany)	6.79%
South Nether. (Netherlands)	-3.05%	West Nether. (Netherlands)	-3.00%
East Austria (Austria)	-3.34%	Île-de-France (France)	-4.14%
Luxembourg	**-6.08%**	**Luxembourg**	**-4.71%**
Ireland	**-11.60%**	**Ireland**	**-13.36%**

Notes: Unskilled/skilled labour mobility between the NUTS 1 regions (EU15) and the Rest of Europe (REU) within the EU27 ($\sigma_L = \sigma_H = 10$).

It can be said that the production outcomes at the NUTS level do not differ greatly between perfect and imperfect competition. In addition, the introduction of the labour mobility improves the likeness of the results between the two schemes.

The reason, which can explain the likeness of the NUTS results and the difference of the results at the macro-area level between the perfect and imperfect competition cases, is that the demand is specified at the macro-area level (EU15 as a whole). As a result, the aggregate demand effect of the shock is shared across all the NUTS 1 regions according to their technology, i.e. the intensity by which the NUTS 1 regions use the input factors (especially the skilled and unskilled factors as explained through the stylised model). These intensities do not change between perfect and imperfect competition. Therefore, the aggregate demand effect of the shock, which in contrast changes between perfect and imperfect competition, is shared across the NUTS 1 regions in the same way. Thus, the interpretation, which was given in the second chapter based on the sectoral difference between the ratios of the unskilled labour intensity to the skilled labour intensity, remains valid.

Conclusions

The aim of this work was to build a global CGE model at the NUTS 1 level for trade policy evaluation. The model was applied to the 68 NUTS 1 regions in the EU15 mainly to assess the production reallocation across sectors in each NUTS 1 region after a world tariff liberalization in agriculture. Nevertheless, it can also be used to simulate other trade policy reforms according to the special interest of the researcher. Special attention is given to the economic interpretation of the trade policy effects. Indeed, a weak link of the CGE approach is the poor economic interpretation of the results.

The results at the NUTS 1 level are the following. The tariff liberalization in agriculture has a strong effect in the Austrian regions (East, West and South), Ireland and Portugal in the AGM sector. However, all the NUTS 1 regions decrease production in this sector. In the IND and SERV sectors it is possible to note inverse patterns of production at the NUTS 1 level. Indeed, Nisia Aigaiou-Kriti, Attica and Portugal show the greatest decreases in the IND sector while Ireland, East Austria and Luxembourg experience the greatest increase in this sector. In contrast, Nisia Aigaiou-Kriti, Attica and Portugal exhibit the greatest increases in the SERV sector while Ireland, East Austria and Luxembourg show the greatest decrease in this sector.

The stylised model allows the key parameter to be determined for interpreting the results. This parameter is the sectoral difference between the ratios of unskilled labour intensity to skilled labour intensity. Indeed, skilled labour and unskilled labour can be considered as the source of the heterogeneity across the NUTS 1 regions. To summarize, trade policy strikes the AGM sector and causes a production decrease in the AGM sector for all the NUTS 1 regions. The NUTS 1 regions, which use unskilled labour in the AGM sector and skilled labour in the IND and SERV sectors more intensively with respect to the other NUTS 1 regions, are the regions most affected in the AGM sector. The decrease in the AGM production, in turn, determines a production reallocation and reduces the labour demand for unskilled labour. As a result, in general the unskilled factor loses (the wage goes down) and the skilled factor wins (the wage goes up). However, in the NUTS 1 regions which use the unskilled labour in the IND sector and the skilled labour in the SERV sector more intensively, the IND production decreases and SERV production increases. In contrast, in the NUTS 1 regions, which use the unskilled and skilled factors in the IND and SERV sectors by similar intensities, the IND production goes up and the SERV production goes down.

The introduction of the labour mobility within the EU15 and the EU27 causes *amplification* effects for the NUTS 1 regions which experienced strong increases or decreases in the IND and SERV sectors under the assumption of perfect immobility at the NUTS 1 level. In general, this hypothesis has a strong impact on the outcomes and determines unrealistic variations of the production in the services and manufactures sectors after agricultural liberalization. These results are not intended to be realistic but are a guide regarding the relevance of the assumption about labour mobility.

The results at the NUTS 1 level are robust enough between perfect competition and imperfect competition. A possible explanation is that the demand is specified at the macro-area level (EU15 as a whole). As a result, the aggregate demand effect of the shock is shared across all the NUTS 1 regions according to their technology, i.e. the intensity by which the NUTS 1 regions use the input factors (especially the skilled and unskilled factors). These intensities do not change moving from perfect to imperfect competition.

In contrast, the results at the macro-area level change greatly. Imperfect competition influences inter-industry production reallocation and welfare at the macro-area level.

Concerning the welfare analysis, very limited gains are obtained from trade liberalization with the perfect competition scheme. The welfare change is measured in terms of equivalent variation. The world gains are light under all three labour mobility scenarios, especially if compared to those observed in other studies (Hertel and Keeney, 2005; Bouet *et al*., 2005). In the third scenario, the integrated labour market within the EU27, the EU15 loses and the Rest of Europe (REU) wins.

With the imperfect competition the tariff liberalization in the agricultural sector causes a decrease in the overall welfare at the world level in all three labour market scenarios. This is a very striking result but great caution should be exercised because the outcomes could depend on the NUTS regional level adopted to define the production structure. Only the EU15 benefits from agricultural liberalization. Concerning the integrated labour market within the EU27, it can be noted that there is an opposite outcome with respect the perfect competition scheme; indeed in this case the EU15 wins and REU loses.

In the imperfect competition framework the welfare analysis can also be carried out by assessing the change in the number of varieties at the macro-area level according to the "love of variety" approach of Krugman (1979). This analysis confirms the fact that in the Rest of the world (ROW) the welfare also decreases in terms of number of varieties in all three labour market scenarios. Concerning the EU15 and REU, the EU15 is again the winner while the REU is the loser.

To summarize, the distance between the first best solution (perfect competition) and a second best solution (imperfect competition), modelled by the Cournot-Nash scheme, is appreciable in terms of welfare at the macro-area level, while the results for the production reallocation at the NUTS level are not very different between the two schemes.

Let us now move on to a description of the possible extensions for further research.

The focus of this model is on the production side. I concentrated my attention on the skilled and unskilled factors at the NUTS 1 level because of data constraints. Nevertheless other factors can be considered or added in order to make the analysis more complete.

Another issues is the welfare analysis. The policy maker is probably also interested in assessing the welfare change at the NUTS 1 level after a trade liberalization. This implies the introduction of a representative household in each NUTS 1 region, as in the approach of Jean and Laborde (2004). This, in turn, requires much more data, for example, on consumption, income and savings at the regional level. However, the lack of well suited data to model the trade flows across the NUTS regions and between the NUTS regions and the other parts of the world remains a serious constraint. Simplifying assumption must be made.

A more detailed regional level (NUTS 2 or NUTS 3) could be developed even if the computational tractability of the model should be verified.

In this model an agricultural tariff liberalization was implemented but only the agricultural market access at the world level was analysed. I made this choice to preserve the simplicity of the model in order to better understand its economic results and to make the most of the MAcMap database, which was expressly created for the *computable general equilibrium* analysis. However, the protection of agriculture is very tricky, especially in the European Union, where the *Common Agricultural Policy* (CAP) plays an important role. Therefore, it could be interesting to study the interactions between the market access liberalization with the other pillars of trade protection in agriculture: export subsidies, domestic support and quotas.

A more technical development of the model concerns the elasticity value of migration in the CET functions within Europe. As noted, a high labour mobility within Europe implies unrealistic production reallocation between the IND and SERV sectors. Common sense would suggest an elasticity value closer to zero than to ten. However, an econometric analysis would help to give a greater robustness to the model. In addition, the econometric analysis should distinguish between unskilled labour mobility and skilled labour mobility.

Other weak links of the CGE trade models, such as GTAP and MIRAGE, is the full employment of the factors (especially labour) and the exogenus aggregate productivity. An attempt to incorporate endogenous unemployment and productivity in the model would be praiseworthy. The Melitz model (2003) allows for the endogenous determination of aggregate productivity. As shown, two applications of the Melitz assumption to CGE trade models exist: Balistreri, Hillberry and Rutherford (2007) and Zhai (2008). However, inserting these two variables at the NUTS 1 level is a very difficult task in terms of data requirements and computational resources.

Appendix 1: notation

i and j denote the sector ($i \neq j$)

nut and nut* denote the NUTS 1 regions ($nut \neq nut*$)

mac and mac* denote the macro-areas ($mac \neq mac*$)

Appendix 2: list of variables

Demand

$DEMTOT_{i,mac}$	Total demand
$PDEMTOT_{i,mac}$	Price of total demand
$PY_{i,mac}$	Marginal cost
$BUDC_{mac}$	Budget allocated to consumption
UT_{mac}	Utility
PUT_{mac}	Price of utility
$C_{i,mac}$	Consumption
$PC_{i,mac}$	Price of consumption
$KG_{i,mac}$	Capital goods
$PKG_{i,mac}$	Price of capital goods
$D_{i,mac}$	Domestic demand
$PD_{i,mac}$	Price of domestic good
$M_{i,mac}$	Aggregate imports
$PM_{i,mac}$	Price of aggregate imports
$DEM_{i,mac,mac*}$	Demand in macro-area *mac** of good *i* produced in *mac*
$PDEM_{i,mac,mac*}$	Price in macro-area *mac** of good *i* produced in *mac*
$PINI_{i,j,mac}$	Price of intermediate inputs in macro-area *mac* produced in sector *i* and sold to sector *j*
$DVAR_{i,mac}$	Domestic demand for variety produced in macro-area *mac*

$PDVAR_{i,mac}$	Price of variety produced in *mac* and sold in *mac*
$DEMVAR_{i,mac,mac*}$	Demand in macro-area *mac** for variety produced in *mac*
$PDEMVAR_{i,mac,mac*}$	Price of variety produced in *mac* and sold in *mac**
$EPD_{i,mac}$	Perceived price elasticity in market *mac* for domestic variety
$EP_{i,mac,mac*}$	Perceived price elasticity in macro-area *mac** for variety produced in *mac*
$SDT_{i,mac}$	Share of domestic demand over total demand in *mac*
$SM_{i,mac,mac*}$	Share of imports in macro-area *mac** of good *i* produced in *mac* over total imports of *mac**
$ST_{i,mac,mac*}$	Share of imports in macro-area *mac** of good *i* produced in *mac* over total demand of *mac**

Production

$VA_{i,nut}$	Value added
$PVA_{i,nut}$	Price of valued added
$AINI_{i,nut}$	Aggregate intermediate inputs
$PAINI_{i,nut}$	Price of aggregate intermediate inputs
$INI_{i,nut,nut*}$	Intermediate inputs
$L_{i,nut}$	Unskilled labour demand
PL_{nut}	Price of unskilled labour
$TE_{i,nut}$	Land demand
$PTE_{i,nut}$	Price of land
$RN_{i,nut}$	Natural resources demand
$PRN_{i,nut}$	Price of natural resources
$Q_{i,nut}$	Fictive factor demand
$PQ_{i,nut}$	Price of fictive factor
$K_{i,nut}$	Capital demand
PK_{mac}	Price of capital in macro-area *mac*
$H_{i,nut}$	Skilled labour demand
PH_{nut}	Price of skilled labour
$N_{i,nut}$	Number of varieties

Factor markets

$HSUP_{nut}$	Skilled labour supply
$LSUP_{nut}$	Unskilled labour supply

Macro-economic closure

INV_{mac}	Investment
$PINV_{mac}$	Price of investment
REV_{mac}	Income

Appendix 3: list of parameters

Demand

$\alpha C_{i,mac}$	Coefficient of consumption in LES-CES function
$\alpha KG_{i,mac}$	Coefficient of capital goods in CES function
$\alpha D_{i,mac}$	Coefficient of domestic good in CES Armington function
$\alpha M_{i,mac}$	Coefficient of aggregate imports good in CES Arm. function
$\alpha IMP_{i,mac,mac*}$	Coefficient of imports from *mac* to *mac** in CES imp. function
$ATR_{i,mac,mac*}$	*Ad valorem* tariff rate applied by *mac** and paid by *mac*
σ_C	Elasticity of substitution of consumption
σ_{KG}	Elasticity of substitution of capital goods
σ_{INI}	Elasticity of substitution of intermediate inputs
σ_{ARM_i}	Armington elasticity of substitution
σ_{IMP_i}	Elasticity of substitution across imports
σ_{VAR_i}	Elasticity of substitution across varieties
$cmin_{i,mac}$	Minimum consumption in LES-CES function

Production

$\alpha VA_{i,nut}$	Coefficient of value added in Leontief function
$\alpha AINI_{i,nut}$	Coef. of aggregate intermediate input in Leontief function
$\alpha INI_{i,j,nut}$	Coef. of intermediate input in aggr. interm. input CES function
$\alpha L_{i,nut}$	Coef. of unskilled labour in valued added CES function
$\alpha TE_{i,nut}$	Coef. of land in valued added CES function
$\alpha RN_{i,nut}$	Coef. of natural resources in valued added CES function
$\alpha Q_{i,nut}$	Coef. of fictive factor in valued added CES function
$\alpha K_{i,nut}$	Coef. of capital in fictive factor CES function
$\alpha H_{i,nut}$	Coef. of skilled labour in fictive factor CES function
σ_{VA}	Elasticity of substitution across primary inputs
σ_{CAP}	Elasticity of substitution between capital and skilled labour
$fc_{i,nut}$	Fixed cost in imperfect competition scheme

Factor markets

αLS_{nut}	Coef. of unskilled labour in unsk. labour supply CET function
αHS_{nut}	Coef. of skilled labour in skilled labour supply CET function
σ_{L}	Elasticity of migration in unsk. labour supply CET function
σ_{H}	Elasticity of migration in skilled labour supply CET function
$KSUP_{mac}$	Capital supply at macro-area level
$HTOTSUP_{mac}$	Skilled labour supply at macro-area level
$LTOTSUP_{mac}$	Unskilled labour supply at macro-area level
$RNSUP_{i,nut}$	Natuaral resources supply at NUTS level
$TESUP_{nut}$	Land supply at NUTS level
$HTOTSUP_{EU27}$	Skilled labour supply at macro-area level in the EU27
$LTOTSUP_{EU27}$	Unskilled labour supply at macro-area level in the EU27

Macro-economic closure

sav_{mac}	Exogenous saving rate
BAL_{mac}	Current account balance surplus

Appendix 4: list of equations

Equilibrium in the goods market (perfect competition):

$$\sum_{nut \in mac} Y_{i,nut} = D_{i,mac} + \sum_{mac^* \neq mac} DEM_{i,mac,mac^*} \qquad \text{(A.1)}$$

Equilibrium in the goods market (imperfect competition):

$$\sum_{nut \in mac} Y_{i,nut} = DVAR_{i,mac} + \sum_{mac^* \neq mac} DEMVAR_{i,mac,mac^*} \qquad \text{(A.2)}$$

Demand

Total demand:

$$DEMTOT_{i,mac} = C_{i,mac} + KG_{i,mac} + \sum_{nut \in mac} \sum_{j} INI_{i,j,nut} \qquad \text{(A.3)}$$

LES-CES constraint for consumption:

$$\begin{aligned} &\min PUT_{mac} UT_{mac} = \sum_{i} PC_{i,mac} \left(C_{i,mac} - cmin_{i,mac} \right) \\ &s.t. \quad UT_{mac}^{1-1/\sigma_C} = \sum_{i} \alpha C_{i,mac} \left(C_{i,mac} - cmin_{i,mac} \right)^{1-1/\sigma_C} \end{aligned} \qquad \text{(A.4)}$$

Budget allocated to consumption:

$$BUDC_{mac} = \sum_{i} PC_{i,mac} C_{i,mac} \qquad \text{(A.5)}$$

CES constraint for capital goods:

$$\begin{aligned}&\min PINVTOT_{mac}INVTOT_{mac}=\sum_i PKG_{i,mac}KG_{i,mac}\\&s.t.\quad INVTOT_{mac}^{1-1/\sigma_{KG}}=\sum_i \alpha KG_{i,mac}KG_{i,mac}^{1-1/\sigma_{KG}}\end{aligned} \tag{A.6}$$

Armington CES function:

$$\begin{aligned}&\min PDEMTOT_{i,mac}DEMTOT_{i,mac}=PD_{i,mac}D_{i,mac}+PM_{i,mac}M_{i,mac}\\&s.t.\quad DEMTOT_{i,c}^{1-1/\sigma_{ARM_i}}=\alpha D_{i,mac}D_{i,mac}^{1-1/\sigma_{ARM_i}}+\alpha M_{i,mac}M_{i,mac}^{1-1/\sigma_{ARM_i}}\end{aligned} \tag{A.7}$$

CES imports function:

$$\begin{aligned}&\min PM_{i,mac}M_{i,mac}=\sum_{mac^*\neq mac} PDEM_{i,mac^*,mac}DEM_{i,mac^*,mac}\\&s.t.\quad M_{i,mac}^{1-1/\sigma_{IMP_i}}=\sum_{mac^*\neq mac}\alpha IMP_{i,mac^*,mac}DEM_{i,mac^*,mac}^{1-1/\sigma_{IMP_i}}\end{aligned} \tag{A.8}$$

Varieties (imperfect competition):

$$\left(\sum_{nut\in mac} N_{i,nut}\right)DEMVAR_{i,mac}^{1-1/\sigma_{VAR_i}}=DEM_{i,mac}^{1-1/\sigma_{VAR_i}} \tag{A.9}$$

$$\left(\sum_{nut\in mac} N_{i,nut}\right)DVAR_{i,mac}^{1-1/\sigma_{VAR_i}}=D_{i,mac}^{1-1/\sigma_{VAR_i}} \tag{A.10}$$

Mark-ups (imperfect competition):

$$\left(\sum_{nut\in mac} N_{i,nut}\right)\left(EPD_{i,mac}+\frac{1}{\sigma_{VAR_i}}\right)=\left(\frac{1}{\sigma_{VAR_i}}-\frac{1}{\sigma_{ARM_i}}\right)+\left(\frac{1}{\sigma_{ARM_i}}-\frac{1}{\sigma_C}\right)SDT_{i,mac} \tag{A.11}$$

$$\left(\sum_{nut\in mac} N_{i,nut}\right)\left(EP_{i,mac,mac*}+\frac{1}{\sigma_{VAR_i}}\right)=\left(\frac{1}{\sigma_{VAR_i}}-\frac{1}{\sigma_{IMP_i}}\right)+ \\ +\left(\frac{1}{\sigma_{IMP_i}}-\frac{1}{\sigma_{ARM_i}}\right)SM_{i,mac,mac*}+\left(\frac{1}{\sigma_{ARM_i}}-\frac{1}{\sigma_C}\right)ST_{i,mac,mac*} \tag{A.12}$$

Market-shares (imperfect competition):

$$SDT_{i,mac}=\frac{PDT_{i,mac}D_{i,mac}}{PDEMTOT_{i,mac}DEMTOT_{i,mac}} \tag{A.13}$$

$$SM_{i,mac,mac*}=\frac{PDEM_{i,mac,mac*}DEM_{i,mac,mac*}}{PM_{i,mac*}M_{i,mac*}} \tag{A.14}$$

$$ST_{i,mac,mac*}=\frac{PDEM_{i,mac,mac*}DEM_{i,mac,mac*}}{PDEMTOT_{i,mac*}DEMTOT_{i,mac*}} \tag{A.15}$$

Price of domestic good (perfect competition):

$$PD_{i,mac}=PY_{i,mac} \tag{A.16}$$

Price of variety produced in *mac* and sold in *mac* (imperfect competition):

$$PDVAR_{i,mac}=\frac{PY_{i,mac}}{1+EPD_{i,mac}} \tag{A.17}$$

Price in macro-area *mac** of good *i* produced in *mac* (perfect competition):

$$PDEM_{i,mac,mac*}=PY_{i,mac}\left(1+ATR_{i,mac,mac*}\right) \tag{A.18}$$

Price of variety produced in *mac* and sold in *mac** (imperfect competition):

$$PDEMVAR_{i,mac,mac*} = \frac{PY_{i,mac}\left(1+ATR_{i,mac,mac*}\right)}{1+EP_{i,mac,mac*}} \tag{A.19}$$

Production

Leontief technology (perfect competition):

$$\begin{aligned}&\min PY_{i,mac}Y_{i,nut} = PVA_{i,nut}VA_{i,nut} + PAINI_{i,nut}AINI_{i,nut}\\ &s.t.\quad Y_{i,nut} = \alpha VA_{i,nut}VA_{i,nut} = \alpha AINI_{i,nut}AINI_{i,nut}\\ &nut \in mac\end{aligned} \tag{A.20}$$

Leontief technology (imperfect competition):

$$\begin{aligned}&\min N_{i,nut}PY_{i,mac}\left(Y_{i,nut}+cf_{i,nut}\right) = PVA_{i,nut}VA_{i,nut} + PAINI_{i,nut}AINI_{i,nut}\\ &s.t.\quad N_{i,nut}\left(Y_{i,nut}+cf_{i,nut}\right) = \alpha VA_{i,nut}VA_{i,nut} = \alpha AINI_{i,nut}AINI_{i,nut}\\ &nut \in mac\end{aligned} \tag{A.21}$$

CES value added technology:

$$\begin{aligned}&\min PVA_{i,nut}VA_{i,nut} = PL_{nut}L_{i,nut} + PQ_{i,nut}Q_{i,nut} + PTE_{i,nut}TE_{i,nut} + PRN_{i,nut}RN_{i,nut}\\ &s.t.\quad VA_{i,nut}^{1-1/\sigma_{VA}} = \alpha L_{i,nut}L_{i,nut}^{1-1/\sigma_{VA}} + \alpha Q_{i,nut}Q_{i,nut}^{1-1/\sigma_{VA}} + \alpha TE_{i,nut}TE_{i,nut}^{1-1/\sigma_{VA}} + \alpha RN_{i,nut}RN_{i,nut}^{1-1/\sigma_{VA}}\end{aligned} \tag{A.22}$$

CES fictive factor technology:

$$\begin{aligned}&\min PQ_{i,nut}Q_{i,nut} = PH_{nut}H_{i,nut} + PK_{mac}K_{i,nut}\\ &s.t.\quad Q_{i,nut}^{1-1/\sigma_{CAP}} = \alpha H_{i,nut}H_{i,nut}^{1-1/\sigma_{CAP}} + \alpha K_{i,nut}K_{i,nut}^{1-1/\sigma_{CAP}}\\ &nut \in mac\end{aligned} \tag{A.23}$$

CES technology of aggregate intermediate input:

$$\begin{aligned}&\min PAINI_{j,nut} AINI_{j,nut} = \sum_i PINI_{i,j,mac} INI_{i,j,nut}\\&s.t.\quad AINI_{j,nut}^{1-1/\sigma_{INI}} = \sum_i \alpha INI_{i,j,nut} INI_{i,j,nut}^{1-1/\sigma_{INI}}\\&nut \in mac\end{aligned} \tag{A.24}$$

Zero profit condition to determine the number of varieties at the NUTS level:

$$\begin{aligned}&N_{i,nut}\left(\frac{PY_{i,mac} DEMVAR_{i,mac,mac^*}}{1+EP_{i,mac,mac^*}} + \frac{PY_{i,mac} DVAR_{i,mac}}{1+EPD_{i,mac}}\right) =\\&= PVA_{i,nut} VA_{i,nut} + PAINI_{i,nut} AINI_{i,nut}\end{aligned} \tag{A.25}$$

Equilibrium in the factor markets:

Equilibrium in the capital market:

$$KSUP_{mac} = \sum_{nut \in mac} \sum_i K_{i,nut} \tag{A.26}$$

Equilibrium in the land market:

$$TESUP_{nut} = TE_{i,nut} \tag{A.27}$$

Equilibrium in the natural resources market:

$$RNSUP_{i,nut} = RN_{i,nut} \tag{A.28}$$

Unskilled labour supply (CET function):

$$LSUP_{nut} = \frac{\alpha LS_{nut} PL_{nut}^{\sigma_L}}{\sum_{nut \in mac} \alpha LS_{nut} PL_{nut}^{\sigma_L}} LTOTSUP_{mac} \qquad \text{(A.29)}$$

Equilibrium in the unskilled labour market:

$$LSUP_{nut} = \sum_i L_{i,nut} \qquad \text{(A.30)}$$

Skilled labour supply (CET function):

$$HSUP_{nut} = \frac{\alpha HS_{nut} PL_{nut}^{\sigma_H}}{\sum_{nut \in mac} \alpha HS_{nut} PL_{nut}^{\sigma_H}} HTOTSUP_{mac} \qquad \text{(A.31)}$$

Equilibrium in the skilled labour market:

$$HSUP_{nut} = \sum_i H_{i,nut} \qquad \text{(A.32)}$$

Unskilled labour supply in the integrated labour market within the EU27 (CET function):

$$LSUP_{nut} = \frac{\alpha LS_{nut} PL_{nut}^{\sigma_L}}{\sum_{nut \in EU27} \alpha LS_{nut} PL_{nut}^{\sigma_L}} LTOTSUP_{EU27} \qquad \text{(A.33)}$$

Skilled labour supply in the integrated labour market within the EU27 (CET function):

$$HSUP_{nut} = \frac{\alpha HS_{nut} PL_{nut}^{\sigma_H}}{\sum_{nut \in EU27} \alpha HS_{nut} PL_{nut}^{\sigma_H}} HTOTSUP_{EU27} \tag{A.34}$$

Macro-economic closure

Investment:

$$REV_{mac} sav_{mac} = PINV_{mac} INV_{mac} \tag{A.35}$$

Income of the macro-area:

$$\begin{aligned} & REV_{mac} + BAL_{mac} = \\ & = \sum_{mac^* \neq mac} \sum_{i \in PC} \left[ATR(i, mac^*, mac) DEM_{i,mac^*,mac} \right] + \\ & + \sum_{mac^* \neq mac} \sum_{i \in IC} \left[ATR(i, mac^*, mac) \left(\sum_{nut \in mac} N_{nut} \right) DEMVAR_{i,mac^*,mac} \right] + \\ & + \sum_{nut \in mac} \sum_{i} \left(PL_{nut} L_{i,nut} + PH_{nut} L_{i,nut} + PK_{mac} K_{i,nut} + PTE_{i,nut} TE_{i,nut} + RN_{i,nut} RN_{i,nut} \right) \end{aligned} \tag{A.36}$$

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